Research on the Evaluation of High Quality Development of Shipping Based on Entropy Weighted Matter Element Extension Model

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Abstract. With the needs of social development and strong support from the country, China's shipping industry is bound to move steadily towards high-quality development. In this context, studying the evaluation of high-quality shipping development provides theoretical reference for high-quality shipping development, which is of great significance. On the basis of the "Research on evaluation index system of shipping high-quality development", Firstly, the basic principles and application steps of entropy weight method and matter element extension method are analyzed and compared; Secondly, the entropy weight method is used to calculate the indicator weights, and the comprehensive matter-element extension method is used to analyze and evaluate the overall level of high-quality development of shipping; Finally, in order to promote the high-quality development of China's shipping industry, reasonable development suggestions are proposed based on experimental results.

Keywords: Entropy weight method · Matter element extension method · Evaluation of high quality development of shipping

1 Introduction

Shipping involves a wide range of content, and it is not easy to conduct a systematic and comprehensive evaluation of it. Most of the research on the development of shipping by domestic and foreign experts and scholars is focused on a specific aspect of shipping, and there is relatively little research on shipping as the research object. From the existing research results, there are two types of shipping evaluation models: qualitative and quantitative. The use of different evaluation models can lead to differences in the calculated experimental results. Therefore, choosing a suitable evaluation model is particularly important.

Chao [1] used dynamic network Data envelopment analysis to evaluate the efficiency of 13 major container ship companies in the world. Lee [2] identified 24 factors that affect the shipping competitiveness of countries through questionnaires and Delphi method method, and built a shipping competitiveness index to quantitatively measure and rank

S. H. B. D. M. Zailani et al. (Eds.): ICMSEM 2023, 259, pp. 1483–1491, 2024.
https://doi.org/10.2991/978-94-6463-256-9_150

major shipping countries. Fan [3] innovatively proposed a comprehensive evaluation model that combines Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD), and applied this evaluation model to evaluate the international shipping centers in London, Shanghai, and Singapore. Feng [4] objectively analyzed and evaluated the development level of shipping modernization in Jiangsu Province using a fuzzy comprehensive evaluation model. Jia [5] comprehensively used the analytic hierarchy process and Delphi method method to evaluate green inland river shipping enterprises. Li [6] used the Shapley value variable weight method to evaluate the development level of the shipping industry in order to improve the accuracy of the evaluation results. Cai [7] used entropy method, kernel density estimation, cluster analysis and spatial autocorrelation method to comprehensively evaluate the shipping competitiveness of countries (regions) along the 21st century Maritime Silk Road. Feng [8] comprehensively used grey correlation analysis and regression analysis to measure the correlation between Yangtze River shipping and the economy of the Yangtze River Economic Belt. Zhang [9] used Analytic Hierarchy Process and Grey Clustering Method to analyze the competitiveness of shipping talents in Jiangsu Province. Liu [10] used the Data envelopment analysis method to explore the adaptive relationship between the Yangtze River shipping and the Yangtze River Economic Belt.

There is no unified standard for measuring the development of shipping in existing reference literature, and the selection of evaluation methods and models varies. Only by utilizing reasonable and scientific evaluation methods and models can reliable experimental data be provided for subsequent research, and accurate research conclusions can be obtained. Therefore, this article objectively analyzes and evaluates the development level of China's shipping industry by using the entropy weight matter element extension model, which helps to clarify the problems in the development of the shipping industry and proposes targeted suggestions for the high-quality development of China's shipping industry.

2 Evaluation Method

2.1 Entropy Weight Method

The calculation steps of entropy weight method are as follows:

(1) Data standardization. Assuming there are k evaluation indicators $C_1, C_2, \cdots C_k$, each with n samples. Assuming that after standardizing the data of each indicator, the value obtained is $Y_1, Y_2, \cdots Y_k$.
(2) Calculate the entropy value of each indicator. The formula is as follows:

$$E_i = -\frac{1}{ln(n)} \sum_{i=1}^{n} p_{ij} lnp_{ij} \tag{1}$$

In the formula, E_i is the entropy value; n is the number of samples; $p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}}$ is the proportion of the j-th sample under the i-th indicator.
(3) Determine the weights of each indicator. The formula is as follows:

$$W_i = \frac{1 - E_i}{k - \sum E_i} \tag{2}$$

In the formula, W_i is the indicator weight; k is the total number of indicators.

2.2 Matter element extension method

The calculation steps of the matter element extension method are as follows:

(1) Determine Classic Domain

In matter element analysis, the ordered ternary combination composed of object N, object feature C, and the magnitude V of C is called matter element, represented by $R = (N, C, V)$. There are m evaluation levels $N_1, N_2, \cdots N_m$, and the corresponding range of values for each indicator is represented by [a_{ij},b_{ij}], where [a_{ij},b_{ij}] represents the range of values specified by N_j for c_j, that is, the classical domain.

(2) Determine Section Domain

$$R = (P, C, V_p) \tag{3}$$

$$V_p = \left[mina_{ip}, maxb_{ip}\right] \tag{4}$$

In the formula, P represents all evaluation levels, $p = 1, 2, \cdots, m$; C represents all indicators; V_p is the range of values taken by P regarding c_i, that is, the nodal region.

(3) Determine the element to be evaluated

$$R = (P, c_i, v_i) \tag{5}$$

In the formula, v_i is the numerical value corresponding to P and c_i.

(4) Determine correlation degree

① Calculate the distance using the following formula:

$$\rho\left(v_i, v_{ij}\right) = \left|v_i - \frac{1}{2}\left(a_{ij} + b_{ij}\right)\right| - \frac{1}{2}\left(b_{ij} + a_{ij}\right) \tag{6}$$

$$\rho\left(v_i, v_{ip}\right) = \left|v_i - \frac{1}{2}\left(a_{ip} + b_{ip}\right)\right| - \frac{1}{2}\left(b_{ip} - a_{ip}\right) \tag{7}$$

In the formula, a_{ij}, b_{ij} represents the lower and upper limits of the classical domain, respectively; a_{ip}, b_{ip} represents the lower and upper limits of the node domain, respectively; $\rho(v_i, v_{ij})$ represents the distance between v_i and the v_{ij} interval; $\rho(v_i, v_{ip})$ represents the distance between point v_i and interval v_{ip}.

② Calculate the correlation function using the following formula:

$$K_j(v_i) = \begin{cases} -\frac{\rho\left(v_i, v_{ij}\right)}{\left|v_{ij}\right|}, v_i \in v_{ij} \\ \frac{\rho\left(v_i, v_{ij}\right)}{\rho\left(v_i, v_{ij}\right) - \rho\left(v_i, v_{ij}\right)}, v_i \notin v_{ij} \end{cases} \tag{8}$$

In the formula, $K_j(v_i)$ is the correlation function, representing the degree of belonging of indicator c_i to the evaluation level j; $\left|v_{ij}\right|$ is the length of interval [a_{ij},b_{ij}], denoted as $\left|b_{ij} - a_{ij}\right|$.

③ Calculate the correlation degree using the following formula:

$$K_j(p) = \sum_{i=1}^{n} W_i K_j(v_i) \tag{9}$$

In the formula, $K_j(p)$ is the combination value of the correlation degree of each indicator c_i with respect to the evaluation level j, taking into account the weight of the indicators; W_i is the weight calculated using the entropy weight method.

(5) Evaluation level

The evaluation p belongs to the evaluation level j*, and the formula is as follows:

$$K_{j^*}(p) = \max_{j \in (1,2,\cdots,m)} K_j(p) \tag{10}$$

3 Calculation Results for High Quality Development of Shipping

3.1 Determination of Indicator Weight

After standardizing the raw shipping data from 2015 to 2020, the weights of each indicator are obtained according to formulas (1)–(2). The weights of the evaluation index system for high-quality shipping development are shown in Table 1.

3.2 Comprehensive Evaluation of High-Quality Development of Shipping

According to formulas (3)–(10), evaluate the five aspects of high-quality development of shipping from 2015 to 2020, namely infrastructure, shipping management, green and safety, open and lead, innovative and advanced, and the overall evaluation level of high-quality development of shipping. The calculation results are shown in Table 2.

4 Conclusion

This article takes shipping as the research object, based on the theory of "high-quality development", and conducts a comprehensive evaluation of shipping development through the entropy weight matter element extension model. Research has shown that the overall level of high-quality development in China's shipping industry from 2015 to 2020 is showing a positive trend, and the shipping industry in China is continuously moving towards the goal of high-quality development and has achieved certain results. Among them, the evaluation levels of "infrastructure" and "green and safety" are not ideal from 2015 to 2020, while the evaluation levels of "shipping management", "open and lead", and "innovative and advanced" increased year by year from 2015 to 2020.

In order to promote the high-quality development level of China's shipping industry, the following development suggestions are proposed: (1) For the three aspects of shipping management, open and lead, innovative and advanced, it is necessary to continue to maintain a good development trend and provide strong support for the high-quality development of shipping. (2) For the infrastructure of shipping, it is necessary to

strengthen ship construction and optimize the scale and structure of the fleet. (3) In terms of green and safety in shipping, it is necessary to significantly reduce shipping energy

Table 1. Weight of evaluation index system for high-quality development of shipping

One-level indicator	Weight	Second-level indicator	Weight	Third-level indicator	Weight
A_1	0.04845	B_1	0.00011	C_1	0.00003
				C_2	0.00008
		B_2	0.01473	C_3	0.00807
				C_4	0.00666
		B_3	0.03360	C_5	0.01597
				C_6	0.01763
A_2	0.15529	B_4	0.06221	C_7	0.01625
				C_8	0.01156
				C_9	0.02166
				C_{10}	0.01274
		B_5	0.05265	C_{11}	0.01176
				C_{12}	0.01668
				C_{13}	0.00919
				C_{14}	0.01502
		B_6	0.04043	C_{15}	0.01526
				C_{16}	0.02517
A_3	0.22291	B_7	0.02431	C_{17}	0.01214
				C_{18}	0.01217
		B_8	0.04678	C_{19}	0.02768
				C_{20}	0.01909
		B_9	0.04969	C_{21}	0.03735
				C_{22}	0.01234
		B_{10}	0.08047	C_{23}	0.02549
				C_{24}	0.04408
				C_{25}	0.01091
		B_{11}	0.02166	C_{26}	0.00184
				C_{27}	0.01982
A_4	0.10803	B_{12}	0.03165	C_{28}	0.01820
				C_{29}	0.01345
		B_{13}	0.07638	C_{30}	0.01430

(*continued*)

Table 1. (*continued*)

One-level indicator	Weight	Second-level indicator	Weight	Third-level indicator	Weight
				C_{31}	0.02396
				C_{32}	0.01914
				C_{33}	0.01897
A_5	0.46532	B_{14}	0.35626	C_{34}	0.20862
				C_{35}	0.11877
				C_{36}	0.02886
		B_{15}	0.10906	C_{37}	0.08055
				C_{38}	0.01150
				C_{39}	0.01701

Note: The first level indicator is represented by Ag, g=1,2...,5; the second level indicator is represented by Bh, h=1,2...,15; and the third level indicator is represented by Ci, i=1,2...,39.

consumption, increase investment in environmental protection, and improve shipping safety.

Acknowledgments. This paper is a phased achievement of the National Social Science Foundation Youth Program (22CJY066) and the Ministry of Transport Research Fund Program (2018-6-5).

Table 2. Comprehensive evaluation of high-quality development of shipping

Evaluation aspect	Year	Level I	Level II	Level III	Level IV	Level V	Evaluation level
Infrastructure	2015	-0.0148	-0.0484	-0.0484	-0.0484	-0.0336	I
	2016	-0.0115	-0.0077	-0.0239	-0.0238	-0.0220	II
	2017	-0.0209	-0.0115	0.0116	-0.0046	-0.0176	III
	2018	-0.0283	-0.0207	-0.0087	0.0065	-0.0126	IV
	2019	-0.0252	-0.0321	-0.0337	-0.0257	0.0020	V
	2020	-0.0336	-0.0484	-0.0484	-0.0484	-0.0148	V
Shipping management	2015	-0.1317	-0.1480	-0.1516	-0.1529	-0.0144	V
	2016	-0.0993	-0.1045	-0.0856	-0.0386	-0.0160	V
	2017	-0.0589	-0.0468	0.0147	-0.0316	-0.0683	IV
	2018	-0.0536	-0.0137	-0.0590	-0.0919	-0.0826	III
	2019	0.0211	-0.0283	-0.0918	-0.1130	-0.1235	II
	2020	-0.0162	-0.1553	-0.1553	-0.1553	-0.1390	I
Green and safety	2015	-0.1007	-0.2154	-0.2117	-0.2029	-0.1205	I
	2016	-0.0830	-0.0977	-0.0832	-0.0373	-0.0757	IV
	2017	-0.0989	-0.0572	-0.0156	-0.0406	-0.0840	III
	2018	-0.0834	-0.0675	-0.0347	-0.0467	-0.0902	III
	2019	-0.0850	-0.1295	-0.1460	-0.1179	-0.0501	V
	2020	-0.1122	-0.2175	-0.2165	-0.2112	-0.1061	V
Open and lead	2015	-0.0940	-0.1072	-0.1068	-0.1056	-0.0110	V
	2016	-0.0662	-0.0686	-0.0573	-0.0229	-0.0163	V
	2017	-0.0513	-0.0299	0.0009	0.0021	-0.0390	IV
	2018	-0.0470	-0.0208	-0.0239	-0.0272	-0.0380	II
	2019	-0.0187	-0.0231	-0.0400	-0.0640	-0.0616	I
	2020	-0.0045	-0.0944	-0.0947	-0.0991	-0.1013	I
Innovative and advanced	2015	-0.4570	-0.4542	-0.6550	-0.4385	-0.0049	V
	2016	-0.4406	-0.4324	-0.6200	-0.3829	0.0316	V
	2017	-0.4396	-0.4311	-0.6221	-0.3968	0.0118	V
	2018	-0.4027	-0.3710	-0.3823	-0.3598	-0.0031	V
	2019	-0.3304	-0.7627	-0.3320	-0.2190	-0.0654	V
	2020	0.0000	-0.4653	-0.4653	-0.4653	-0.4653	I

(*continued*)

Table 2. (*continued*)

Evaluation aspect	Year	Level I	Level II	Level III	Level IV	Level V	Evaluation level
High quality development level of shipping	2015	-0.7982	-0.9733	-1.1736	-0.9482	-0.1844	V
	2016	-0.7006	-0.7109	-0.8700	-0.5055	-0.0984	V
	2017	-0.6697	-0.5764	-0.6106	-0.4715	-0.1971	V
	2018	-0.6150	-0.4938	-0.5086	-0.5192	-0.2264	V
	2019	-0.4383	-0.9757	-0.6435	-0.5397	-0.2986	V
	2020	-0.1665	-0.9810	-0.9802	-0.9794	-0.8266	I

Note: Excellent (Level I), Good (Level II), Fair (Level III), Poor (Level IV), and Poor (Level V).

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