On the evaluation of sustainable development of marine economy based on AHP - a case study of the New District in Zhoushan Islands

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Abstract

Based on the general and concrete principles of index system of marine economy and the choices of the evaluation index, this paper analyzes the index importance by means of AHP and establishes a set of the evaluation index system of marine economy in the New District in Zhoushan Islands, to which an overall analysis and appraisal is given. The main factor that has limited its sustainable development of marine economy, in combination with the factors that influence its development, are put forward in accordance with its connotation of sustainable development of marine economy.

Keywords: AHP, marine economy, sustainable development, evaluation, the New District in Zhoushan Islands

1 Introduction

On 30th June, 2011, the State Council published the paper on the approval to establish the New District in Zhoushan Islands. On 7th July in the same year, the New District was officially founded conforming to the executive division of the Zhoushan Islands, and became the fourth state-level new district after Shanghai Pudong New District, Tianjin Binhai New District and the Chongqing Liangjiang New District, and also the first one themed on marine economy. On 23th, January in 2013, the development plan of the New District in Zhoushan Islands was officially approved by the State Council, and Zhoushan Islands is the first one with the provincial economic and social management authority, and its development is concerned by all parties.

As the fourth state-level new district, it is granted with great historic mission, which needs the realization of a series of strategic objectives such as the important growth pole of Zhejiang marine economic development pilot area, our national marine comprehensive experimental zone and the Yangtze river delta economic development and the opening of the east China sea etc. Against such background, how to make a suitable development strategy is becoming thought-provoking. Rely on their own advantages to attract important resources and promote its economic and social development by both making good use of the national preferential policies for regional development and exerting great subjective initiative.

2 The analytic hierarchy process AHP

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then.It has particular application in group decision making, and is used around the world in a wide variety of decision situations.

Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. It is mainly featured by the combination of quality and quantity, and more suitable to handle complex social science problems by expressing people's subjective judgment in quantity. As a result, it is widely used in practice, and these steps are more fully described below.

2.1 THE BUILDING OF HIERARCHY

During the process of solving problems, the first step is to build a hierarchy of analyzing elements, establishing the priorities of the elements in the hierarchy. It's mainly composed of three levels: 1) goal level: an overall goal; criteria level and a group of factors or criteria that relate the alternatives to the goal; 2) the option level: a group of options or alternatives for reaching the goal. In this process, the final decision objective must be clearly established. 3) the goal, as the element in goal level, should be unique, that is to say, the goal level has but one element.

2.2 THE ESTABLISHMENT OF JUDGMENT CRITERIA TAKEN FROM THE UPPER ELEMENT HS

TABLE 1 Criteria

Criteria	Definition
1	For Hs two factors are equally important
3	For Hs one factor is slightly more important than another one
5	For Hs one factor is obviously more important than another one
7	For Hs one factor is much more important than another one
9	For Hs one factor is extremely more important than another one
2,4,6,8	For Hs its importance is between two close factors

2.3 ESTABLISH JUDGMENT MATRIX

Comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy, and mark them according to judgment criteria, and thus the matrix A=$\{a_{ij}\}$, as follows:

TABLE 2 Judgment criteria

	Hs	A_1	A_2	…	A_n
	A_1	a_{11}	a_{12}	…	a_{1n}
A=	A_2	a_{11}	a_{12}	…	a_{2n}
	…	…	…	…	…
	A_n	a_{n1}	a_{n2}	…	a_{nn}

A_{ij} means the relative importance of A_i to A_j from the perspective of the judgment criteria H_s, namely, $a_{ij}=W_i/W_j$,a_{ij} should meet the following requirements:

$A_{ii}=W_i/W_i=l$, $a_{jj}=W_j/W_j=l$, $a_{ij}=l/a_{ji}$

2.4 CALCULATING THE PRIORITIES

2.4.1 For W_i in eigenvector

$$W_i=\left[\prod_{i=1}^{n} a_{ij}\right]1/n,\ i=1,2,\ldots,n. \tag{1}$$

n is the order number in judgment matrix.

2.4.2 Normalization processing, calculating the importance of each index

$$WA=\sum_{i=1}^{n} W_i\ . \tag{2}$$

The processing result of the normalization is : W_{ii} is the importance of A_i for H_s

$$W_i^0=W_{\ i}/W_A=W_i\Big/\sum_{i=1}^{n} W_i\ . \tag{3}$$

C. consistency check

$$C.I=\frac{\lambda\max-n}{n-1} \tag{4}$$

and

$$n\max=\sum_{i=1}^{n}\frac{(AW)_i}{nW_i}\ . \tag{5}$$

C.I. is the consistency index. When C.I>0.1, it means that the consistency check is unqualified, and the judgment matrix needs restructuring. When C.I$\leqslant$0.1, it means the consistency check is qualified, namely, the judgment matrix is qualified.

3 The building of the evaluation model of the sustainable development of marine economy in the New District in Zhoushan Islands

3.1 DETERMINATION OF INDEXES

This paper establishes a set of evaluation index system, based on the general and concrete principles of index system of marine economy and the choices of the evaluation index, to meet the development connotation of the New District in Zhoushan Islands in combination with the factors influencing the sustainable development of the marine economy in New District in Zhoushan Islands. The hierarchy is composed of 3 levels, the upper one is the overall goal A, namely, the sustainable development possibility of its marine economy, and below this are B and C (Table3).

TABLE 3 The evaluation index system of the sustainable development of the marine economy in New District in Zhoushan islands

Goal	A-level index	B-level index
A the sustainable development possibility of the marine economy in New District in Zhoushan Islands	B regional economic development	B1the gross value growth rate of regional production B2 the gross value of regional production per capita B3 the engel coefficient B4 city population proportion
	C marine industry structure	C1 the proportion of the growth value of the marine second industry in the gross growth value of marine industry C2 the proportion of the growth value of the marine third industry in the gross growth value of marine industry C3 growth rate of the gross value of the marine economy C4 the proportion of the growth value of the marine economy in the regional GDP C5 the gross value of the regional marine production per capita
	D the development quality of the marine economy	D1the production efficiency of marine economy D2 the proportion the ocean high-technology industry in the gross value of the marine production D3 the proportion of the employment in marine science and technology in the gross marine employment

	D4 the proportion of marine science and technology funds in the regional science and technology funds
	D5 the energy consumption in the gross marine production per unit area
	D6 the water consumption in the gross marine production per unit area
E marine eco-environmental system	E1 the ratio of the total marine production and the utilization of the regional industrial solid waste
	E2 the ratio of the gross marine production and the direct emission of the regional industrial waste water into the sea
	E3 the ratio of the quantity of the completion of regional pollution- control project and scheduled quantity
	E4 the ratio of the coastal marine natural reserve area and the total coastal area
	E5 the ratio of the gross marine production and the standard discharge rate of the regional industrial waste water

3.2 THE CALCULATING AND PROCESSING OF THE IMPORTANCE OF THE EVALUATION INDEX

Its sustainable is a complicated economic, social and ecosystem, and the judgment on each index involves many fields of knowledge, which can hardly be finished by a single person or one mathematical statistics method. However, the relative objective judgment on the importance of features can be offered here by means of expert judgment method which collects all the wisdom in this field.

Taking into consideration the relevant ideas and suggestions, the overall goal of the suatainable development possibility of its marine economy, regional economic development, the structure of marine industry. The quality of the marine economy development and pairwise comparison matrix of the index (A,B,C,D,E in Table 3) of the eco-environmental system of the ocean have been built respectively, according to the development condition of the marine economy, the basic features and the existing problems during the process of the investigation. In the building of the comparison matrix A of the overall goal of its sustainable development, three-level indexes, to be manipulated easily, are taken as the decision factors of the overall goal, each index is scaled by the expert assignment.

3.2.1 The weight calculation of the overall goal index of the sustainable development of marine economy

$$A=\begin{bmatrix} 1 & 2 & 3 & 5 \\ 1/2 & 1 & 2 & 4 \\ 1/3 & 1/2 & 1 & 2 \\ 1/5 & 1/4 & 1/2 & 1 \end{bmatrix}.$$

According to $WA=\sum_{i=1}^{n}W_i$, the normalization result is that A_i is the weight W_i of H_s.

$$W_i^0=W_i/W_A=W_i\Big/\sum_{i=1}^{n}W_i\ . \tag{6}$$

C. consistency check

$$C.I=\frac{\lambda\max-n}{n-1}, \tag{7}$$

and

$$n\max=\sum_{i=1}^{n}\frac{(AW)_i}{nW_i}\ . \tag{8}$$

After calculation, C.I.=0.0082 ⩽ 0.1, it means the consistency check is qualified, namely, the judgment matrix is qualified.

B=0.0820, C=0.2869, D=0.4840, E=0.1471.

3.2.2 The weight calculation of the regional economic development index

$$B=\begin{bmatrix} 1 & 2 & 3 & 5 \\ 1/2 & 1 & 2 & 4 \\ 1/3 & 1/2 & 1 & 2 \\ 1/5 & 1/4 & 1/2 & 1 \end{bmatrix}.$$

According to $WA=\sum_{i=1}^{n}W_i$, the normalization result is that A_i is the weight W_i of H_s.

$$W_i^0=W_i/W_A=W_i\Big/\sum_{i=1}^{n}W_i\ . \tag{9}$$

C. consistency check

$$C.I=\frac{\lambda\max-n}{n-1} \tag{10}$$

and

$$n\max=\sum_{i=1}^{n}\frac{(AW)_i}{nW_i}\ . \tag{11}$$

After calculation, C.I.=0.0182<0.1, it means the consistency check is qualified, namely, the judgment matrix is qualified.

B_1=0.3134, B_2=0.3024, B_3=0.1858, B_4=0.1159.

3.2.3 The weight calculation of marine industry structure

$$C=\begin{bmatrix} 1 & 2 & 3 & 5 \\ 1/2 & 1 & 2 & 4 \\ 1/3 & 1/2 & 1 & 2 \\ 1/5 & 1/4 & 1/2 & 1 \end{bmatrix}.$$

According to $WA=\sum_{i=1}^{n}W_i$, the normalization result is that A_i is the weight W_i of H_s.

$$W_i^0 = W_i / W_A = W_i \Big/ \sum_{i=1}^{n} W_i \ . \tag{12}$$

C. consistency check

$$C.I = \frac{\lambda \max - n}{n-1} \tag{13}$$

and

$$n\max = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \ . \tag{14}$$

After calculation, C.I$\leqslant$0.1, it means the consistency check is qualified, namely, the judgment matrix is qualified. C_1=0.3139, C_2=0.3147, C_3=0.1891, C_4=0.0895, C_5=0.0929.

3.2.4 The weight calculation of the development quality index of marine economy

$$D = \begin{bmatrix} 1 & 2 & 3 & 5 \\ 1/2 & 1 & 2 & 4 \\ 1/3 & 1/2 & 1 & 2 \\ 1/5 & 1/4 & 1/2 & 1 \end{bmatrix}.$$

According to $WA=\sum_{i=1}^{n}W_i$, the normalization result is that A_i is the weight W_i of H_s.

$$W_i^0 = W_i / W_A = W_i \Big/ \sum_{i=1}^{n} W_i \ . \tag{15}$$

C. consistency check

$$C.I = \frac{\lambda \max - n}{n-1} \tag{16}$$

and

$$n\max = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \ . \tag{17}$$

After calculation, C.I$\leqslant$0.1, it means the consistency check is qualified, namely, the judgment matrix is qualified. D_1=0.3518, D_2=0.2584, D_3=0.1681, D_4=0.1695, D_5=0.0664.

3.2.5 The weight calculation of the marine eco-environmental index system

$$E = \begin{bmatrix} 1 & 2 & 3 & 5 \\ 1/2 & 1 & 2 & 4 \\ 1/3 & 1/2 & 1 & 2 \\ 1/5 & 1/4 & 1/2 & 1 \end{bmatrix}.$$

According to $WA=\sum_{i=1}^{n}W_i$, the normalization result is that that A_i is the weight W_i of H_s.

$$W_i^0 = W_i / W_A = W_i \Big/ \sum_{i=1}^{n} W_i \ . \tag{18}$$

C. consistency check

$$C.I = \frac{\lambda \max - n}{n-1} \tag{19}$$

and

$$n\max = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \ . \tag{20}$$

After calculation, C.I$\leqslant$0.1, it means the consistency check is qualified, namely, the judgment matrix is qualified. E_1=0.3528, E_2=0.3528, E_3=0.1195, E_4=0.1195, E_5=0.0683.

4 The comprehensive evaluation on the sustainable development of marine economy in Zhoushan New District

Its evaluation is composed of 4 levels, as follows: regional economic development, marine industry structure, the development quality of the marine economy and marine eco-environmental system. Based on the 4 above-mentioned indexes, the development sustainability can be deduced from the calculation:

$$W = W_B \cdot 8.2\% + W_C \cdot 28.69\% + W_D \cdot 48.40\% + W_E \cdot 14.71\% = 0.59 \tag{21}$$

Based on the above calculation, each sub-system and the state of the sustainable development of the marine economy are shown in the grade table of the sustainable development (Table 4). This table is determined by the evaluation grade in "the sustainable development index system of regional economy" made by the Institute of Geography in Chinese Academy of Sciences. In this index system, the closer the index is to 1, the closer the system is to the standard value; on the contrary, the closer the index is to 0, the farther the system is to the standard value.

TABLE 4 The evaluation grade table of sustainable development

Grade	Non-sustainability	Slight sustainability	Moderate sustainability	Strong sustainability
Index value	<0.25	0.25-0.5	0.5-0.75	>0.75

The development sustainability for the New District in Zhoushan Islands is 0.59, and from the table, it shows that it is in the state of moderate sustainability developing from the slight one. For the value of each index, 0.84 is for regional economic development and 0.77 for marine industry structure, both of which are in a state of strong sustainability. The main factor leading to the decrease of its development sustainability is the development quality of marine economy, whose value is 0.4, in a state of slight sustainability. The value for the marine eco-environmental system is 0.43, just a little higher than the one for the marine development quality, still in a state of slight sustainability. All of these are the main causes for the slight-moderate state of development sustainability for the New District in Zhoushan islands.

5 Conclusion

To be concrete, the main factors influencing the sustainable development of the New District in Zhoushan Islands are as follows: the gross regional marine production per capita, the proportion of marine science and technology funds in the regional science and technology funds, the proportion the ocean high-technology industry in the gross value of the marine production, the proportion of the employment in marine science and technology in the gross marine employment, the production efficiency of marine economy, the ratio of the coastal marine natural reserve area and the total coastal area, the ratio of the total marine production and the utilization of the regional industrial solid waste and the ratio of the gross marine production and the standard discharge rate of the regional industrial waste water etc.

The development sustainability in 2008 for the New District in Zhoushan Islands is 0.48 after calculation by the same method, and it was in a state of slight sustainability. Presumably, it will take 10 years to reach 0.8-0.85 on the basis of its annual increase of improvement from 2008-2013, that is to say, by the year of 2024 its development sustainability will reach a strong sustainability of 0.8-0.85.

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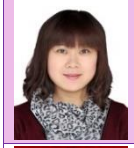

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