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Comprehensive evaluation of environmental dimension reduction of multi-type islands: a sustainable development perspective

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ABSTRACT

In recent years, the exploration and sustainable development of islands is getting more and more attention around the world. However, the development of China's islands is somewhat disorder and spatial unbalanced. Therefore, we need to conduct a scientific assessment of the islands in order to fully understand the islands. In this paper, We analyze the possible development path of the islands by evaluating the value of the islands. To be specific, we present an extensive evaluate model design based on analysis of the environmental resources conditions, economic values, and existing problems of the seven typical islands in China. This model is applied to evaluate the sustainability levels and development advantages of seven typical islands. The island's evaluation results are consistent with the island's actual development level, which proves that the model is believable. Generally, the more indicators involved in the evaluation model, the more accurate the evaluation result will be. However, numerous indicators will cause two problems. One is that some indicators are highly correlated and make the evaluation results inaccurate. Therefore, it is necessary to remove redundant indicators; the other is that the calculation process will be cumbersome. In this study, we used factor analysis to solve the problems, making the evaluation results more accurate. Meantime, the experiment has proved that the model can simultaneously use multiple types of islands as samples for unified evaluation.

Keywords: Island environment, Sustainability, Indicator construction, Evaluation model, Factor analysis, Development path

1 INTRODUCTION

Since the 20th century, oceans and islands have gradually become the focus of national and social attention(Zhang et al., 2020; He and Wang, 2020; Zheng et al., 2020). The importance of island development, management, ecological protection, etc. is increasing day by day(Liu et al., 2018), and the island view of coordinated development, green development and sustainable development has gradually formed. In response to the island's complex geography, resource endowments, and various conflicts arising from the development process(Douglas, 2006), the island's development situation tends to shrink. Affected by the long-term concept of valuing land and ignoring sea, as well as unfavorable factors such as being far away from the mainland, inconvenient transportation, and hard life, the development of China's islands is basically in a lagging, disorderly, and extensive stage. In the process of island development, there are the following problems: the development order is chaotic, the construction level lags behind, the development level is low, and the resources and environment are seriously damaged. In recent years, islands gradually towards the ecological island reef construction direction, but still difficult. The island development and construction has stalled, the core reason is the lack of accurate positioning of the island and scientific planning assessment.

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Western maritime powers and international small island countries have in fact done a lot of scientific research on the scientific development and utilization of islands(Rigg and Richardson, 1934; Tokusige, 1939), such as island management(Kim, 2020), island ecology(Petridis et al., 2017) and non-resident island development and utilization(Hwang and Ko, 2018). Many countries with islands in the world are more likely to adopt centralized and specialized agency management systems for island management. Centralized formulation of marine island master plans through a unified organization makes it easier to achieve high resource utilization and ecological environment protection(Shi et al., 2015). International research on islands mostly focuses on ecological and environmental protection. The restoration of island ecological environment is exemplified by New Zealand. As a small island country, New Zealand attaches great importance to the research of ecological restoration, and has made a series of achievements in island ecological restoration(Towns and Ballantine, 1993). Although China's effort on island ecological environment protection started relatively late compared to foreign countries, with China's emphasis on islands in recent years, the protection and management works of islands has been increasing. Some achievements have been made in island development(Shen, 1995), island protection(Zhang et al., 2020) and ecosystem evaluation(Chen and Dong, 2019). Compared with other countries with more successful island development (e.g. Australia, Thailand, etc.), the overall development and utilization level of uninhabited islands in China is low, and both efficiency and benefit are not commensurate with the relatively superior natural endowment status.

The concept of sustainable development can be traced back to the 1970s, and then quickly penetrated into all areas of social development. In 2004, some experts and scholars(Li and Wang, 2004) made the following definitions for the sustainable development of the island: adapt measures to island conditions, plan rationally, rely on scientific and technological progress, strengthen legal management, and rationally and effectively develop and utilize the island's ecological environment without reducing its carrying capacity so that it not only meets the needs of the present generation and does not pose a hazard to the needs of future generations. Since then, the sustainable development of the island has become the main line in the study of the island environment. The development of islands is susceptible to human activities and environmental changes(Brauko et al., 2020). From the perspective of politics(Liao and Liu, 2019), economy(Baldacchino, 2006; Liu et al., 2020; He et al., 2020), resources(Zheng et al., 2020; del et al., 2020), and the environment(Liu et al., 2017), disorderly islands' human activities and economic development models are not conducive to the sustainable development of islands(Zhao et al., 2016). The vulnerability of islands compared to land emphasizes the importance of island management and planning. Establish the concept of sustainable development with strategic significance and a fair and just support system to provide a solid foundation and guarantee for the sustainable development of the island(Wang et al., 2006). Domestic and international research on the application of the concept of island sustainable development involves ecology(Li et al., 2019), tourism(Moreno, 2005), fishery(Karcher et al., 2020), land resources(Zhang and Xiao, 2020), etc. Its emphasis is on balancing the natural ecology and social development of the island. For small island States in particular, sustainable development research is more relevant. Small island States pay more attention to how to achieve the sustainable development of islands(Tilley et al., 2019), and the study of protecting the island's ecological environment(Hafezi et al., 2020) and socio-economic development(Mauthoor, 2017) is more in-depth.

Sustainable development has increasingly become the central concept of island development. Many scholars at home and abroad have conducted research on the evaluation system of island sustainable development(Ke et al., 2013; Long et al., 2020; Nesticò and Maselli, 2020). Since the establishment of the evaluation index system for the sustainable development of islands in 2004, many scholars have successively evaluated the sustainable development of islands(Xu et al., 2020). So far, representative evaluation models for the sustainable development include analytic hierarchy process(Zhu and Wang, 2017), ecological footprint model(Fang et al., 2018), variable fuzzy set theory comprehensive evaluation model(Ke et al., 2014), and catastrophe progression method(Gao et al., 2019). The existing island evaluation methods are not perfect. When there are too many indicators, the calculation process is cumbersome. On the other hand, it is difficult to accurately reflect the environmental conditions of the island with fewer evaluation indicators. Therefore, the evaluation results have limitations. Although China has made some achievements in the evaluation of the sustainable development of islands, there are still many problems in the investigation and evaluation of the current situation of the island environment. The lack of understanding of the islands is not conducive to the sustainable development of the islands. The

assessment of foreign islands is mainly centered on risk assessment, which explores the impact of disturbance on the island environment itself and human society, involving anthropogenic factors such as fisheries fishing(Gilman et al., 2014) and natural factors such as hurricane crossing(Sealey et al., 2020).

With the development of the island evaluation system, the evaluation system is becoming more and more in-depth, comprehensive and three-dimensional. At present, there is no unified and universally applicable island evaluation model at domestic and abroad(You et al., 2015). There is basically no integrated framework, including various methods. This situation obscures the overall assessment(Karampela et al., 2017). Experts and scholars mainly evaluate the environment of a single island to discuss the development level of this island and give development suggestions. Drawing on the island research experience of major international marine countries and small coastal island countries, combined with the results of the evaluation of the sustainable development of domestic islands, this study uses network information collection method and statistical analysis method to study and analyze the representative data of the sustainable development of the islands, and constructs the classification and evaluation system of factor analysis method. The study uniformly evaluated seven different types of islands to test the feasibility of the evaluation method. Using seven different types of islands as samples for unified evaluation, not only reduces the amount of calculation for individual evaluation of each island, but also helps analyze the development of different types of islands. This is conducive to the state's hierarchical and classified management of islands and the macro-control of the development of different types of islands. The evaluation provides a theoretical basis for the sustainable development of the islands and a decision-making basis for the formulation of island development measures.

2 MATERIAL AND METHOD

2.1 The study area

The results of the national survey of island names in sea areas show that there are more than 11,000 islands in China(Pan et al., 2018), including 12 major island counties (cities and districts)(Zhao and Zheng, 2017). The total area of islands accounts for about 0.8% of China's land area. According to whether the island has a household registration, it is divided into resident islands and non-resident islands. The evaluation model requires that the evaluation objects have universal applicability, so the study selected seven representative islands in terms of residents' life, tourism, natural environment and ecology.

Table 1 Evaluation target situation

Island type	Island name	Reason for selection
Social life	Chongming Island(D1)	It has a vast area, a large population, complete functions, industries, and infrastructure, and a high level of political, cultural, transportation and economic construction.
	Zhoushan Islands(D2)	
Leisure travel	Weizhou Island(D3)	The area is relatively small, the permanent population is small, and the island has a unique landscape. The island's economic development is dominated by tourism.
	Miaodao Islands(D4)	
	Nanji Island(D5)	
Ecology	Shedao Island(D6)	The only island in the world where only vipers live. There is a national protection zone for vipers on the island to protect snake resources.
	Shanhu Island(D7)	It is an island composed of coral reefs. The island is rich in coral and guano resources. It is one of the islands with the richest phosphate rock.

Fig. 1 Location of evaluation object

2.2 Data acquisition

The island is a special regional type with a series of unique natural and economic characteristics. As a complete geographical unit, the island's environmental elements are special. Therefore, it is necessary to combine the personality of the island to explore its development model. The scientific development of islands should follow the natural laws of the islands and adapt to local conditions. The environmental quality of the islands should be assessed on the basis of accurate acquisition of the island's ecological environmental quality information, so as to formulate a reasonable development plan for the sustainable development of the islands. Large-scale islands that are well developed and utilized, such as Chongming Island, Zhoushan Island, Weizhou Island, and Nanji Island, can separately assess resources, environment and society according to island types and development and utilization conditions; Unmanned islands with special functions such as Shanhu Island and Shedao Island should be evaluated according to the characteristics of the island.

The island survey is the basis for the ecological environment quality assessment of the island. Data acquisition methods include statistical yearbooks, data and literature inquiries, field surveys and measurements, satellite remote sensing and camera equipment monitoring, etc. The data in this experiment come from various regional government portals and district and county statistical yearbooks, which are authoritative and representative. The study counts the data of China's seven islands in 2019.

Table 2 Survey data sources of typical islands

Island	Data source URL
D1	http://www.shcm.gov.cn/cmmh_web/html/shcm/portal/index/index.htm
D2	http://www.shanghai.gov.cn/
D3	http://www.zhoushan.gov.cn/
D4	http://www.bhhc.gov.cn/
D5	http://www.weizhouisland.com.cn/
D6	http://www.changdao.gov.cn/
D7	http://www.zjpy.gov.cn/
	http://www.dllsk.gov.cn/index_new.asp
	http://www.sansha.gov.cn/

For qualitative data, comprehensively consider the overall impact of the indicators on the islands and the comparative differences between the islands, and quantify the qualitative indicators according to the 0-9 scoring method.

2.3 Method

The evaluation system is divided into the following four steps, namely, the construction of the index system, the standardization of data, the determination of weight, and the comprehensive processing of index factors. For the four steps, we filter out the minority and complex evaluation methods, and select the appropriate evaluation methods. These methods are universal and meet the needs of the vast majority of island evaluations.

Fig. 2 Evaluation method diagram

2.3.1 Construction of indicator system

The construction of the qualitative indicators of the island environmental indicator system adopts the Delphi method. Delphi is a process of repeated expert consultation with the aim of integrating all participating expert opinions and ultimately reaching consensus(Yang et al., 2019).

Islands of different types and geographic locations will lead to differences in evaluation objectives. In the actual evaluation process, we select indicators based on the functions of different islands. For the indicator division of uninhabited islands, social factors are negligible, focusing on their natural ecological environment; For tourist islands, appropriately increase the factors of island tourism; For islands with special resources, emphasis is placed on the evaluation of their resource protection.

The research refers to the indicator setting of many experts and scholars in the evaluation of the sustainable development of the island. In the evaluation of the sustainable development of the island, relevant experts and scholars generally set social, resource, environmental, and economic indicators. Some experts and scholars set indicators such as marine industry, development potential, and humanities. In this study, referring to the indicator settings of experts and scholars, and combining the objectives and research objects of this study, two first-level indicators were established, namely nature and society. Then the study select the available secondary indicators. The secondary indicator layer is divided into 38 more detailed indicators, involving the key elements of the island such as culture, economy, resources, ecology, and environment. The island environmental indicator system is constructed.

Fig. 3 Evaluation indicators and elements of islands

2.3.2 Data standardization

The different formats of the data in the evaluation system result in the incomparability of different indicators, so the selected indicator data should be normalized. The SAVEE method(Chen, 2011) provides a standardized equation to realize the normalization of index data. This study improved the SAVEE standardized equation to achieve the normalization of quantitative data. For quantitative data, within the limit distance X , the research object value b can be standardized according to the following equation:

Table 3 Quantitative data standardization equation

Standardized equation	Quantitative index(b) (X)	X Definition basis
$y = 1 - e^{9 \times (-1 \times (b+1) \div X)}$	Island area (150 000 hm ²)	The area of the island is positively correlated with the amount of value, $X >$ any x
$y = 1 - e^{5 \times (-1 \times (b+1) \div X)}$	Highest point elevation (30 m)	The elevation of the island is too low, it is easy to be affected by sea erosion, and the elevation of the highest point is higher than 30 m, and the influence of sea water is less.
$y = e^{-1 \times (b+1) \div X}$	Air quality index (AQI) (100 µg/m ³)	There is a negative correlation between AQI and island value.
$y = 1 - e^{5 \times (-1 \times (b+1) \div X)}$	Educational institutions (300), total tourism income (500 000 yuan), total reception (800 000 people), per capita GDP (100 000 yuan), rural per capita GDP (100 000 yuan)	The index is positively correlated with the island value, and the extreme value is selected according to the actual situation and expert experience.
$y = 1 - e^{3 \times (-1 \times (b+1) \div X)}$	Fitness venues (50), minimum living allowance (1500 yuan), total agricultural output value (10 000 000 yuan), total industrial output value (10 000 000 000 yuan), total retail sales of consumer goods (10 000 000 000 yuan), total fishery output value (1 500 000 yuan)	The index is positively correlated with the island value, and the extreme value is selected according to the actual situation and expert experience.
$y = e^{-\frac{1}{2} \times (\frac{b-\mu}{\sigma})^2}$	Average annual precipitation (1 200 mm), temperature (16°C), population per unit area (4 people/hm ²)	The index and the quantity of value have a normal distribution, μ is the mean, and σ is the standard deviation according to the actual situation.

According to the impact of a single indicator on the total value of the island's environment, the index is divided into positive correlation index, negative correlation index and normal distribution index. The formula is selected as follows:

Positive correlation index:

$$y = 1 - e^{k \times (-1 \times (b+1) \div X)} \quad (1)$$

In the formula: y is the standardized value, b is the unstandardized index value, X is the limit distance value, $k=\{1, 3, 5, 7, 9\}$ (k takes the value according to the degree of discretization of the index data, the greater the degree of discretization, the greater the value of k.)

Negative correlation index:

$$y = e^{-1 \times (b+1) \div X} \quad (2)$$

In the formula: y is the standardized value, b is the unstandardized index value, and X is the limit distance value.

Normal distribution index:

$$y = e^{-\frac{1}{2} \times \left(\frac{b-\mu}{\sigma}\right)^2} \quad (3)$$

In the formula: y is the standardized value, b is the unstandardized index value, μ is the mean, σ is the standard deviation.

Due to the different types of islands, the difference in index data can be large or small. The study uses qualitative adjustment of the k value in the standardization formula to standardize different types of island index data to the same dimension, so as to achieve the same evaluation standard.

Then standardize the qualitative and quantitative data and transform the standardized index value into a percentile form. The 38 secondary indicators are divided into 20 qualitative indicators and 18 quantitative indicators. The quantitative indicators include 13 positive correlation indexes, 1 negative correlation indexes, and 3 normal distribution indexes. Quantitative data is standardized by SAVEE standard equation, and qualitative data is directly converted into a percentile form. Standardized results are shown as follows:

Table 4 Standardized values of island indexes, where: qualitative index (pink), quantitative index (green), positive correlation index (blue), negative correlation index (yellow), positive and Normal distribution index (red)

Index Island	D1	D2	D3	D4	D5	D6	D7
b1	100	100	14	28	5	1	1
b2	60	100	100	100	100	100	81
b3	90	30	30	30	30	30	50
b4	100	97	96	16	66	21	83
b5	100	100	51	88	100	61	25
b6	80	80	90	90	80	50	90
b7	78	81	72	84	59	79	92
b8	80	90	70	90	70	70	70
b9	90	90	90	90	80	90	90
b10	90	80	-	-	-	-	-
b11	80	90	-	-	-	-	-
b12	90	70	80	90	80	90	60
b13	70	90	90	90	90	30	-
b14	60	60	90	80	50	30	50
b15	50	50	90	70	30	30	30
b16	70	60	90	90	90	50	80
b17	70	90	50	80	90	-	-
b18	50	50	90	90	90	80	30
b19	90	90	70	60	70	30	50

b20	-	-	-	90	-	90	90
b21	80	58	62	46	88	-	-
b22	83	98	-	-	-	-	-
b23	84	75	-	-	-	-	-
b24	90	74	-	-	-	-	-
b25	90	90	70	80	70	50	50
b26	90	80	-	-	-	-	-
b27	90	80	-	-	-	-	-
b28	90	90	70	60	70	10	30
b29	90	90	90	80	80	50	60
b30	13	4	-	-	-	-	-
b31	73	94	-	-	-	-	-
b32	34	78	-	-	-	-	-
b33	22	31	-	-	-	-	-
b34	21	100	3	7	7	-	-
b35	77	100	44	97	19	-	-
b36	99	100	43	89	12	-	-
b37	86	90	89	100	92	-	-
b38	75	79	-	-	-	-	-

2.3.3 Determination of weight

Determining the weight of the evaluation index is the difficulty in the construction of the evaluation system. There are many methods to determine the weight. Each method has its advantages and disadvantages (Ni, 2002). Subjective weighting methods are highly subjective, the data can not be true and reliable. Objective weighting method uses rigorous mathematical algorithms and require accurate data. 38 indicators are selected in the study, which are tedious to deal with. Therefore, in order to scientifically determine the weight of the index and accurately summarize the situation of the island, the research adopts factor analysis to determine the weight.

In this study, spss software is used to reduce the dimension of the data by factor analysis. There are 38 indicators and 7 samples in total. First, the indicators are qualitatively divided into five element layers, including social element layer, tourism element layer, ecological element layer, resource element layer and economic element layer. Using the average grouping method to weight the elements, the weight of a single feature layer is 20%. Then, perform factor dimensionality reduction analysis on the selected indicators of each element layer. In the course of the experiment, the over-correlated variables and invalid data were removed to meet the KMO and Bartlett test conditions ($KMO > 0.5$ & $Sig < 0.05$).

Considering the characteristics of the island itself, the development and construction of the island's society, tourism, ecology, resources and economy will restrict and influence each other and cannot be regarded as unrelated factors. Factor analysis requires that the number of indicators is less than the number of samples. However, this study contains 38 indicators and 7 samples. Therefore, this study considers both the principles and data, divides the indicators into different modules, and performs factor analysis on each module.

In the experiment, a total of 38 indexes were investigated, 10 indexes with strong correlation were removed, and 28 indexes were used for factor analysis and dimensionality reduction. The experiment qualitatively divides the indicators into 6 modules, and then carries out factor analysis on the 6 modules respectively. After continuous index adjustment, factor analysis divides 38 indicators into 9 principal factors.

Fig. 4 spss experiment process diagram

Factor analysis can reduce the dimension of the index and transform the general index into several groups of unrelated comprehensive factors through linear combination. The main factor is the linear combination of the index, and the score of the main factor can be obtained according to the score coefficient matrix.

The main factor weight formula of factor analysis is as follows:

$$\omega_i = \frac{e_i}{\sum e_i} \quad (4)$$

In the formula, ω_i is the weight of the index, e_i is the contribution rate of the main factor.

The main factor score formula is as follows:

$$Y_i = \sum A_{ij} \times y_j \quad (5)$$

In the formula: Y_i is the score of the main factor, A_{ij} is the score coefficient matrix, y is the standardized value of the index.

The weights and scores of the main factors are calculated by using formulas (4) and (5), and the results are shown as follows:

Table 5 Factor weights and scores

Essential	Principal	Variance contribution	Main factor	Factor score calculation
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factor	factor	rate(e)/%	weight(ω)/%	expression(Y)
Society	Principal factor 1	61.136	7.007	$Y_1=0.39y_{27}+0.39y_{24}+0.326y_3-0.29y_7$
	Principal factor 2	26.118	2.993	$Y_2=0.091y_{27}+0.087y_{24}-0.248y_3+0.94y_7$
	Principal factor 3	79.943	10.000	$Y_3=0.245y_1+0.234y_{22}+0.234y_{25}+0.16y_{37}+0.234y_{26}$
Tourism	Principal factor 4	78.429	20.000	$Y_4=0.233y_{36}+0.237y_{35}+0.227y_{29}+0.224y_{13}+0.208y_4$
Ecology	Principal factor 5	64.471	20.000	$Y_5=0.298y_8+0.182y_9+0.362y_{10}+0.367y_{11}$
Resources	Principal factor 6	56.780	12.494	$Y_6=-0.099y_{14}-0.308y_{20}-0.149y_{15}+0.263y_{17}+0.302y_{19}+0.281y_{28}$
	Principal factor 7	34.110	7.506	$Y_7=0.52y_{14}+0.134y_{20}+0.561y_{15}-0.035y_{17}-0.072y_{19}-0.011y_{28}$
Economy	Principal factor 8	71.604	14.383	$Y_8=0.348y_{32}+0.313y_{33}+0.366y_{34}+0.07y_2$
	Principal factor 9	27.963	5.617	$Y_9=0.006y_{32}-0.191y_{33}+0.23y_{34}+0.91y_2$

245 2.3.4 Comprehensive processing of index factors

246 The index weights are integrated to analyze the overall environmental conditions of the island, and the
247 weighting formula is shown as follows:

$$248 \quad S = \sum \omega_i \times Y_i \quad (6)$$

249 In the formula, ω_i is the weight and Y_i is the standardized value of the i th main factor.

250 3 RESULTS AND DISCUSSION

251 3.1 Factor analysis condition test

252 Factor analysis requires KMO and Bartlett test conditions ($KMO > 0.5$ & $Sig < 0.05$). The research carried out
253 KMO and Bartlett tests on 6 modules respectively.

Fig. 5 KMO and Bartlett spherical test results

As can be seen from Figure 5, the KMO test results of the 6 modules are all greater than 0.5, and the Bartlett sphere test results are all less than 0.05. The results meet the conditions of factor analysis variable test, and prove that the adjusted index can be used for dimensional reduction experiment through factor analysis.

3.2 Island factor score

The total scores of social factors, tourism factors, ecological factors, resource factors and economic factors are calculated using formula (6), and the score results are shown as follows:

Table 6 Factor scores

Island	Social factor score	Tourism factor score	Ecological factor score	Resource factor score	Economic factor score
D1	17.376	19.645	20.432	10.886	7.515
D2	15.876	21.553	21.038	11.490	17.668
D3	4.430	16.201	7.448	10.688	6.315
D4	5.277	17.075	8.640	7.635	6.577
D5	4.156	11.869	7.084	9.421	6.577
D6	2.274	4.488	7.448	0.259	6.118
D7	2.684	6.177	7.448	2.125	4.956

Fig. 6 Value of factor score

Figure 6 shows that the individual factor scores of social islands, tourist islands and ecological islands all have a downward trend. Compared with other factors, the downward trend of resource factor is more moderate. The scores of social, tourism, ecological, resource and economic factors of social islands are higher than those of other types of islands. The scores of social, tourism, ecological, resource and economic factors of ecological islands are lower than those of other types of islands. The scores of tourism factors of tourist islands are significantly higher than those of other factors, and the scores of ecological factors of ecological islands are significantly higher than the scores of other factors.

Analyzing the results of the island factor score in Figure 6, the score of a single factor shows a downward trend, indicating that there is a certain correlation between the factors. The figure shows that the various factors are positively correlated. The main reason is that in the process of island development, society, tourism, ecology, resources, and economy will restrict and influence each other. Compared with other factors, the change trend of resource factor is more gradual. This is mainly because resource factors are less affected by human activities than social factors, ecological factors, tourism factors, and economic factors. Social, tourism, economic, and ecological factors are formed by human participation in the construction of islands, which are more affected by human activities and have more drastic changes. It shows that the value of an island is not only affected by the characteristics of the island itself, but also restricted by human development and construction activities.

The scores of the five factors of social islands are higher than those of tourist islands and ecological islands, indicating that social islands have the highest level of development and utilization. The social, ecological, resource, economic, and tourism factors are all at a relatively high level, which implies that the development of social islands is balanced. Ecological islands are mostly uninhabited islands. Although they are rich in ecological resources, they are ecologically fragile and the islands are almost in an undeveloped state. Tourist islands are rich in natural landscapes, mainly for the development of tourism. The scores on ecological factors of ecological islands are significantly higher than the values of other factors. Shanhu Island has valuable resources such as coral reefs, and Shedao Island has unique snake resources. Therefore, both islands have high ecological protection value. The evaluation result is consistent with the actual situation of the islands.

3.3 Island total value score

Formula (6) is used to obtain the total score of the island.

Table 7 Total value score of island

Island	D1	D2	D3	D4	D5	D6	D7
Total score	75.854	87.625	45.082	45.203	39.108	20.587	23.390

Table 7 shows that Zhoushan Islands have the highest score of 87.625, and Snake Island has the lowest score of 20.587. Social islands such as Chongming Island and Zhoushan Islands have the highest scores, exceeding 70; tourist islands have a medium score, around 40; ecological islands have the lowest score, around 20.

The evaluation results of seven typical islands show that the comprehensive value of social islands is higher than that of tourist islands, while the comprehensive value of ecological islands is the lowest. The total value of Chongming Island and Zhoushan Islands is the highest compared to other islands. The results indicate that the development of Chongming Island and Zhoushan Islands is in good condition, the facilities on the islands are well constructed, and the islands have the strongest development level. On the one hand, this phenomenon is due to the large area of Chongming Island and Zhoushan Islands, the large population base, and the high level of social development that drives the level of island development and utilization. On the other hand, their social development and the island's natural level are relatively balanced. Weizhou Island, Miaodao Islands and Nanji Island are second in value. This is mainly due to the relatively small area of the island, the small inhabitant population and the uneven development of the island. The islands have a focus on development according to their own characteristics. There are some residents living on Weizhou Island, Miaodao Islands, and Nanji Island. The islands have rich and unique natural landscapes. Good natural scenery and ecology have attracted a large number of tourists. The residents of the islands mainly make a living from fishing and tourism. Therefore, these three islands are defined as tourist islands. Due to their geographical location and geographical area, these islands are not suitable for a large number of residents. The degree of islands development and construction is lower than that of Chongming Island and Zhoushan Islands. The islands mainly relies on the development of tourism, and their value will be relatively low. Shedao Island and Shanhu Island have the smallest value and the weakest level of development. They are in the undeveloped or weakly developed stage. The two islands are uninhabited islands and are almost undeveloped. The islands are very small and lack fresh water resources, which is not conducive to the lives of residents. Shedao Island is the only island in the world where survives a single species of black-browed vipers. The toxins of vipers have scientific research value. China has established nature reserves to protect snake resources and the survival and reproduction of vipers. Shanhu Island is an island composed of coral reefs. The island is rich in corals and rich in guano resources. At the same time, it is one of the islands with abundant phosphate rock. Shedao Island and Shanhu Island are islands that cherish ecological resources. Although the degree of development and construction of the islands is very weak, the ecological value of resources cannot be ignored.

The results of the overall evaluation of different types of islands show that the value of islands with balanced development is higher than that of islands with unbalanced development or undeveloped islands. However, the contradiction between development and the environment is more prominent in islands with fragile ecosystems. How to achieve balanced development and sustainable development is currently facing huge challenges. The main problem of island development is the lack of correct technical guidance. The formulation of an island development plan first requires a scientific assessment of the island to fully understand the island. Compared with the previous environmental assessment of a single island by experts and scholars in related fields, this study compares and analyzes the environmental evaluation of different types of islands. The evaluation results are consistent with the actual development level on the island, which illustrates the feasibility and accuracy of the model. And the experimental results verify that the model can be applied to the unified evaluation of different types of islands. Factor analysis methods are rarely used in the evaluation of sustainable development of islands in previous studies. The study verifies the feasibility of factor analysis and dimension reduction method in the evaluation of islands through examples, and provides a solution to the problem of index selection in the evaluation process. At the same time, through qualitative analysis of indicators of different types of islands, different standardized equations are proposed. For the indicators of different types of islands, set appropriate weights to make the data standardization more fair. The limitation of the model is that the Delphi method has many limitations. The Delphi method is highly subjective, and the opinions of experts can easily influence each other, resulting in inaccurate results. In addition, the model has only been verified for its applicability in the field of islands. As an independent geographic unit, islands are less affected by land. Therefore, the indicator setting can

ignore external influences and mainly consider the internal factors of the islands. Using different types of islands as samples for unified evaluation will have smaller errors. However, in theory, the model can also be used in coastal or inland areas as long as the indicators are set reasonably. The specific feasibility needs further verification.

4 Declarations

4.1 Ethics approval and consent to participate

Not applicable

4.2 Consent for publication

All authors are responsible for the article and agree to publish.

4.3 Availability of data and materials

In this study, the environmental data of the seven islands mainly come from two kinds of websites(Table 2). One is the official website of local government, including the municipal government official website and the district government official website, and the other is the local tourism website. Among them, most of the indicator data comes from the statistical yearbook on the government website. The datasets of both websites are open to public readers.

4.4 Competing interests

The authors declare that they have no competing interests.

4.5 Funding

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4.6 Authors' contributions

Shaoyang Chen: Conceptualization, Data curation, Formal analysis, Funding acquisition, Writing-original draft. **Na Liu:** Data curation, Formal analysis, Funding acquisition, Writing-original draft. **Li Xiao:** Supervision, Writing-review & editing. **Yanwei Gong:** Supervision, Writing-review & editing. **Yun Xiao:** Writing-review & editing.

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5 CONCLUSION

The value of balanced islands is higher than that of unbalanced or undeveloped islands, indicating that the development of islands needs to take the path of sustainable development. The rational development and utilization of islands should undergo overall planning after ecological assessment. The research puts forward factor analysis evaluation model, and conducts example evaluations for seven different types of islands. The results show that the model can use multiple types of islands as samples for unified

evaluation. This not only reduces the amount of calculation for evaluating individual islands, but also facilitates the analysis of the development of different types of islands. Furthermore, this is conducive to the country's macro-control of the development of different types of islands and the classified and hierarchical management of islands. Meantime, the model can effectively deal with the complexity of calculations and the relevance of indicators caused by numerous indicators, making the evaluation results more accurate. Last but not least, the research has improved the SAVEE standardization equation to standardize data for different types of islands. The model needs more indicators as data support. However, data collection is a difficult point, requiring a large amount of information to be collected and integrated. The current research has only verified the application of the model in the field of islands. In theory, the model has universal applicability and can be used for evaluation in other fields. Further attempts can be made to apply the model to coastal zones or coastal areas. So far, the model has been successfully applied to the field of islands in experiments, which can provide data and technical support for the scientific development of islands.

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