Evaluation of the marine economic development quality in Qingdao based on entropy and grey relational analysis

Peide Liu, Xiaoxiao Liu and Hongyu Yang
School of Management Science and Engineering, Shandong University of Finance and Economics, Jinan, China

Received 5 August 2019
Revised 10 August 2019
Accepted 14 August 2019

Abstract

Purpose – Accurately judging the quality of marine economic development is the premise of grasping the level and status of marine economic development. In order to scientifically evaluate the development quality of regional marine economy, the purpose of this paper is to select the marine area of Qingdao as the research object, and construct a marine economic development quality evaluation index system with 16 indicators.

Design/methodology/approach – The raw data is normalized by the range conversion method, and the weight of the index is determined by the information entropy model. Further, the grey relational analysis (GRA) method is used to evaluate the quality of marine economic development of Qingdao from 2012 to 2017.

Findings – The results show that the marine economic development capacity of Qingdao is with the generally increasing trend, the total marine economy is with on the rising trend, the marine storage and transportation capacity, and marine ecological environment are first decreased, and then increased. The utilization of marine resources is generally decreasing, and the comprehensive management of oceans varies with the changes of environment and economy. Therefore, in view of the development capacity of marine economy, the coordinated development of economy and environment should be carried out.

Originality/value – This paper uses the GRA to evaluate the quality of marine economic development and provides a reference for the development of marine economy in Qingdao.

Keywords GRA, Entropy weight method, Economic development quality, Marine economies

Paper type Technical paper

1. Introduction

In recent years, the total value of marine economic production has occupied an increasing proportion in the national economy, and the marine economy has become a new long-term point of economic development. However, there are a series of problems in the rapid development of the marine economy. In order to ensure the sustainable use of marine resources, the harmonious marine environment and the sustainable development of the marine economy, it is necessary to improve the quality of marine economic development. So, accurately judging the quality of marine economic development is the prerequisite for accurately grasping the level and status of marine economic development. The research related to the quality of marine economic development conducted by various scholars mainly includes the following aspects: first, research on the development of marine industry and the utilization of marine resources. Sheng *et al.* (2016) used 16 index data from 2006 to 2013 such as gross ocean product (GOP), output value of the three industries and so onto study the impact of three marine industries. Wang *et al.* (2017) introduced the VAR model to explore the relationship between marine

Marine Economics and Management
Vol. 2 No. 1, 2019
pp. 29-38
Emerald Publishing Limited
2516-158X
DOI 10.1108/MAEM-08-2019-0005

resources development and marine economic growth. Cao and Ning (2019) adopted the entropy weigh and TOPSIS model to dynamically evaluate the carrying capacity of marine resources and environment in Zhanjiang from 2007 to 2016. Second, research on the structure and layout of the development of the marine industry. Ma *et al.* (2013) discussed the increase of Chinese researched on maritime industries structure and layout, offered suggestion on future research exploration in the frontline field and theoretical system building, and scientific guidance for building state-level maritime economy development model district. Based on map of Cite Space knowledge and Excel data statistics for 31 years in China, Han *et al.* (2016) summarized the overall characteristics of the marine industry research. Third, research on the comprehensive evaluation of the development of the marine economy. Jiang (2018) proposed the evaluation index in 11 coastal provinces and cities in China to comprehensively evaluate the marine economy overall development and regional differences. Guo (2014) analyzed the development status of the coastal regions with stronger development capacity. Fourth, research on the sustainable development of the marine economy. Yu *et al.* (2019) evaluated the sustainable developing ability of marine economy about Shanghai. Niu (2015) studied coordinative mechanism for marine economic sustainable development in Shandong province.

At present, multi-attribute evaluation methods, such as TOPISIS, ELECTRE, QUALIFLEX, grey relational analysis (GRA), VIKOR, etc. (Dai and Qi, 2018; Liu and Qin, 2018; Liu and You, 2017), have been widely used in engineering, social, economic and other fields, and have become the focus of today's stduies. The GRA method (Liu, 2010) is an important part of the grey system theory. Based on the generalized GRA method, Li (Li and Xu, 2016) analyzed the influential factors of the development of marine fishery. Liu and Chen (2016) analyzed the relationship between coastal household consumption and marine economic growth by the GRA method. However, there are few studies on the GRA method to analyze the quality of marine economic development. In this paper, the grey relational relative closeness is used as the evaluation standard, which can make full use of the obtained data information and effectively avoid the loss of information in the calculation process.

In view of the development of marine economy in Qingdao, this paper establishes the evaluation index system of Qingdao's marine economic development quality, determines the index weight by the entropy weight method and then uses GRA method to evaluate the quality of marine economic development in Qingdao city from 2012 to 2017. The analysis of development trends provides a certain reference for the development of marine economy in Qingdao.

2. Research methods

2.1 The standardized method

Different criteria can be adopted when conducting evaluations. There are differences in measurement units, dimensions, etc., between indicators, and there are also different types of indicators, both benefit and cost. Therefore, the indicators need to be standardized before the calculations are performed. This paper uses the range conversion method (Liu, 2010):

(1) For benefit indicators:

$$y_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}. \tag{1}$$

(2) For cost indicators:

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

where y_{ij} is the normalized value, x_{ij} is the original value, $\max x_{ij}$ is the maximum value of the index and $\min x_{ij}$ is the minimum value of the index.

2.2 Entropy weight method

This paper uses the more objective entropy weight method (Liu, 2010) to determine the weight of each indicator. Entropy can measure uncertainty. The larger the amount of information, the smaller the uncertainty; the smaller the entropy, the smaller the amount of information; and the greater the uncertainty, the greater the entropy. The calculation steps are as follows:

(1) Calculate the proportion D_{ij} of the i_{th} alternative under the j_{th} indicator:

$$D_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}, \ (j = 1, 2, \ \ldots, \ n), \tag{3}$$

where m is the number of evaluation objects and n is the number of evaluation indicators:

(2) Calculate the entropy weight E_j of the j_{th} indicator:

$$E_j = -K \sum_{i=1}^{m} D_{ij} \ln\left(D_{ij}\right), \tag{4}$$

where $K = 1/\ln(m)$, $0\ln 0 = 0$:

(3) Calculate weight:

$$w_j = \frac{1 - E_j}{n - \sum_{j=1}^{n} E_j}. \tag{5}$$

2.3 GRA method

The GRA method (Liu, 2010) is an important part of the grey system theory, which can quantitatively describe the relative changes of each attribute in the system with time. The steps of the GRA method are:

(1) Determining the ideal solution and negative ideal solution as follows:

$$\begin{cases} V_j^+ = \max\limits_i \left(y_{ij}\right) \\ V_j^- = \min\limits_i \left(y_{ij}\right) \end{cases} \quad j = 1, 2, \ \ldots, n. \tag{6}$$

(2) Calculate the grey correlation coefficient between the i_{th} and ideal solution on the j_{th} index:

$$r_{ij}^+ = \frac{m + \xi M}{\Delta_{ij}^+ + \xi M}, \ \Delta_{ij}^+ = \left|v_j^+ - v_{ij}\right|, \ m = \underbrace{\min}_{i} \underbrace{\min}_{j} \Delta_{ij}^+, \ M = \underbrace{\max}_{i} \underbrace{\max}_{j} \Delta_{ij}^+,$$

$$\xi = 0.5.$$

Calculate the grey correlation degree between the i_{th} and ideal solution:

$$R_i^+ = \sum_{j=1}^{n} w_j r_{ij}^+, (i = 1, 2, \cdots, m). \tag{7}$$

Calculate the grey correlation coefficient between the i_{th} and negative ideal solution on the j_{th} index:

$$r_{ij}^- = \frac{m + \xi M}{\Delta_{ij}^- + \xi M}, \ \Delta_{ij}^- = \left|v_j^- - v_{ij}\right|, \ m = \underbrace{\min}_{i} \underbrace{\min}_{j} \Delta_{ij}^-, \ M = \underbrace{\max}_{i} \underbrace{\max}_{j} \Delta_{ij}^-, \ \xi = 0.5.$$

Calculate the grey correlation degree between the i_{th} and negative ideal solution:

$$R_i^- = \sum_{j=1}^{n} w_j r_{ij}^-, (i = 1, 2, \cdots, m). \tag{8}$$

(3) Calculate the relative closeness of each alternative:

$$C_i = \frac{R_i^+}{R_i^+ + R_i^-}, (i = 1, 2, \cdots, m). \tag{9}$$

3. Evaluation of the marine economic development quality in Qingdao

3.1 Construction of evaluation index system

Based on the existing studies from Di and Gao (2015) and Gao (2016), and we build a marine economic development quality evaluation index system from five aspects: total marine economy, marine storage capacity, marine ecological environment, marine resource utilization and integrated marine management. Finally, the Qingdao Ocean Economic Development Quality Evaluation Index System with 16 indicators including the target layer, the standard layer and the indicator layer was determined, and shown in Table I.

3.2 Data processing

3.2.1 Data normalization. The data used in this study are derived from the Qingdao Statistical Yearbook (2012–2017), the Qingdao Marine Environment Bulletin (2012–2017) and the Qingdao Municipal Statistical Report on National Economic and Social Development (2012–2017). The raw data obtained are shown in Table II, and the standardization results of the evaluation indicators are shown in Table III.

3.2.2 Calculated indicator weights. According to the normalized data, the entropy weight method is used to calculate the weights of each indicator shown as follows in Table IV.

4. Result and analysis

4.1 Evaluation results

Using the GRA method, we get the evaluation results shown in Table V.

Project	Indicator	Indicator attributes
Total marine economy	Gross ocean product (GOP)	Benefit
	GOP's share of GDP	Benefit
	The proportion of tertiary industrial output-value	Benefit
	Total import and export volume of Qingdao Port	Benefit
Marine storage capacity	Coastal passenger throughput	Benefit
	Coastal cargo throughput	Benefit
	Waterborne passenger turnover	Benefit
	Waterborne cargo turnover	Benefit
Marine ecological environment	Beach garbage density	Cost
	Industrial wastewater discharge	Cost
Marine resource utilization	Fishing volume	Benefit
	Aquaculture area	Benefit
	Per capita coastline length	Benefit
Integrated marine management	Environmental protection expenditure	Cost
	Water conservancy and environmental fixed assets investment	Cost
	Territorial marine meteorological expenditures	Cost

Table I.
Qingdao city marine economic development quality comprehensive evaluation index system

Indicator	2012	2013	2014	2015	2016	2017
Total marine economy						
Gross ocean product(GOP)/100m yuan	1,114	1,317	1,751	2,093	2,515	2,909
GOP's share of GDP%	15.3	16.4	20.2	22.5	25.1	26.4
The proportion of tertiary industrial output-value%	48.5	49.8	50.7	52.2	54.1	55.4
Total import and export volume of Qingdao Port/100m yuan	1,489	1,567	1,651	8,973	9,495	11,102
Marine storage capacity						
Coastal passenger throughput/10,000 people	12.56	14.07	12.32	10.9	16.4	16
Coastal cargo throughput/10,000 tons	41,465	45,782	47,701	49,749	51,463	51,314
Waterborne passenger turnover/100m person-km	0.64	0.55	0.34	0.3	0.2	0.22
Waterborne cargo turnover/100m ton-km	1,426	428	427	556	727	808
Marine ecological environment						
Beach garbage density/kg km^{-2}	905	296	1,071	360.1	392.9	177.6
Industrial wastewater discharge/10,000 tons	11,145	10,660	10,989	10,566	6,865	5,613
Marine resource utilization						
Fishing volume/10,000 tons	27.21	26.7	26.78	26.07	26.21	23.83
Aquaculture area/10,000 acres	5.23	5.1	5.01	4.9	4.5	4.3
Per capita coastline length/cm	8.79	8.88	8.98	9.03	9.11	9.21
Integrated marine management						
Environmental protection expenditure/10,000 yuan	191,713	642,809	126,356	72,970	213,621	204,246
Water conservancy and environmental fixed assets investment/100m yuan	232.5	273.7	254.6	354	283.3	452.9
Territorial marine meteorological expenditures/10,000 yuan	85,121	140,768	124,146	153,023	144,448	129,040

Table II. Raw evaluation data for all indicators

As seen from Table VI, the quality of marine economic development in Qingdao has experienced a process of decreasing first and then rising.

4.2 Results analysis

As can be seen from Figure 1, the quality of marine economic development in Qingdao from 2012 to 2017 shows an increasing trend. The total marine economy has been rising steadily. Marine storage and transportation capacity is declining in the first three years, and is rising since 2014. Analyzing the value of ocean storage and transportation capacity index, the passenger turnover of water transport is declining in recent years, which indicates that other modes of transportation will also restrict passenger turnover of water transport. The change trend of marine ecological environment is unstable in the first three years, and it is rising steadily since 2014. The utilization of marine resources shows a downward trend, which indicates that marine environmental problems will restrict the development of marine economy. The unstable trend of integrated marine management indicates that government departments will adjust their expenditure on environmental governance according to the annual environmental changes (Figure 2).

From the analysis of the changes in the quality of Qingdao marine economic development, it can be concluded that from 2012 to 2013, the marine ecological development quality index has declined, and has been steadily rising from 2013 to 2017. From the grey

Table III. Normalization evaluation data for all indexes

Indicator	2012	2013	2014	2015	2016	2017
Total marine economy						
Gross ocean product (GOP)/100m yuan	0	0.113	0.355	0.545	0.781	1
GOP's share of GDP%	0	0.099	0.441	0.649	0.883	1
The proportion of tertiary industrial output-value%	0	0.188	0.319	0.536	0.812	1
Total import and export volume of Qingdao Port/100m yuan	0	0.008	0.017	0.779	0.833	1
Marine storage capacity						
Coastal passenger throughput/10,000 people	0.3	0.576	0.258	0	1	0.927
Coastal cargo throughput/10,000 tons	0	0.432	0.624	0.829	1	0.985
Waterborne passenger turnover/100m person-km	1	0.795	0.318	0.227	0	0.045
Waterborne cargo turnover/100m ton-km	1	0.001	0	0.129	0.3	0.381
Marine ecological environment						
Beach garbage density/kg km^{-2}	0.19	0.867	0	0.796	0.759	1
Industrial wastewater discharge/10,000 tons	0	0.088	0.028	0.105	0.774	1
Marine resource utilization						
Fishing volume/10,000 tons	1	0.849	0.873	0.663	0.704	0
Aquaculture area/10,000 acres	1	0.86	0.763	0.645	0.215	0
Per capita coastline length/cm	0	0.214	0.452	0.571	0.762	1
Integrated marine management						
Environmental protection expenditure/10,000 yuan	0.79	0	0.906	1	0.753	0.77
Water conservancy and environmental fixed assets investment/100m yuan	1	0.813	0.9	0.449	0.77	0
Territorial marine meteorological expenditures/10,000 yuan	1	0.18	0.425	0	0.126	0.353

Table IV. Qingdao city economic development quality evaluation index weight

Project	Indicator	Weights
Total marine economy	Gross ocean product (GOP)	0.0599
	GOP's share of GDP	0.0588
	the proportion of tertiary industrial output-value	0.0552
	Total import and export volume of Qingdao Port	0.1091
Marine storage capacity	Coastal passenger throughput	0.0527
	Coastal cargo throughput	0.0378
	Waterborne passenger turnover	0.0828
	Waterborne cargo turnover	0.1084
Marine ecological environment	Beach garbage density	0.0469
	Industrial wastewater discharge	0.1219
Marine resource utilization	Fishing volume	0.0325
	Aquaculture area	0.0456
	Per capita coastline length	0.0483
Integrated marine management	Environmental protection expenditure	0.0317
	Water conservancy and environmental fixed assets investment	0.0358
	Territorial marine meteorological expenditures	0.0727

Table V. Evaluation results of Qingdao marine economic development project

	2012	2013	2014	2015	2016	2017
Total marine economy	0.25	0.29	0.357	0.579	0.664	0.75
Marine storage capacity	0.627	0.433	0.351	0.359	0.475	0.486
Marine ecological environment	0.273	0.399	0.26	0.393	0.635	0.75
Marine resource utilization	0.559	0.559	0.591	0.561	0.524	0.441
Integrated marine management	0.73	0.394	0.588	0.417	0.46	0.418

correlation, it can be concluded that from 2016, the grey correlation degree between each year and the negative ideal solution is significantly greater than the grey correlation degree with the positive ideal solution. In 2016, there was a turning point. Then in 2017, the grey relational degree with positive ideal scheme was also greater than that with negative ideal scheme, so the evaluation result of Qingdao marine economic development quality after 2016 is more than 0.5. Therefore, although the marine economic development quality index has been rising from 2013 to 2015, the development of the marine economy has been slow due to the decline of the ecological environment and storage and transportation capacity. The economy has risen sharply from 2015 to 2017. From the trend line, we can predict that the marine economy will also rise in the future.

4.3 Comparative analysis

In this part, we will compare and analyze with the other two papers. The first one is the evaluation on the sustainable developing ability of Shanghai marine economy written by

	2012	2013	2014	2015	2016	2017
R_i^+	0.6036	0.465	0.4552	0.5099	0.633	0.7511
R_i^-	0.6963	0.7125	0.697	0.6109	0.503	0.5042
C_i	0.4643	0.3949	0.3951	0.4549	0.5572	0.5983

Table VI. Comprehensive evaluation results of Qingdao marine economic development quality

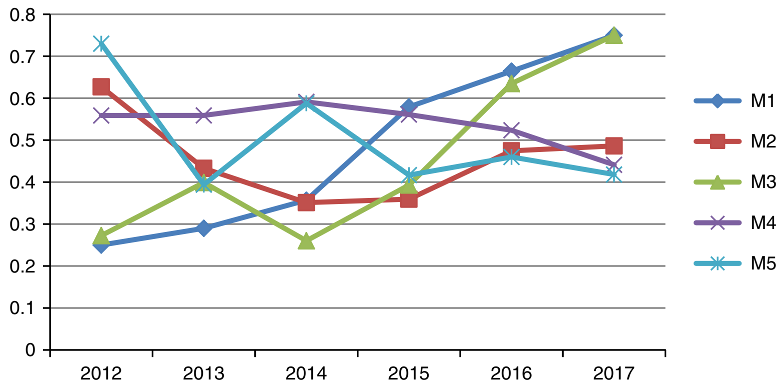

Figure 1. Evaluation results of Qingdao marine economic development project

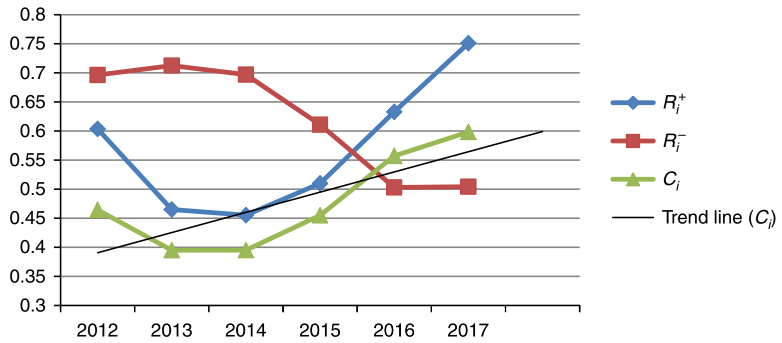

Figure 2. Comprehensive evaluation results of Qingdao marine economic development quality

Yu *et al.* (2019). And the second is an empirical study about the carrying capacity evaluation of marine resources and environment based on the entropy-weight TOPSIS model written by Gou *et al.* (2018). The comparison results are shown in Table VII.

It can be found from Table VII that the cities and contents evaluated by Yu *et al.* (2019) and this paper are different, but the method of normalizing indicators and the method of calculating weights are the same. In calculating the final comprehensive index, Yu *et al.* (2019) use a simple weighted average, and we use the GRA. Gou *et al.*'s (2018) paper and our paper all evaluate Qingdao. The normalization methods both are range conversion method and the method for calculating weights both are entropy weight method. However, the content of the evaluation and the final evaluation method are different. We use GRA to evaluate the quality of marine economic development, while Gou *et al.* (2018) use the TOPSIS to evaluate the environmental carrying capacity of marine resources. In order to better prove the validity and superiority of the evaluation results obtained by the GRA, we use the other two methods to calculate the indicators in this paper. The results obtained are shown in Table VIII and Figure 3.

As shown in Table VIII and Figure 3, the evaluation values calculated by the weighted average and TOPSIS are different from the values obtained by our method, but the trends of the quality of Qingdao's marine economic development reflected are the same. The quality of

Table VII. Comparisons over the above papers

Authors	Evaluation city	Content of the evaluation	Standardized method	Weight determination method	Evaluation method
Yu *et al.* (2019)	Shanghai	Sustainable developing ability of marine economy	Range conversion method	Entropy weight method	Weighted average
Gou *et al.* (2018)	Qingdao	Carrying capacity evaluation of marine resources and environment	Range conversion method	Entropy weight method	TOPSIS
Liu *et al.* (this paper)	Qingdao	Marine economic development quality	Range conversion method	Entropy weight method	GRA

Table VIII. Evaluation results obtained by three different methods

	2012	2013	2014	2015	2016	2017
Weighted average (Yu *et al.*, 2019)	0.0884	0.0628	0.0609	0.0956	0.1402	0.1587
TOPSIS (Gou *et al.*, 2018)	0.4506	0.3166	0.2861	0.4053	0.5669	0.6243
GRA	0.4643	0.3949	0.3951	0.4549	0.5572	0.5983

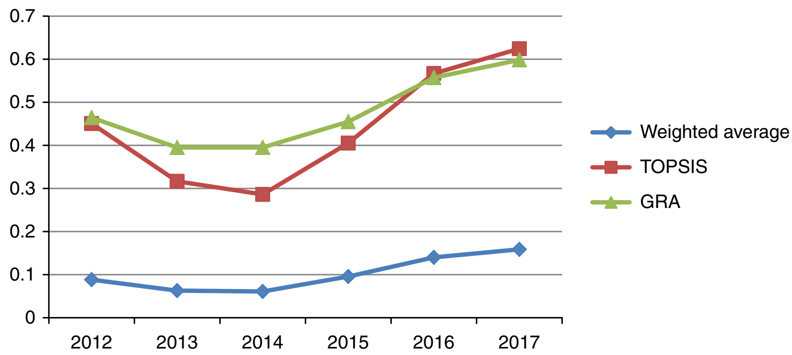

Figure 3. Comprehensive evaluation results of Qingdao marine economic development quality obtained by different methods

economic development in 2013 and 2014 is at a low level, lower than the quality development level of 2012. After 2014, the quality of marine economic development increase year by year. Therefore, we believe that our evaluation results are valid. For a given decision problem, it is not easy to determine which method is more reasonable and reliable. A more reasonable and reliable method of evaluation is to apply several different methods to the same problem, compare their results, and then make the final decision (Wu, 2002). GRA is an important part of the grey system theory and has been proven to be useful for dealing with poor, incomplete, and uncertain information. Therefore, we choose GRA to evaluate the quality of the marine economy and we believe that GRA is effective and superior for the evaluation.

5. Conclusions

This paper constructs a regional marine economic development quality evaluation index system from the five dimensions, including total marine economy, marine storage capacity, marine ecological environment, marine resource utilization and integrated marine management. The entropy weight method is used to calculate the index weight, and the GRA method is used to evaluate the quality of marine economic development. Through the analysis of the research results, it can be concluded that the quality of marine economic development in Qingdao has experienced a process of decreasing first and then rising. Through the comparative analysis with the other two methods, the rationality of the evaluation research in this paper is proved.

Through the analysis of the research results, it can be concluded that the marine economic development capacity of Qingdao is generally on the increase trend, the total marine economy has been on the rise trend, the marine storage and transportation capacity, marine ecological environment first declined and then increased. The utilization of marine resources is generally declining, and the comprehensive management of oceans varies with the changes of environment and economy. Therefore, we should rationally exploit and utilize marine resources, give full play to marine regional advantages and pay attention to the development of marine tertiary industry. At the same time, we should pay attention to marine environmental protection and promote the green development of marine economy.

References

Cao, Y. and Ning, L. (2019), "Evaluation of environmental carrying capacity of marine resources based on entropy weight TOPSIS model: taking Zhanjiang as an example", *Marine Science Bulletin*, Vol. 38 No. 3, pp. 266-272.

Dai, W. and Qi, C. (2018), "Multi-attribute group decision making method based on interval 2-tuple linguistic VIKOR", *Decision Making*, Vol. 34 No. 9, pp. 41-45.

Di, Q. and Gao, Q. (2015), "Comprehensive evaluation of marine economic development quality in liaoning province", *Marine Development and Management*, Vol. 32 No. 11, pp. 74-78.

Gao, Q. (2016), *Comprehensive Evaluation of the Quality of Marine Economic Development in 11 China's Coastal Provinces and Cities*, Liaoning Normal University, Dalian.

Gou, L., Wang, Y. and Jin, W. (2018), "Empirical study about the carrying capacity evaluation of marine resources and environment based on the entropy-weight TOPSIS model", *Marine Environmental Science*, Vol. 37 No. 4, pp. 586-594.

Guo, Y. (2014), "Evaluation of the comprehensive development capacity of marine economy", *Marine Economy*, Vol. 4 No. 4, pp. 1-8.

Han, Z., Hu, W., Li, B., Liu, T. and Hu, Y. (2016), "Progress and prospect on the research of marine industry in China", *Economic Geography*, Vol. 36 No. 1, pp. 89-96.

Jiang, L. (2018), "Study on the evaluation of comprehensive development strength of regional marine economy in China", *Feature*, Vol. 350 No. 3, pp. 38-42.

Li, Y. and Xu, Z. (2016), "Evaluation on the influential factors of the development of marine fishery: based on the generalized grey relational grade analysis", *Marine Development and Management*, Vol. 33 No. 7, pp. 37-40.

Liu, H. and Chen, D. (2016), "Grey relational analysis of coastal households consumption and marine economy growth", *Journal of Qingdao University* (Natural Science edition), Vol. 29 No. 4, pp. 105-109.

Liu, P. (2010), *Study on the Evaluation Methods and Application of Enterprise Information Level Based on Fuzzy Multi-attribute Decision Making*, Beijing Jiaotong University, Beijing.

Liu, P. and Qin, X. (2018), "An extended TOPSIS method based on interval-valued linguistic intuitionistic fuzzy numbers and information entropy", *Economic and Management Review*, Vol. 34 No. 3, pp. 87-94.

Liu, P. and You, X. (2017), "Research on selection of the offshore platform based on entropy weight and extended ELECTRE method", *Economic and Management Review*, Vol. 33 No. 3, pp. 53-59.

Ma, R., Li, J., Zhao, J. and Zhuang, P. (2013), "Progress on the research of maritime industry structure and layout in China", *Geographical Research*, Vol. 32 No. 5, pp. 902-914.

Niu, D. (2015), "Coordinative mechanism for marine economic sustainable development in Shandong province", *Journal of Ocean University of China*, No. 1, pp. 44-49, doi: 10.16497/j.cnki.1672-335x.2015.01.007.

Sheng, N., Gao, J. and Liu, Y. (2016), "Incidence research between marine industry and resource factors in China", *Marine Economy*, Vol. 6 No. 5, pp. 19-25.

Wang, Z., Lu, H. and Sun, C. (2017), "The relationship between marine resources development and marine economic growth in China", *Economic Geography*, Vol. 37 No. 11, pp. 117-126.

Wu, H. (2002), "A comparative study of using grey relational analysis in multiple attribute decision making problems", *Quality Engineering*, Vol. 15 No. 2, pp. 209-217.

Yu, D., Yang, T. and Yang, G. (2019), "Evaluation on the sustainable developing ability of marine economy about Shanghai", *Marine Development and Management*, Vol. 36 No. 6, pp. 55-58, 66.

About the authors

Peide Liu received the BS and MS Degrees in Signal and Information Processing from Southeast University, Nanjing, China, in 1988 and 1991, respectively, and the PhD Degree in information management from Beijng Jiaotong University, Beijing, China, in 2010. He is currently Professor at the School of Management Science and Engineering, Shandong University of Finance and Economics, Shandong, China. He is Associate Editor of the *Journal of Intelligent and Fuzzy Systems*, the editorial board of the journal *Technological and Economic Development of Economy*, and the member of editorial board of the other 12 journals. He has authored or coauthored more than 200 publications. His research interests include aggregation operators, fuzzy logic, fuzzy decision making, three-way decision and their applications. Peide Liu is the corresponding author and can be contacted at: peide.liu@gmail.com

Xiaoxiao Liu received the BS Degree in Mathematics, Shandong University of Finance and Economics, Jinan, China, in 2017. Now she is pursuing a Master's Degree in Management Science and Engineering, Shandong University of Finance and Economics, Shandong, China. She has coauthored four publications. Her research interests include aggregation operators, three-way decision, fuzzy decision making and their applications.

Hongyu Yang received the BS Degree in Industrial Engineering, Shandong University of Technology, Zibo, China, in 2017. Now she is pursuing a Master's Degree in Management Science and Engineering, Shandong University of Finance and Economics, Shandong, China. She has coauthored four publications. Her research interests include aggregation operators, three-way decision, fuzzy decision making and their applications.