Research on Modern Intelligent Port Evaluation

Huan Zhou[1,a*], Dan Zhou[2,b], Zihao Liu[3,c]

[1]School of Marxism, Dalian Maritime University, Dalian, China
[2]Intelligent Shipping Center, China Waterborne Transport Research Institute, Beijing, China
[3]Navigation College, Dalian Maritime University, Dalian, China

[a*]1991zhouhuan@dlmu.edu.cn;
[b]zhoudan@wti.ac.cn;[c]zihaoliu@dlmu.edu.cn

Abstract. This article focuses on the evaluation of intelligent ports and studies an improved matter-element structure model based on cloud models for intelligent port evaluation. Using the indicators proposed in the "Intelligent Port Evaluation Indicator System" (T/CIN 011-2023) as the evaluation indicators, an intelligent port evaluation indicator level cloud model is constructed based on the improved matter-element structure model of the cloud model. The correlation degree calculation method and entropy weight method are used to calculate the correlation degree and indicator weight of the evaluation indicators, and the evaluation level is determined based on the principle of maximum membership degree. Taking a certain port in China as an example, the effectiveness of the evaluation method was verified, and the evaluation confidence obtained was low, and the evaluation results obtained compared with other evaluation methods were the same. This proves that the reliability of the evaluation results is high, and the evaluation method is effective.

Keywords: intelligent port, cloud matter element theory, intelligent port evaluation, evaluation indicators.

1 Introduction

At the national governance level, modernization is reflected in the modernization of the national governance system and governance capacity. The smart port evaluation reflects the problems of "what is being done" and "what is being done" at the current level of smart port construction in China. Only by establishing a scientific and reasonable evaluation system can we accurately grasp the degree of Chinese-style modern smart port construction and timely discover problems. In addition, the national governance system and governance capacity in the field of transportation will be modernized.

In recent years, intelligent ships in the shipping industry have attracted widespread attention from society. At the same time, smart ports and intelligent ports have also made bold innovations, and fully automated ports have been put into operation. Intelligent entry and exit gates, intelligent cargo tallying, electronic documents, equipment and facilities cargo supervision and control are widely used in ports. But different ports

K. Elbagory et al. (eds.), *Proceedings of the 9th International Conference on Financial Innovation and Economic Development (ICFIED 2024)*, Advances in Economics, Business and Management Research 281,
https://doi.org/10.2991/978-94-6463-408-2_42

have different application stages of intelligent technology, different levels of intelligent technology, and different ideas for intelligent development. How to evaluate the intelligent development level of different ports has become a new issue.

At present, there is no real evaluation method for smart ports, and there is relatively little research. Reference [1] proposed an evaluation model for the development level of smart ports based on the improved matter-element method. This study constructed an evaluation index system suitable for the construction and development of smart ports in China, and used the subjective and objective comprehensive weighting method to reduce the impact of subjective factors on indicator weights in the traditional evaluation process. The improved matter-element theory based on cloud models was introduced, Solved the errors caused by fuzziness and randomness in traditional evaluation methods. Reference [2] interprets the purpose and scope of application of the group standard "Guidelines for the Evaluation of Smart Port Grades for Container Terminals" (T/CPHA 9-2022), as well as the main evaluation indicators of the standard. Reference [3] provides evaluation indicators for intelligent ports.

This article focuses on the evaluation of intelligent ports and the evaluation indicators provided in reference [3]. Through extensive on-site research and expert consultation, the subjectivity of human factors and the fuzziness and randomness of evaluation in intelligent port evaluation are addressed. Based on the improved matter-element structure model of cloud models, the evaluation of intelligent ports is studied, and a method suitable for intelligent port evaluation is proposed.

2 Intelligent Port Evaluation Indicators and Indicator Measurement Methods

The concept of intelligent port was first proposed by Port of Rotterdam in the Netherlands in 2014. It is an advanced port model that achieves high integration and optimization of logistics, information flow, and capital flow within the port through digital technology and refined management methods, improving port operation efficiency and service quality. It utilizes technologies such as the Internet of Things, big data, and cloud computing to collect, process, and analyze data on various management and operational activities within the port, thereby optimizing operational processes, adjusting personnel configurations, and improving equipment efficiency, achieving an efficient and collaborative overall operational model. Intelligent ports can not only improve port operation efficiency and service quality, but also reduce logistics costs and environmental pollution. With the development and application of digital technology, intelligent ports have been increasingly widely applied and promoted globally, becoming one of the important trends in port development today. For the evaluation of smart ports, China has released the "Intelligent Port Evaluation Indicator System" (T/CIN 011-2023), which is a group standard of the Chinese Society of Navigation. The standard provides the evaluation indicators and measurement methods for smart ports, for example:

(1) Network security C1: Network security is calculated according to the method specified in [GBT28448-2012 Information security technology information system security grade protection assessment Requirements].

(2) Network coverage guarantee rate C2: the area of the port meeting the operation network transmission demand divided by the total area of the port.

(3) Data processing support guarantee rate C3: daily port data volume to meet operational data processing/daily total data volume.

(4) Data security C4: data risk points.

(5) Security facility coverage C5: security area divided by the total area of security should be equipped ect.

3 Improved matter-element structure evaluation model of smart port based on cloud model

3.1 Cloud Model

The prediction of things should follow the development law of things, and the prediction process is often accompanied by a lot of uncertainty. The cloud model mainly reflects the ambiguity and randomness of concepts in human knowledge, and provides a new method for the study of uncertain artificial intelligence [4-5].

Suppose U is a quantitative discourse domain represented by an exact number, and C is a qualitative concept on U. If the quantitative value $x \in U$, and x is a random implementation of the qualitative concept C, and the certainty of x to C is $\mu_c \in [0,1]$ is a random number with a stable tendency, then the distribution of x on the discourse domain U is called a cloud, and each x is called a cloud droplet [6].

Cloud is composed of several cloud droplets. Cloud droplets are a random realization of a qualitative concept, and the cloud droplets produced several times can comprehensively reflect the overall characteristics of this qualitative concept. The overall characteristics of a concept can be represented by the three numerical characteristics of the cloud, namely, expected E_x, entropy E_n, and superentropy H_e, so the characteristics of the cloud model can be described by the vectors (E_x, E_n, H_e) composed of these three numerical characteristics. E_x represents the expected value of the spatial distribution of cloud droplets in the discourse domain, that is, the point that can best represent the qualitative concept. Cloud entropy E_n represents the uncertainty measure of qualitative concept, which can be used to describe the span of cloud and reflect the dispersion degree of cloud droplets. Superentropy H_e is an uncertainty measure of entropy that can be used to describe the thickness of a cloud [6].

3.2 Improved matter-element model based on cloud model

In the matter-element model, the triplet (M, C, x) composed of things M, features C, and the magnitude value x of things about features is called matter-element and recorded as R= (M, C, x) [7]. In the matter-element model, x is regarded as a definite value, and the fuzziness and randomness of x are not considered. In order to solve this problem, the cloud model(E_x, E_n, H_e) is used to replace x in the literature [4], that is, an improved matter-element model based on cloud model is obtained, which is hereinafter referred to as the cloud matter-element model, which can reduce the fuzziness and randomness of the evaluation index classification data. The model is expressed as [7]:

$$R=\begin{bmatrix} M & C_1 & x_1 \\ & C_2 & x_2 \\ & \cdots & \cdots \\ & C_n & x_n \end{bmatrix}=\begin{bmatrix} M & C_1 & (E_{m_1} & E_{n_1} & H_{e_1}) \\ & C_2 & (E_{m_2} & E_{n_2} & H_{e_2}) \\ & \cdots & & \cdots & \\ & C_n & (E_{m_n} & E_{n_n} & H_{e_n}) \end{bmatrix} \tag{1}$$

In the evaluation process, if the object M has k evaluation grades, respectively $N_j(j=1,2,...,k)$, the scope of the feature $C_i(i=1,2,...,n)$ corresponding to the grade $N_j(j=1,2,...,k)$ is $(C_{i\min}, C_{i\max})$, $C_{i\min}$, $C_{i\max}$ is the minimum and maximum value of the belonging grade interval respectively, then [8],

$$E_{m_i}=\frac{C_{i\min}+C_{i\max}}{2}(i=1,2,...,n) \tag{2}$$

$$E_{n_i}=\frac{C_{i\max}-C_{i\min}}{2.3548}(i=1,2,...,n) \tag{3}$$

$$H_{e_i}=s(i=1,2,...,n) \tag{4}$$

3.3 Cloud model of smart port evaluation based on cloud model improved matter-element model

In view of the intelligent level evaluation of smart ports, combined with the research results of literature [7-9] and the opinions of port experts, the intelligent level is divided into five levels: "high", "high", "general", "low" and "low". Each index is divided into indicator quantity values corresponding to the five levels, and the evaluation level standard of smart ports is constructed. This paper uses the expert opinion method to classify the index levels, and organizes 10 industry experts, including senior experts in the field of ports and smart ports, and full and associate professors in universities, etc., to give the evaluation level standards of smart ports. Some data (due to space limitations, only some data are listed) are shown in Table 1.

Table 1. Classification of smart port evaluation indicators

Index	Index classification				
	high	higher	generally	lower	low
C_1	(0,1]	(1,2]	(2,3]	(3,4]	(4,5]
C_2	(95%,100%]	(90%,95%]	(85%,90%]	(80%,85%]	(0%,80%]
C_3	(95%,100%]	(90%,95%]	(85%,90%]	(80%,85%]	(0%,80%]
C_4	(0,1]	(1,2]	(2,3]	(3,4]	(4,5]
C_5	(95%,100%]	(90%,95%]	(85%,90%]	(80%,85%]	(0%,80%]
C_6	(80%,100%]	(60%,80%]	(50%,60%]	(30%,50%]	(0%,30%]
C_7	(80%,100%]	(60%,80%]	(50%,60%]	(30%,50%]	(0%,30%]
C_8	(80%,100%]	(60%,80%]	(50%,60%]	(30%,50%]	(0%,30%]
…	…	…	…	…	…
C_{61}	(20%,100%]	(15%,20%]	(8%,15%]	(5%,8%]	(0%,5%]

Table 1 shows the characteristic indicators C1, C2,... The classification of C61 at different levels has strong subjectivity, fuzziness and randomness. Therefore, the cloud mature-element model is used to replace the fixed interval of grade classification with (Ex, En, He), which will reduce the strong subjectivity, fuzziness and randomness of grade classification data. According to the cloud matter-element model construction method in Section 3.2, Table 1 is converted into a cloud matter-element model, that is, the cloud model of smart port evaluation index level, as shown in Table 2.

Table 2. Cloud model of smart port evaluation index level

in-dex	high	higher	generally	lower	low
C_1	(0.5, 0.425, 0.328)	(1.5, 0.425, 0.328)	(2.5, 0.425, 0.328)	(3.5, 0.425, 0.328)	(4.5, 0.425, 0.328)
C_2	(0.975, 0.021,0.016)	(0.925, 0.021,0.016)	(0.875, 0.021,0.016)	(0.825, 0.021,0.016)	(0.4, 0.34, 0.262)
C_3	(0.975, 0.021,0.016)	(0.925, 0.021,0.016)	(0.875, 0.021,0.016)	(0.825, 0.021,0.016)	(0.4, 0.34, 0.262)
C_4	(0.5, 0.425, 0.328)	(1.5, 0.425, 0.328)	(2.5, 0.425, 0.328)	(3.5, 0.425, 0.328)	(4.5, 0.425, 0.328)
C_5	(0.975, 0.021,0.016)	(0.925, 0.021,0.016)	(0.875, 0.021,0.016)	(0.825, 0.021,0.016)	(0.4, 0.34, 0.262)
C_6	(0.9, 0.085, 0.066)	(0.7, 0.085, 0.066)	(0.55, 0.042, 0.033)	(0.4, 0.085, 0.066)	(0.15,0.127,0.098)
C_7	(0.9, 0.085, 0.066)	(0.7, 0.085, 0.066)	(0.55, 0.042, 0.033)	(0.4, 0.085, 0.066)	(0.15,0.127,0.098)
C_8	(0.9, 0.085, 0.066)	(0.7, 0.085, 0.066)	(0.55, 0.042, 0.033)	(0.4, 0.085, 0.066)	(0.15,0.127,0.098)
…	…	…	…	…	…
C_{61}	(0.6,0.34,0.262)	(0.175,0.021,0.016)	(0.115,0.03,0.023)	(0.065,0.013,0.01)	(0.025,0.021,0.016)

3.4 Calculation of correlation degree

The correlation function between the evaluation index $C_i(i=1,2,...,61)$ of the port to be evaluated and the features $C_{ji}(i=1,2,...,61, j \in [low, lower, generally, higher, high])$ under each grade j (j $\in$ [low, low, average, high, high]) is set as $k_{ji}(x_i)$ [7].

$$k_{ji}(x_i) = \exp\left[\frac{-(x_i - E_{m_i})^2}{2(E'_{n_i})^2}\right] \tag{5}$$

Is a normal random number that is expected to be the standard deviation.

3.5 Weight Calculation

Weight calculation The entropy weight method is chosen to calculate the weight coefficient of each evaluation index. The calculation process is as follows [9]:

(1) Normalization treatment: Because the evaluation indicators are all positive, the positive range method is adopted for standardization treatment:

$$y_{ki} = \frac{x_{ki} - x_{\min}}{x_{\max} - x_{\min}} \quad (k=1,2,...,m; i=1,2,...,n) \tag{6}$$

m indicates the number of objects to be evaluated.

(2) Calculate the entropy value, set as $H_i \quad (i=1,2,...,61)$

$$H_i = -\frac{1}{\ln m}\sum_{k=1}^{m} f_{ki} \ln f_{ki} \quad (i=1,2,...,61) \tag{7}$$

Among:

$$f_{ki} = (1+y_{ki}) \Big/ \sum_{k=1}^{m}(1+y_{ki}) \quad (i=1,2,...,n) \tag{8}$$

(3) Calculate the entropy weight of each evaluation index:

$$\omega_i = (1-H_i) \Big/ \sum_{i=1}^{n}(1-H_i) \tag{9}$$

$\omega_i \ (i=1,2,...,n)$ Is the weight of each indicator.

3.6 Smart port evaluation level

The comprehensive correlation degree between the evaluation object and the evaluation grade j is set as K_j [8].

$$K_j = \sum_{i=1}^{n} \omega_i k_j (y_{kj}) \tag{10}$$

The evaluation level is determined according to the principle of maximum correlation degree, and the evaluation level is set as K[7].

$$K = \max_{j \in [low, lower, generally, higher, high]} (K_j) \tag{11}$$

3.7 Reliability of evaluation results

In the entire calculation process, when formula (5) is used to obtain the correlation degree of the index, due to E_{n_i}' random generation, in order to reduce the random error caused by E_{n_i}' the generation process to the overall result, mathematical tools are used to calculate the expectation and entropy of the index several times, as shown in Formula (12) and (13) [7]:

$$E_K = \frac{K_1 + K_2 + \cdots + K_m}{m} \tag{12}$$

$$E_{Kj} = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (K_i - E_K)^2} \tag{13}$$

Where: E_K is the expectation of K; E_{Kj} is the entropy of K; m is the number of repeated calculations; Take 100 loops.

When the value of E_{Kj} is smaller, it means that the more concentrated the evaluation results are, the higher the credibility of the results; otherwise, it means that the credibility is lower. In order to express the level of confidence, confidence ρ is used to express [4]:

$$\rho = \frac{E_{Kj}}{E_K} \tag{14}$$

4 Smart port evaluation case analysis

4.1 Data

A representative port of our country is selected as the evaluation object, and the evaluation index data of the port is obtained through systematic investigation of the port according to the evaluation index measurement method given in Section 1.

Table 3. Smart port evaluation index data

indicators	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
Index value	Primary level of 100%	95%	80%	Grade 1	100%	30%	10%	10%	20%	30%	50%	5%	5%
indicators	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
Index value	1%	80%	50%	0%	20%	20%	5%	5%	80%	0%	0%	0%	20%
indicator	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}
Index value	10%	40%	0%	10%	10%	0%	50%	0%	0%	90%	30%	0%	0%
indicator	C_{40}	C_{41}	C_{42}	C_{43}	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9
Index value	10%	20%	50%	40%	90%	Grade 1	3	1.8次	100%	99%	67.76 Nature box/hour	80%	3days
indicator	D_{10}	D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	D_{16}	D_{17}	D_{18}				
Index value	85min	0.40%	0%	26	72	98.60%	95.60%	9.34	8%				

4.2 Calculation results of correlation degree and weight

python programming was used to calculate the correlation degree between the port data to be evaluated and each column in the cloud model of the smart port evaluation index level according to equation (5), that is, the correlation degree of each index in Table 3 with respect to different levels of Table 2 was calculated (limited by space, some results were listed in Table 4). Then, the weights of each indicator are calculated according to the weight calculation method in Section 3.5, and the calculation results are shown in Table 4.

Table 4. Correlation degree and weight

indicator	low	lower	generally	higher	high	weight
C_1	2.95E-09	7.61E-05	0.009481872	0.496988587	0.450740073	0.075838738
C_2	0.251598268	2.84E-08	0.001983373	0.50099336	0.499979885	0.002600278
C_3	0.466266147	0.501203755	0.002057084	3.10E-08	2.32E-15	0.002585852
C_4	1.81E-08	5.21E-05	0.012317944	0.49240584	0.458562124	0.075838738
C_5	0.212828389	2.86E-15	3.07E-08	0.001968972	0.500716544	0.002606304
C_6	0.494046177	0.492819708	4.68E-08	2.70E-05	9.08E-11	0.002606304
C_7	0.926623716	0.002389634	7.24E-24	1.22E-10	5.02E-17	0.002606304
C_8	0.925111833	0.002287852	1.30E-23	1.22E-10	4.31E-18	0.003016128
…	…	…	…	…	…	…
C_{61}	0.034642955	0.499887992	0.499630221	4.67E-05	0.28659903	0.013525385

4.3 Evaluation Results

The comprehensive correlation degree between the evaluated port and each evaluation level is calculated according to formula (10), and the results of one calculation are shown in Table 5.

Table 5. Comprehensive correlation degree

low	lower	generally	higher	high
0.4237	0.0210	0.01124	0.0820	0.0735

In Table 5, the maximum comprehensive correlation degree is 0.4237. According to equation (11), the intelligence level of the port is considered to be low. At the same time, the methods in literature [10] and [11] are used to calculate the example, and the effectiveness of the proposed algorithm is verified. The result is that the evaluation result of the traditional matter-element method is the low intelligence level of the port, and the evaluation result of the grey correlation method is also the low intelligence level of the port. In addition, the confidence is calculated according to equations (12), (13) and (14), and $\rho = 2.34 \times 10^{-4}$ is obtained.

According to the above results, the evaluation method of smart port based on cloud model with improved matter-element structure is consistent with the results obtained by other evaluation methods, which proves the effectiveness of the model. The confidence coefficient of the evaluation results is small, indicating that the calculation results of the method are highly reliable.

5 Conclusion

In this paper, the index in the Evaluation Index System of Smart Port (T/CIN 011-2023), the group standard of the Chinese Society of Navigation, is taken as the index of smart port evaluation, and the improved matter-element model theory based on cloud model is introduced to evaluate the intelligent level of smart port, which effectively solves the randomness and fuzziness problems existing in smart port evaluation and smart port evaluation. The evaluation example proves that the evaluation method is highly reliable and the evaluation results are effective, which can provide an evaluation method for smart port evaluation.In the future, we will use ship-borne automatic identification system [12] , GPS embedded computer [13] and other ways to improve the evaluation level.

Acknowledgment

[1]"the Fundamental Research Project for the Department of Education of Liaoning Province" (Grant. JYTQN2023041).

References

1. Cao Jie, Wang Dacheng, Dai Ran et al. Smart port development level evaluation model based on improved matter-element method [J]. Journal of Chongqing Jiaotong University (Natural Science Edition), 2021,40 (6) :59-65.
2. Liang Hua, Du Jingbo, Wang Dacheng. Interpretation of group standards for Smart Port Grade Evaluation Guide Container Terminals (T/CPHA 9-2022), Port Science and Technology, 1-5:15.
3. Smart Port Evaluation Index System (T/CIN 011-2923) group standard,2023-02-24.
4. liu Ke, Zhang Ran, Cui Zhibin, Zhang Dianbao, Gao Shegan. Research on radial basis function neural network algorithm for cloud model optimization[J]. Engineering Science, 2023, 44(5):50.
5. Li D Y, Han J W, Shi X M, et al. Knowledge representation and discovery based on linguistic atoms[J]. Knowledge-based Systems,1998(10):431-440.
6. LI Hailin, Guo Chonghui, Qiu Wangren. Similarity calculation method of Positive cloud Model [J]. Acta Electronica Sinica, 2011,39 (11): 2561-2567. (in Chinese)
7. Huang Cheng, Zhu Jinshan, Zhang Feng, et al. An improved matter-element structure evaluation model for ship night navigation light environment based on cloud model [J]. Journal of Dalian Maritime University, 2018,44 (4): 43-48.
8. Zhou Lanting, Ni Zhiqiang. Safety evaluation of earth-rock dam in areas with increasing extreme rainfall events based on cloud-matter element model [J]. Journal of China Three Gorges University (Natural Science Edition), 2018,40 (5) :22-26.
9. Cheng Hao, Liu Lingling. Research on development level evaluation of regional intelligent manufacturing based on entropy weight and normal cloud model [J]. Science and Management, 2015,23 (6): 21-29.
10. Huang Cheng, Ruan Guanghui, Ma Ye, et al. Evaluation of ship light environment during night navigation based on matter-element method [J]. Journal of Lighting Engineering, 2017,28 (6): 77-82.

11. Yang Le, Chen Jie. Analysis of influencing factors of geological hazard risk based on grey correlation method [J]. Journal of Chongqing Jiaotong University (Natural Science Edition), 2017,36 (6): 80-84.
12. Zhang liye, Big data-based estimation for ship safety distance distribution in port waters[J]. Transportation research record: journal of the transportation research board, 2015,2479:16-24.
13. IEE E A. Cyber physical systems: design challengers[C]//Proceedings of 11th IEEE International Symposium on Object Oriented Real-Time Distributed Computing. Piscataway: IEEE,2008:363-369.