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Original scientific paper

Performance Evaluation of Port Enterprise Resource Integration Based on Fuzzy Comprehensive Evaluation Method

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Abstract: With increasingly mature global supply chain network with ports as the core, competition among ports has gradually turned to the ability and efficiency of resource integration. However, there is a lack of relevant studies on how to scientifically evaluate the resource integration performance of port enterprises. To comprehensively evaluate the actual effect of port enterprises in process of resource integration, a performance evaluation system of port enterprises resource integration covering 19 secondary indicators from the four dimensions of financial integration, operational efficiency, technological innovation, and realized benefit was built, fuzzy analytic hierarchy process (FAHP) was used to determine weights of various indicators and port enterprises in Zhejiang, Jiangsu, Liaoning, Shandong and Guangdong provinces of China were taken as samples, and fuzzy comprehensive evaluation (FCE) was used to evaluate its resource integration performance. Results show that technological innovation is the primary performance indicator, followed by financial integration indicators, and the impact of realization efficiency and operational efficiency indicators is relatively weak. Resource integration performances of port enterprises in Zhejiang, Jiangsu, Liaoning, Shandong, and Guangdong are generally good. Evaluation results of sample ports reflect the actual integration of ports, and the model can effectively evaluate the performance of port enterprise resource integration. Conclusions obtained from this study provide theoretical support for the scientific performance evaluation of port enterprise resource integration.

Keywords: fuzzy comprehensive evaluation; performance evaluation; port enterprises; port logistics; resource integration

1 INTRODUCTION

The port is the hub of waterway connection, gateway of foreign trade of a country or a region, and junction of various modes of transportation, which plays an important role in development of national economy. For a long time, ports have dominated import and export trade of various countries. With arrival of economic globalization and integration, supremacy of ports is under threat. Problems such as repeated construction of ports and waste of resources have led to disorderly competition and opposition between neighboring ports, which restricts development of ports [1]. Since 2014, the growth rate of China's cargo throughput has also gradually slowed down, and port industry has entered the "mature period" from the "growth period". Operation of some ports in China has deteriorated, debt pressure has become prominent, and competition between regional ports has become increasingly prominent. Therefore, large-scale port resource integration has emerged at a historic moment. To get rid of excessive density of port construction and excessive competition among ports, to rationally allocate resources, to optimize the industrial structure, and to reduce risk of port operation, ports in the same region, ports in adjacent geographical locations, or ports with close connections have sought cooperation or integration, and integrated resources among ports to seek greater economic benefits [2].

There are many successful cases of resource integration of port enterprises in recent decades. The New York-New Jersey Port Group in the United States adopts "landlord port" operation mode, separating port ownership and operation rights. The government is responsible for port planning, approval and resident enterprise management, and chartered terminal operator is responsible for terminal operation and management. The Tokyo Bay Port Group of Japan has integrated resources of the entire port group by means of overall publicity, reasonable location, and unified pricing policy, and has improved overall competitiveness. The Hamburg Port and Bremen Port in Germany cooperate to resist competition from other ports through public operators. With the approval of the Ministry of Transport, China's Ningbo Port and Zhoushan Port have been integrated, and integrated Ningbo Zhoushan Port has occupied the first place in the world's cargo throughput for 13 consecutive years [3].

Integration of port resources is to use administrative means to optimize overall allocation of natural resources, operating resources and administrative resources of ports with overlapping hinterland, similar resources and fierce competition in the region, to realize efficient use of overall resources of the port group in the region. How is resource integration performance of port enterprises? How to construct evaluation system scientifically and reasonably? This is worth thinking deeply. Looking at global port development trends, the process of resource integration of port enterprises is in full swing. How to scientifically evaluate resource integration performance of port enterprises and comprehensively reflect on the actual effect of integration is particularly important for the high-quality development of ports. This study intends to take five major port provinces in China as a sample, to give scientific and reasonable integration evaluation results and to put forward relevant management suggestions based on the construction of a performance evaluation system of port enterprise resource integration.

2 LITERATURE REVIEW

Resource integration is one of the important fields of enterprise sustainable development research. Many scholars carried out meaningful discussions in this field and accumulated valuable research results. Sklyar et al. [6] proposed to integrate resources through digitalization from the perspective of service ecosystem to improve effectiveness of resource integration and to change resource integration mode. Existing literature has fully demonstrated the value of resource integration and its driving factors, but there is a lack of systematic performance evaluation of resource integration, and literature related to the field of port enterprises is also very scarce.

Some scholars also conducted meaningful discussions on port performance evaluation. Early research on this topic mostly focused on evaluation of port location, container terminal productivity, port efficiency and port service quality. Somensi et al. [7] and Ha et al. [8] selected container port productivity, delivery time, human capital, services, multimodal transport system and information system as indicators to evaluate port performance from the perspective of different port stakeholders. Sun et al. [9], Duru et al. [10], and Ju and Liu [11] used data envelopment analysis and regression model to study efficiency and its influencing factors of listed companies in Chinese ports and found that proportion of state-owned shares, ratio of liabilities to assets and ratio of operating costs were negatively correlated with efficiency, while scale of enterprises, proportion of external directors and human capital were positively correlated with efficiency. Hua et al. [12] and Wu et al. [13] noted heterogeneity of input-output indicators in performance evaluation of container ports, and pointed out that number of berths and capital deployment were the most sensitive indicators affecting performance of most container ports. Although construction of port performance evaluation and its indicator system is relatively mature, evaluation research in the field of port resource integration is still relatively rare, and this aspect is an important trend of port development, which needs to be paid enough attention.

To sum up, there are many studies about port performance and performance evaluation, but there are few on resource integration performance, that is, how to build evaluation system of resource integration performance still needs further discussion. This study focuses on performance evaluation of port enterprise resource integration, attempts to build a more scientific and comprehensive evaluation system, and takes practice of resource integration in major port provinces in China as a case to verify effectiveness of the evaluation model, to provide theoretical contributions to integration and development of port enterprises and enrich research results in this field. The research contribution of this study is to build a port enterprise resource integration evaluation model covering four dimensions of financial integration, operational efficiency, technological innovation and realized benefit, and to verify its effectiveness with examples of major port provinces in China.

The rest of this study is organized as follows: Section 3 constructs the performance evaluation index system and evaluation model of port enterprise resource integration. Section 4 carries out an empirical analysis of the performance evaluation of port enterprise resource integration. Section 5 concludes this study.

3 METHODOLOGY

3.1 Evaluation Indicator System

Based on the principles of science, effectiveness and availability, referring to the findings of Ha et al. [14] and Sun et al. [9], this study constructs a performance evaluation index system for resource integration of Chinese port enterprises around four dimensions of financial integration, operational efficiency, technological innovation and realized benefit. Among them, financial integration includes asset use, service cost, solvency, financing capacity and profitability. Operational efficiency includes policy and system consistency, overall service reliability, efficiency of multimodal transport, provisioning efficiency and customs clearance efficiency. Technological innovation includes information level, input in multimodal transport system, information capital investment, technology update cost and overall R & D investment. Realized benefit includes brand awareness, ecological and environmental benefits, regional economic contribution, and social participation.

3.2 Evaluation Model

This study selects experts in the fields of port management, enterprise merger, performance evaluation, etc., issues questionnaires, widely collects the scores of various indicators, uses Fuzzy Analytic Hierarchy Process (FAHP) to scientifically calculate weights of various indicators, and constructs FAHP and Fuzzy Comprehensive Evaluation (FCE) model based on which evaluation criteria and judgment matrices are established respectively. Combining actual situation of the case port, it collects and collates relevant data for empirical analysis.

3.2.1 Fuzzy Analytic Hierarchy Process

(1) Triangular fuzzy number:

FAHP relies on experts' pairwise comparison of relative importance of each criterion and index in evaluation system to construct an index. Weights obtained by the Participatory approach are associated with two frequent problems: assessments errors and international comparisons [15]. Compared with traditional AHP, FAHP introduces fuzzy number in mathematics to reflect fuzzy comparison in the expert evaluation system. Compared with AHP, FAHP can better reflect fuzziness of human thinking process, and its evaluation is more scientific and accurate. This study uses triangular fuzzy number proposed by Laarhoven to reflect fuzziness of expert judgment [16]. The possibility that a real number z is subordinated to a triangular fuzzy number $M = (l, m, u)$ with the value of $\mu_M(z)$. Only if $\mu_M(z)$ is defined according to the following Eq. (1).

$$\mu_M(z) = \begin{cases} \dfrac{z-l}{m-l}, \ l \le z \le m \\ \dfrac{z-u}{m-l}, \ m \le z \le u \\ 0, \text{Other conditions} \end{cases} \tag{1}$$

As a real number z can be understood as possible deterministic value of M. To obtain the "possibility" of this z, l is the "minimum possible value" of M, m is the "most likely value" of M, and u is the "maximum possible value" of M. When z is equal to the "most likely value", z belongs to fuzzy number M with the possibility of l. When z is gradually away from the "most likely value", the possibility of its subordination to M decreases linearly. When z is less than l or greater than u, z cannot belong to

M. The algorithm of two triangular fuzzy numbers $M_1 = (l_1, m_1, u_1)$and $M_2 = (l_2, m_2, u_2)$ is further defined as shown in Eq. (2).

$$\begin{cases} M_1 \oplus M_2 = \left(l_1 + l_2,\, m_1 + m_2,\, u_1 + u_2\right) \\ M_1 \otimes M_2 = \left(l_1 l_2,\, m_1 m_2,\, u_1 u_2\right) \\ \lambda \otimes M_1 = \left(\lambda l_1,\, \lambda m_1,\, \lambda u_1\right) \\ \dfrac{1}{M_1} = \left(\dfrac{1}{u_1},\, \dfrac{1}{m_1},\, \dfrac{1}{l_1}\right) \end{cases} \tag{2}$$

(2) Expert judgment and consistency test:

FAHP starts with paired comparison of relative importance of each criterion by experts. Therefore, first of all, it defines relative importance of criterion C_i compared with criterion C_j, that is, to compare each factor with each other by using scale method of 0.1 - 0.9. It specifies that 0.1 - 0.9 respectively shows that factor i is unimportant, very unimportant, relatively unimportant, slightly unimportant, equally important, slightly important, relatively important, very important, and more important than factor j.

The above 0.1 - 0.9 scale method is used to compare the evaluation factors in pairs to obtain the fuzzy analytic hierarchy process scoring matrix $\boldsymbol{X}$, as shown in the following Eq. (3). The matrix $\boldsymbol{X}$ meets the requirements of the fuzzy complementary matrix, that is $0 < x_{ij} < 1$, $x_{ij} + x_{ji} = 1$, and $x_{ij} = 0.5(i = j)$.

$$\boldsymbol{X} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix} \tag{3}$$

It sums matrix $\boldsymbol{X}$ by row, as shown in Eq. (4).

$$x_i = \sum_{k=1}^{n} x_{ik},\ \left(i, k = 1, 2, ..., n\right) \tag{4}$$

Then it calculates the weight determinant WI of each factor, as shown in the following Eq. (5) and Eq. (6).

$$w_i = \frac{1}{n} - \frac{1}{2\alpha} + \frac{a_i}{n\alpha},\ \alpha = \frac{n-1}{2} \tag{5}$$

$$WI = \left[w_1 \quad w_2 \quad \cdots \quad w_n\right]^{\mathrm{T}} \tag{6}$$

In AHP analysis, although inconsistent thinking of experts is acceptable to some extent, expert judgment with too serious inconsistent thinking is unacceptable. Therefore, Saaty proposed to conduct consistency analysis on reciprocal judgment matrix to ensure that reciprocal judgment matrix was close enough to consistency matrix, to control inconsistency of thinking within a certain range, thus ensuring rationality of AHP analysis [17]. Similar problems also appear in FAHP analysis. Therefore, it is necessary to analyze consistency of the judgment made by experts in FAHP analysis. This study defines the consistency index CI as follows (7).

$$CI = \frac{\lambda_{\max} - N}{N - 1} \tag{7}$$

Among them, $\lambda_{\max}$ is the maximum characteristic heel of X. $CI = 0$ indicates that X is a strict uniform matrix. The larger the CI is, the higher the inconsistency of $\boldsymbol{X}$ is, and the more unreasonable the result of expert judgment is.

Weight matrix $\boldsymbol{W}$ is constructed as shown in the following Eq. (8) and Eq. (9), and CI value is shown in the following Eq. (10). The smaller the CI value is, the better the consistency is. Generally, $CI < 0.1$ means that consistency requirements are met.

$$w_{ij} = \alpha\left(w_i - w_j\right) + 0.5 \tag{8}$$

$$\boldsymbol{W} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{bmatrix} \tag{9}$$

$$CI\left(X, W\right) = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left|w_{ij} - x_{ij}\right|}{n^2} \tag{10}$$

(3) Fuzzy number comprehensive judgment matrix

After obtaining judgment matrix $\boldsymbol{X}$ of each expert and confirming that the expert's judgment has passed consistency test, it synthesizes judgment of the K expert to form a comprehensive judgment matrix with real number representing majority as the expert's judgment. On the basis of $m_{i,j}$ as element of the column j in the row i of the matrix, it refers to the practice of Su [18], such as Eq. (11) and Eq. (12) to convert real number $m_{i,j}$ to fuzzy number $M_{i,j} = (l_{i,j}, m_{i,j}, u_{i,j})$.

$$l_{i,j} = \begin{cases} \dfrac{1}{\dfrac{1}{m_{i,j}} + 1},\ m_{i,j} < 1 \\ 1, m_{i,j} = 1 \\ m_{i,j} - 1,\ m_{i,j} > 1 \end{cases} \tag{11}$$

$$u_{i,j} = \begin{cases} \dfrac{1}{\dfrac{1}{m_{i,j}} - 1},\ m_{i,j} < 1 \\ m_{i,j} + 1,\ m_{i,j} \geq 1 \end{cases} \tag{12}$$

(4) Complementary judgment matrix:

The fuzzy number comprehensive judgment matrix is still composed of fuzzy numbers, which only reflects relative importance of the fuzzy between the criteria, but cannot give precise relative importance of the criteria for further analysis. Therefore, it is necessary to further de-blur fuzzy number judgment matrix into a complementary judgment matrix ***CM*** expressed in real numbers. To express conciseness, it takes elements in row i and column j of ***CM*** as $R_{i,j}$. First of all, comprehensive fuzzy value of criterion C_i is defined as follows Eq. (13).

$$d_i = \frac{\sum_{i=1}^{n} M_{i,j}}{\sum_{i=1}^{n}\sum_{j=1}^{n} M_{i,j}} \tag{13}$$

Obviously, d_i is still a fuzzy number. To remove ambiguity, it defines that probability function which $d_i = (l_i, m_i, u_i)$ is greater than $d_j = (l_j, m_j, u_j)$ is as following Eq. (14).

$$V(d_i - d_j) = \begin{cases} 1, m_i \ge m_j \\ \dfrac{u_i - l_j}{(u_i - m_i) + (m_j - l_j)}, m_i < m_j \text{ and } u_i > 1 \\ 0, \textit{Other} \end{cases} \tag{14}$$

Obviously, $V(d_i \ge d_j) = 1$. The average dominance provided by Su [18] is adopted, as shown in Eq. (15) below.

$$P(d_i \ge d_j) = \frac{V(d_i \ge d_j) + 1 - V(d_j \ge d_i)}{2} \tag{15}$$

Average dominance is a real number calculated from the possibility. Su [18] proved three properties of average dominance, that was $0 \le P(d_i > d_j) \le 1$, $P(d_i > d_j) = 0$, and $P(d_i > d_j) + P(d_j > d_i) = 1$. It was valid for any $i \ne j$. Finally, it makes $R_{i,j} = P(d_i - d_j)$, and above three properties can effectively avoid the problem that weight of the criterion is 0 caused by construction of CM using $V(d_i \ge d_j)$.

(5) Relative weight of criteria and indicators:

According to simple algorithm proposed by Xu [19], relative weight of criterion C_i to the target is shown in Eq. (16).

$$\omega_i' = \frac{\sum_{i=1}^{n} R_{i,j} + \frac{n}{2} - 1}{n(n-1)} \tag{16}$$

3.2.2 Fuzzy Comprehensive Evaluation

(1) Determining index set of fuzzy evaluation:

$U = \{u_1, u_2, \ldots, u_q\}$ can effectively evaluate evaluation object from q aspects, that is, evaluated object contains q secondary indicators. Sub-indicator set of each secondary indicator can be expressed as $u_1 = \{u_{11}, u_{12}, \ldots, u_{1r}\}$, $u_2 = \{u_{21}, u_{22}, \ldots, u_{2r}\}, \ldots, u_q = \{u_{q1}, u_{q2}, \ldots, u_{qr}\}$, which indicates that above-mentioned aspects can be evaluated.

(2) Establishing comment set of evaluation indicators:

Comment set is a collection of comments made by selected experts on each evaluation index. Generally, V is used to represent set of comments $V = \{V_1, V_2, \ldots, V_n\}$. In this study, evaluation indicators are designed as excellent, good, average, poor, and very poor. It assigns a value of 0 - 100, and classifies grades according to status of indicators, as shown in Tab. 1.

Table 1 Correspondence table of satisfaction scores and representations

Degree of evaluation	Excellent	Good	Average	Poor	Very poor
Score	90 - 100	70 - 90	50 - 70	30 - 50	10 - 30

(3) Determining weight of each indicator:

According to frequency of experts' evaluation grade of each indicator, specific score of evaluation object in each indicator can be determined by sorting out statistics, which can be represented by $o_i = \{o_{i1}, o_{i2}, \ldots, o_{in}\}$ $(i = 1, 2, \ldots, n)$, where o_{ij} represents subordination grade of evaluation object in the ith indicator, and a single factor fuzzy comprehensive evaluation matrix can be constructed with $\boldsymbol{O}_i$ as the row, as shown in Eq. (17) below.

$$\boldsymbol{O}_i = \begin{pmatrix} o_{i11} & o_{i12} & \cdots & o_{i1n} \\ o_{i21} & o_{i22} & \cdots & o_{i2n} \\ \vdots & \vdots & \ddots & \vdots \\ o_{ir1} & o_{ir1} & \cdots & o_{irn} \end{pmatrix} \quad (i = 1, 2, \ldots, q) \tag{17}$$

According to weight of evaluation index and score of evaluation object, fuzzy comprehensive evaluation matrix of single factor can be obtained.

(4) Comprehensive evaluation:

Through conversion of fuzzy factors, a fuzzy comprehensive evaluation model of integration performance of Chinese port resources can be obtained.

4 EMPIRICAL ANALYSIS

4.1 Sample Selection

In 2015, Zhejiang Province of China took lead in starting integration of ports, and Zhejiang Provincial Seaport Group was established. With the group as platform, port enterprises of the five major ports, including Ningbo Port, Zhoushan Port, Jiaxing Port, Taizhou Port and Wenzhou Port, were integrated and operated in a unified manner. In 2017, Jiangsu Province set up a port group and began to promote integration of relevant port assets, and completed integration of some provincial ports and shipping assets such as Nanjing Port Group and Suzhou Port Group. In 2017, Liaoning Provincial Government signed the Port Cooperation Framework Agreement with China Merchants Group to establish a unified operation platform for Liaoning ports. In 2020, Dalian Port plans to merge Yingkou Port by issuing A-share exchange. In 2018, Shandong Bohai Bay Port Group was established to further integrate Weifang Port, Binzhou Port and Dongying Port, and port integration took the first step. In 2019, 100% equity of Weihai Port Group was transferred to Qingdao Port Group for free, and the second step of Shandong integration was completed. In 2018, Port Resources Integration Plan of Guangdong Province proposed to integrate provincial and municipal state-owned port assets in the 14 coastal cities and Foshan by region, with Guangzhou Port Group and Shenzhen Port Group as the two main bodies. Resource integration of port enterprises in these five provinces is typical and representative. Port integration cases in Zhejiang, Jiangsu, Liaoning, Shandong and Guangdong provinces in China are selected as samples. Through designing questionnaires and in-depth interviews, relevant information on evaluation indicators is obtained. Through evaluation and comparison, performance of resource integration of port enterprises in the head can be found out, which can provide reference for port enterprises in other provinces to carry out resource integration.

4.2 Calculation of Weight

Using the 0.1 - 0.9 scale method, it compares indicators of criterion layer and indicator layer, confirms their comparative significance, and obtains fuzzy analytic hierarchy process scoring matrix. This process uses questionnaires, and invites five relevant experts to assign their subjective weights to their importance, and makes group decisions based on the results of different experts. Weight matrix is shown in Tab. 2 to Tab. 6.

Table 2 Corrected weight matrix for calculation (criterion level, CI = 0.098)

	Financial integration, a	Operating efficiency, b	Technological innovation, c	Realized benefit, d	Weight, w_i
Financial integration, a	0.5	0.3361	0.6156	0.6691	0.2701
Operating efficiency, b	0.6639	0.5	0.1912	0.4294	0.2141
Technological innovation, c	0.3844	0.8088	0.5	0.571	0.2941
Realized benefit, d	0.3309	0.5706	0.429	0.5	0.2217

Table 3 Corrected weight matrix for calculation (level of financial integration, CI = 0.082)

	Asset use, a_1	Service cost, a_2	Solvency, a_3	Financing capacity, a_4	Profitability, a_5	Weight, w_i
Asset use, a_1	0.5	0.5744	0.6642	0.4177	0.2975	0.1953
Service cost, a_2	0.4256	0.5	0.309	0.6892	0.5755	0.1998
Solvency, a_3	0.3358	0.691	0.5	0.2964	0.5073	0.1831
Financing capacity, a_4	0.5823	0.3108	0.7036	0.5	0.594	0.2191
Profitability, a_5	0.7025	0.4245	0.4927	0.406	0.5	0.2026

Table 4 Corrected weight matrix for calculation (level of operating efficiency, CI = 0.072)

	Policy and system consistency, b_1	Overall service reliability, b_2	Efficiency of multimodal transport, b_3	Provisioning efficiency, b_4	Customs clearance efficiency, b_5	Weight, w_i
Policy and system consistency, b_1	0.5	0.5	0.6	0.7	0.4	0.22
Overall service reliability, b_2	0.5	0.5	0.4	0.6	0.7	0.22
Efficiency of multimodal transport, b_3	0.4	0.6	0.5	0.4	0.6	0.2
Provisioning efficiency, b_4	0.3	0.4	0.6	0.5	0.4	0.17
Customs clearance efficiency, b_5	0.6	0.3	0.4	0.6	0.5	0.19

Table 5 Corrected weight matrix for calculation (level of technological innovation, CI = 0.082)

	Informatization level, c_1	Input of multimodal transport system, c_2	Information capital investment, c_3	Technology update cost, c_4	Overall R&D investment, c_5	Weight, w_i
Informatization level, c_1	0.5	0.8	0.9	0.7	0.4	0.28
Input of multimodal transport system, c_2	0.2	0.5	0.4	0.4	0.3	0.13
Information capital investment, c_3	0.1	0.6	0.5	0.8	0.6	0.21
Technology update cost, c_4	0.3	0.6	0.2	0.5	0.4	0.15
Overall R & D investment, c_5	0.6	0.7	0.4	0.6	0.5	0.23

Table 6 Corrected weight matrix for calculation (level of realized benefit, CI=0.075)

	Brand awareness, d_1	Ecological and environmental benefits, d_2	Regional economic contribution, d_3	Social participation, d_4	Weight, w_i
Brand awareness, d_1	0.5	0.6	0.6	0.8	0.3333
Ecological and environmental benefits, d_2	0.4	0.5	0.7	0.4	0.25
Regional economic contribution, d_3	0.4	0.3	0.5	0.6	0.2167
Social participation, d_4	0.2	0.6	0.4	0.5	0.2

The results show that all CI values are lower than 0.1 and each judgment matrix has passed consistency test, indicating that setting of evaluation indicators is scientific and reasonable, and can be used for evaluation research. Finally, indicator level is calculated by multiplying all levels, and total weight corresponding to target level is comprehensive weight. It is shown in Tab. 7 for specific calculation results.

According to Tab. 7 above, the first-level indicators are technological innovation (0.2941), financial integration (0.2701), realized benefit (0.2217) and operational efficiency (0.2141) according to their weights. The second-level indicators are relatively high in terms of informatization level (0.0823), brand awareness (0.0739), overall R & D investment (0.0677) and informatization capital investment (0.0618).

4.3 Comprehensive Evaluation Results

The above fuzzy comprehensive evaluation model is applied to measure and evaluate resource integration performance of the selected five provincial port enterprises, and valuation index weight is shown in Eq. (18).

$$X = (0.2701,\ 0.2141,\ 0.2941,\ 0.2217) \tag{18}$$

Table 7 Bottom conclusions of group decision-making (weight)

Underlying element	Conclusion value (global weight)	Peer weight	Superior
Asset use, a_1	0.0528	0.1953	Financial integration, a 0.2701
Service cost, a_2	0.0540	0.1998	
Solvency, a_3	0.0495	0.1831	
Financing capacity, a_4	0.0592	0.2191	
Profitability, a_5	0.0547	0.2026	
Policy and system consistency, b_1	0.0471	0.22	Operating efficiency, b 0.2141
Overall service reliability, b_2	0.0471	0.22	
Efficiency of multimodal transport, b_3	0.0428	0.2	
Provisioning efficiency, b_4	0.0364	0.17	
Customs clearance efficiency, b_5	0.0407	0.19	
Informatization level, c_1	0.0823	0.28	Technological innovation, c 0.2941
Input of multimodal transport system, c_2	0.0382	0.13	
Information capital investment, c_3	0.0618	0.21	
Technology update cost, c_4	0.0441	0.15	
Overall R&D investment, c_5	0.0677	0.23	
Brand awareness, d_1	0.0739	0.3333	Realized benefit, d 0.2217
Ecological and environmental benefits, d_2	0.0554	0.25	
Regional economic contribution, d_3	0.0480	0.2167	
Social participation, d_4	0.0443	0.2	

It qualitatively processes evaluation grades of resource integration performance of port enterprises in each province, divides them into five grades, namely "excellent", "good", "average", "poor" and "very poor", and conducts questionnaire survey on experts. Based on survey results of port enterprises in Zhejiang Province, a response fuzzy evaluation matrix is formed, as shown in Eq. (19).

$$R_{ZJ1}=\begin{bmatrix}0.5&0.3&0.1&0.1&0\\0.4&0.3&0.2&0.1&0\\0.4&0.2&0.2&0.2&0\\0.5&0.3&0.1&0.1&0\\0.5&0.2&0.3&0&0\end{bmatrix}\quad R_{ZJ2}=\begin{bmatrix}0.6&0.2&0.1&0.1&0\\0.5&0.3&0.2&0&0\\0.6&0.2&0.1&0.1&0\\0.4&0.3&0.2&0.1&0\\0.4&0.4&0.1&0.1&0\end{bmatrix}$$
$$R_{ZJ3}=\begin{bmatrix}0.6&0.2&0.1&0.1&0\\0.5&0.3&0.1&0.1&0\\0.5&0.2&0.2&0.1&0\\0.4&0.3&0.2&0.1&0\\0.3&0.3&0.2&0.2&0\end{bmatrix}\quad R_{ZJ4}=\begin{bmatrix}0.6&0.2&0.2&0&0\\0.5&0.3&0.1&0.1&0\\0.4&0.2&0.2&0.1&0\\0.4&0.4&0.2&0&0\end{bmatrix} \tag{19}$$

Using the MCE tool, the secondary comprehensive evaluation is obtained as shown in Eq. (20).

$$Y_{ZJ}=X*R_{ZJ}=\left(0.4817,\ 0.2638,\ 0.1644,\ 0.0901,\ 0\right) \tag{20}$$

Similarly, evaluation results of the resource integration of the provincial port enterprises can be obtained, as shown in Eq. (21) to Eq. (24).

$$Y_{JS}=X*R_{JS}=\left(0.4541,\ 0.2728,\ 0.1413,\ 0.1318,\ 0\right) \tag{21}$$

$$Y_{LN}=X*R_{SL}=\left(0.4035,\ 0.3573,\ 0.1073,\ 0.0726,\ 0.0593\right) \tag{22}$$

$$Y_{SD}=X*R_{SD}=\left(0.3021,\ 0.2155,\ 0.1813,\ 0.1719,\ 0.1292\right) \tag{23}$$

$$Y_{GD}=X*R_{GD}=\left(0.4431,\ 0.2738,\ 0.1607,\ 0.1584,\ 0\right) \tag{24}$$

From above analysis, it can get comprehensive evaluation score of the resource integration performance of port enterprises in each province, shown as Eq. (25). Here, corresponding median is selected for the score value, namely V = [95 80 60 40 20].

$$G=Y*V^{\mathrm{T}} \tag{25}$$

Then, it gets G_{ZJ} = 80.33, G_{JS} = 78.71, G_{LN} = 77.44, G_{SD} = 66.28, G_{GD} = 79.98. According to Tab. 1, resource integration performance of four provincial port enterprises is "good", and that of one provincial port enterprise is "average". By comparing the above values, it is concluded that resource integration performance of port enterprises in Zhejiang Province is the best. From the perspective of comprehensive scores, all indicators of resource integration performance of port enterprises in Zhejiang Province are good, and most indicators are rated as "excellent".

4.4 Discussions

The above empirical results show that, from perspective of weight, the first-level indicators include technological innovation > financial integration > realized benefits > operational efficiency, and that the second-level indicators have relatively high weight of informatization level, brand awareness, overall R & D investment and informatization capital investment. This conclusion means that technological innovation is primary factor to be considered in port enterprise resource integration, and high brand awareness and profitability also have an important impact on port integration performance. These points have been confirmed by scholars in discussing driving factors of resource integration and evaluating port performance. For example, in terms of technological innovation, when enterprises have high resource similarity and low resource complementarity, integrators should increase number of innovation cooperation and technological innovation to ensure strength and performance of enterprise resource integration [20]. In process of enterprise resource integration, enterprises that adopt information technology are more likely to develop their capabilities, create value through continuous resource reallocation, and increase their competitive advantages [21], while advanced technology can significantly affect customer responsiveness [22], and translate into higher operational performance, such as better facility utilization, higher productivity, lower costs and more satisfied customers [23]. In addition, in terms of financial integration and operational efficiency, designing a reasonable port price adjustment system, stabilizing transport costs and port service quality is an important guarantee for realizing integration of port group resources [24]. In addition to paying attention to port costs, more emphasis should be placed on importance of investment to make port system more competitive [25]. Lack of construction funds will affect operation and economic efficiency of the port.

Whether it is developed informatization level, sufficient capital investment, interconnected multimodal hinterland, high-quality services, high-quality human resources, etc., will affect port operation efficiency, brand awareness of port enterprises, port competitiveness, and then port resource integration performance. Therefore, to improve the above situation, port enterprises need to pay attention to application of information technology, accelerate pace of technological innovation, and increase investment in technological R & D in the development process. At the same time, it is necessary to make full use of basic resources such as area of anchorage, number of berths, and passage capacity of the waterway, to continuously optimize allocation of resources and to enhance financing and profitability of port enterprises.

5 CONCLUSIONS

How to effectively evaluate resource integration performance of port enterprises is particularly important for strengthening or performance assessment and promoting comprehensive efficiency of port enterprises. Based on FAHP and FCE, this study evaluates resource integration performance of port enterprises from four dimensions of financial integration, operational performance, technological innovation and realized benefit, and verifies it with actual situation of port enterprises in five provinces. Conclusions of this study are as follows.

(1) From the result of weight, in the first-level indicators, it shows technological innovation > financial integration > realized benefits > operational efficiency, and in the second-level indicators, it shows that weight of informatization level (0.0823), brand awareness (0.0739), overall R & D investment (0.0677) and informatization capital investment (0.0618) is relatively high. This shows that technological innovation is primary factor to be considered in port enterprise resource integration and has a great impact on port resource integration.

(2) Based on comprehensive evaluation results, resource integration performances of port enterprises in Zhejiang, Jiangsu, Liaoning, Shandong and Guangdong are generally good. Evaluation results of four case enterprises are "good", and only one case is "average". Zhejiang has achieved the best resource integration performance, reaching 80.33 due to its resource endowment and the advantages of Ningbo-Zhoushan Port. This finding is consistent with actual development, and to some extent, it verifies effectiveness of the evaluation system and model.

(3) Port enterprises need to pay attention to application of information technology, to accelerate pace of technological innovation, and increase investment in technological R & D. At the same time, it is necessary to make full use of basic resources such as area of anchorage, number of berths, and passage capacity of the waterway, to continuously optimize allocation of resources and enhance financing and profitability of port enterprises. In combination with training of professional talents, strength of port enterprises will be strengthened to achieve sustained economic growth.

Compared with many studies on port performance evaluation, existing literature on performance evaluation of port enterprise resource integration is rare. This study constructs an evaluation index system from four dimensions and uses FAHP and FCE for analysis, which can provide theoretical support for port enterprises to promote resource integration and optimize performance. The performance evaluation method of port enterprises proposed in this study can effectively measure performance level of port enterprise resource integration, and relevant research conclusions can provide decision support for port management department to accelerate development of regional port integration. The main limitation of the research is that existing evaluation methods lack strong support for objective data. For example, objective weighting can improve credibility, and evaluation based on objective data is more scientific, which is the future direction of further research.

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