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# SUMMARY OF THE PORT SHORELINE RESOURCE EVALUATION BASED ON TRIANGULAR FUZZY ANALYTIC HIERARCHY PROCESS

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## ABSTRACT

*Port shoreline resources are the basis of port and shipping development, and its assessment method has become one of the hot issues in port research. On the basis of constructing a reasonable index evaluation system, this paper constructs the fuzzy evaluation matrix based on the triangular fuzzy analytic hierarchy process and constructs the fuzzy evaluation matrix by using the fuzzy comprehensive evaluation method, and obtains the maximum membership degree of the port shoreline resources. Compared with the traditional port shoreline Resource evaluation methods, the new one got more advantages in objective and quantitative. Finally, Combined with the Nanjing section of the Yangtze River as a case for verification, the results show that the model can accurately solve the problem of resource evaluation of port shoreline.*

**Keywords:** Port shoreline evaluation; Triangular fuzzy AHP; Fuzzy comprehensive evaluation; Shoreline of Nanjing port

## INTRODUCTION

In recent years, the port has become a gathering point of regional high-quality resources, and become a regional economic growth point. The development and utilization of shoreline resources is closely related to the speed of regional economic development [1, 2]. Therefore, the evaluation of shoreline resources has become an important issue in regional development. It is very important to carry out the evaluation of the rationality of port shoreline resources to the future development of port and port area [3].

On the port shoreline resource evaluation at present, scholars have made a series of results, the current popular methods are mathematical model evaluation and field monitoring. Field monitoring use GPS, GIS, RS and other software as the technical platform, the use of remote sensing image data, the port shoreline resources to monitor the dynamic changes [4, 5], field monitoring methods due to field monitoring requires a lot of data and equipment, The main shortcomings of the monitoring method are twofold: First, the cost is too expensive, the second is unable to quickly and efficiently form the evaluation conclusion. And the mathematical model evaluation method is convenient and low cost advantage, more conducive to the port shoreline planners and managers to its assessment and decision-making.

### RESEARCH SUMMARY

At present, the main methods of port shoreline resource evaluation are AHP, data envelopment analysis, gray system theory, cellular automata and neural network [6, 10]. The methods are quantitative data Methods. However, some important indicators in the analysis and evaluation of port shoreline resources are qualitative indicators, which cannot be directly quantified, such as the relationship with national policy, the significance of urbanization in the surrounding areas [11]. Therefore, these methods have difficulties in solving the problem of resource evaluation and analysis of inland riverline with qualitative indicators.

The Analytic Hierarchy Process was first proposed by the scholar Saaty, Analytic Hierarchy Process (AHP) is a measure that is used to measure deterministic and uncertain, tangible and intangible, clear and vague quantitative and qualitative equivalents. Method, because of its practical and effective in dealing with complex decision-making issues, and soon in the world attention and widely used [12, 13]. Triangular Fuzzy Analytic Hierarchy Process (TFAHP) is an improvement to the traditional hierarchical analysis method. Fuzzy theory is used to fuzzify the values of the judgment matrix. When faced with complex and uncertain decisions, the judgment matrix Blurring will yield better results than classical analytic hierarchy process. At present, scholars have applied AHP or fuzzy theory to the evaluation of port shoreline. For example, Ledoux has constructed a systematic evaluation procedure to solve the problem of shoreline resource degradation due to sporadic or unrestricted use of shoreline resources And other issues [14]; Renzo DalCin classifies the southern coast of Marche, Italy, based on the study of the interrelationships between coastal characteristic variables, and establishes models to measure various types of coastal vulnerability and risk [15]; Bagdanaviciute takes the Baltic Sea The southern coast of Lithuania 90 km of the coastline as the object of study, to build a set of coastal vulnerability index system, and the use of hierarchical analysis of the coastline of the vulnerability level [16], Nouri to southern Iran's northern Persian Gulf coastline as the object, through Analysis of its ecological characteristics and tourism development potential[17], Sha using k cluster analysis method, the classification of China's Fujian coastline, and port development potential assessment[18].

In summary, the current research results are mainly focused on the index system and its quantitative calculation. In the existing research, the index system cannot reflect the dynamic characteristics of the shoreline comprehensively. The weight determination is more subjective and the evaluation method is not rigorous. Therefore, based on the improved triangular fuzzy analytic hierarchy process (AHP), the fuzzy comprehensive evaluation of shoreline is used to overcome the dynamic characteristics and difficult to quantify the characteristics of shoreline evaluation by trigonometric function and fuzzy comprehensive method. It provides the rationality evaluation of port shoreline in the new period new methods to make the evaluation results more consistent with the status quo, to enhance the evaluation results.

## PORT SHORELINE EVALUATION INDEX SYSTEM

Port shoreline comprehensive evaluation, is a kind of typical composite system comprehensive evaluation, which involves the evaluation index and many factors. The evaluation of the use of port shoreline mainly need to consider three aspects: (1) select a reasonable evaluation system of port shoreline; (2) use the trigonometric function to determine the weight of the index system; (3) using the improved fuzzy evaluation to calculate the port shoreline evaluation level. This paper constructs the port shoreline evaluation system as shown in Table 1.

*Tab. 1. Port shoreline evaluation index system table*

| Target layer | criteria layer | | indicator layer | | |
|---|---|---|---|---|---|
| Port shoreline evaluation index system A | port planning compliance | $B_1$ | Operational compliance of the functional properties of the terminal | $C_1$ | Qualitative |
| | | | Coastline level planning compliance | $C_2$ | Qualitative |
| | usage efficiency | $B_2$ | Effective utilization rate of port shoreline | $C_3$ | Quantitative |
| | | | Unit berth shoreline throughput | $C_4$ | Quantitative |
| | Use benefit | $B_3$ | Shoreline public service rate | $C_5$ | Quantitative |
| | | | Unit shoreline supply value | $C_6$ | Quantitative |
| | | | Unit shoreline revenue | $C_7$ | Quantitative |
| | | | Unit shoreline employment | $C_8$ | Quantitative |
| | Area function | $B_4$ | And functional zoning compliance | $C_9$ | Qualitative |
| | | | Consistent with the overall urban planning | $C_{10}$ | Qualitative |
| | | | Area of the same type of dock capacity ratio | $C_{11}$ | Quantitative |
| | Ecological Benefits | $B_5$ | Unit throughput comprehensive energy consumption | $C_{12}$ | Quantitative |
| | | | Unit throughput CO2 emissions | $C_{13}$ | Quantitative |
| | Set the way | $B_6$ | Railway transit transport | $C_{14}$ | Qualitative |
| | | | Road transit transport | $C_{15}$ | Qualitative |
| | The match degree of the terminal cargo structure and the local industry | $B_7$ | Industry agglomeration degree | $C_{16}$ | Qualitative |
| | | | Set distribution level | $C_{17}$ | Qualitative |
| | Shoreline layout type | $B_8$ | Terminal cluster level | $C_{18}$ | Qualitative |
| | | | Shoreline contiguous degree | $C_{19}$ | Qualitative |

## MATERIAL AND METHODS

### METHOD OF WEIGHT DETERMINATION BASED ON TFAHP

**Definition 1**: Set a fuzzy number M on a real number set $R=(-\infty,+\infty)$ , and when its membership function $u_M : R \to [0,1]$ satisfies the following formula, it is called a triangular fuzzy number.

$$u_M(x)=\begin{cases} x/(m-1)-I/(m-I), & x\in[I,m] \\ x/(m-u)-u/(m-u), & x\in[m,u] \\ 0, \quad \text{other} & \end{cases} \tag{1}$$

In Equation (1), $I \le m \le u$ , $I$ and $u$ represent the upper and lower bounds of $M$ support, respectively, and m is the median of $M$ , and the triangular fuzzy number M can be expressed as $(I,m,u)$.

**Definition 2:** The algorithm of triangular fuzzy numbers

If $u_M$ and $u_N$ denote the membership functions of two triangular fuzzy numbers $M$ and $N$ respectively, then the membership function of the triangular fuzzy number $T=f(M,N)$ is given by:

$$u_T(z)=\sup_{(x,y)\in R^2, z=f(x,y)}\min(u_M(x),u_N(y)) \tag{2}$$

Based on the above formula, the triangular fuzzy number of the algorithm is as follows:

Make $M_1=(I_1,m_1,u_1)$ , $M_2=(I_2,m_2,u_2)$ two Triangular fuzzy number, then:

$$M_1\oplus M_2=(I_1,m_1,u_1)\oplus(I_2,m_2,u_2)=(I_1+I_2,m_1+m_2,u_1+u_2) \tag{3}$$

$$M_1\otimes M_2=(I_1,m_1,u_1)\otimes(I_2,m_2,u_2)=(I_1+I_2,m_1+m_2,u_1+u_2) \tag{4}$$

$$M^{-1}=(I,m,u)^{-1}=(\frac{1}{u},\frac{1}{m},\frac{1}{I}) \tag{5}$$

*Tab. 2. Triangular fuzzy number on the basis of the lower bound*

| Score self - confidence | $u-I$ | Digital features | Score meaning |
|---|---|---|---|
| High | 1 | $(\max(m-1/2,1)),m,\min(m+1/2,9)$ | Experts play scores are not blurred |
| low | 2 | $(\max(m-1,1),m,\min(m+1,9))$ | Experts play scores more vague |
| normal | 3 | $(\max(m-3/2,1),m,\min(m+3/2,9))$ | Experts play scores very vague |

The calculation steps of the improved triangular fuzzy hierarchy analysis method are as follows:

**Step 1:** Constructs the triangular fuzzy judgment matrix according to the expert judgment result, $A=(a_{ij})_{n\times n}$ , where the element $a_{ij}=(I_{ij},m_{ij},u_{ij})$ is a closed interval with $m_{ij}$ as the median.

For the index between the two pairs of triangular fuzzy values, the average judgment can be used to represent the comprehensive judgment matrix, the formula is:

$$a_{ij}=\frac{1}{T}\otimes(a_{ij}^1+a_{ij}^2+\Lambda+a_{ij}^T) \tag{6}$$

In which, $T=1,2,\Lambda,t$ Where T denotes the number of experts involved in triangular fuzzy judgment.

**Step 2:** Consistency check of the median matrix:

Calculate the maximum eigenvalue $\lambda_{\max}$ of the median matrix M, and substitute $\lambda_{\max}$ into the formula for the consistency check according to the calculation method described earlier.

**Step 3:** Construct the fuzzy evaluation factor matrix $E$.

$$E=(e_{ij})_{n\times n}=\begin{bmatrix} 1 & 1-\frac{u_{12}-I_{12}}{2m_{12}} & \cdots & 1-\frac{u_{1n}-I_{1n}}{2m_{1n}} \\ 1-\frac{u_{21}-I_{21}}{2m_{21}} & 1 & \cdots & 1-\frac{u_{2n}-I_{2n}}{2m_{2n}} \\ \vdots & \vdots & \vdots & \vdots \\ 1-\frac{u_{n1}-I_{n1}}{2m_{n1}} & 1-\frac{u_{n2}-I_{n2}}{2m_{n2}} & \cdots & 1 \end{bmatrix} \tag{7}$$

Where $S_{ij}=(u_{ij}-I_{ij})/2m_{ij}$ is the standard deviation rate, which reflects the fuzzy degree of expert judgment, the greater the $S_{ij}$ the greater the ambiguity of the evaluation, the less the credibility.

**Step 4:** Calculate the adjustment judgment matrix $Q$

$$Q=M\times E=\begin{bmatrix} m_{11} & m_{12} & \cdots & m_{1n} \\ m_{21} & m_{22} & \cdots & m_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ m_{n1} & m_{n2} & \cdots & m_{nn} \end{bmatrix}=\begin{bmatrix} 1 & 1-\frac{u_{12}-I_{12}}{2m_{12}} & \cdots & 1-\frac{u_{1n}-I_{1n}}{2m_{1n}} \\ 1-\frac{u_{21}-I_{21}}{2m_{21}} & 1 & \cdots & 1-\frac{u_{2n}-I_{2n}}{2m_{2n}} \\ \vdots & \vdots & \vdots & \vdots \\ 1-\frac{u_{n1}-I_{n1}}{2m_{n1}} & 1-\frac{u_{n2}-I_{n2}}{2m_{n2}} & \cdots & 1 \end{bmatrix} \tag{8}$$

**Step 5:** The adjustment judgment matrix $Q$ is converted into a judgment matrix $Q'$ with a diagonal line of 1.

**Step 6:** Use the root method to calculate the weight of the indicators

Calculate the Nth root of all elements of each row:

$$\bar{\omega} = \left( \prod_{j=1}^{n} a_{ij} \right)^{\frac{1}{n}} \quad i = 1, 2, \Lambda, n \tag{9}$$

Normalize $\bar{\omega}$:

$$\bar{\omega}_j = \frac{\bar{\omega}_i}{\sum_{i=1}^{n} \bar{\omega}_i} \quad i = 1, 2, \Lambda, n \tag{10}$$

Then $\omega = \left( \omega_1, \omega_2, \Lambda, \omega_n \right)^{\mathrm{T}}$ is the approximation of the required weight.

## USING FUZZY COMPREHENSIVE EVALUATION METHOD TO ESTABLISH FUZZY EVALUATION MATRIX

Fuzzy evaluation method, the need to use fuzzy mathematics method to establish a fuzzy evaluation matrix R, the specific evaluation process is as follows:

**Step 1:** Establish a set of evaluation factors

The establishment of the evaluation factor set should be comprehensive, perfect and accurate, and the factors that affect the evaluation object are listed as far as possible, that is, $U = \{u_1, u_2, \Lambda, n\}$, where $u_i (i = 1, 2, \Lambda, n)$ is the evaluation factor; $n$ is the number of individual factors at the same level.

**Step 2:** Determine the level of reviews set

The grade comment set contains all the possible evaluation results in the evaluation object, which can be expressed as: $V = \{v_1, v_2, \Lambda, v_m\}$, $v_j (j = 1, 2, \Lambda, m)$ is the evaluation grade standard; m is the number of reviews.

**Step 3:** Determination of membership function

The membership of qualitative indicators in this paper combined with expert experience method, through the questionnaire by the expert scoring to determine the classification criteria, membership function.

**Step 4:** Single factor fuzzy evaluation, the establishment of fuzzy evaluation matrix

Univariate fuzzy evaluation refers to the evaluation of a factor in the process of fuzzy comprehensive evaluation, and to determine the degree of membership of this factor for the evaluation set.

Assuming the $i$ th evaluation factor $u_i$, the evaluation membership degree of the $j$ th element $v_j$ is $r_{ij}$, where $0 \le r_{ij} \le 1$. So the fuzzy set can be used to express the evaluation of the $i$ th element:

$$R_i = (R_{i,1}, R_{i,2}, \Lambda, R_{i,m}) \tag{11}$$

The membership evaluation matrix $R_{m \times n}$ of the $n$ factors is finally determined, as shown in the following equation.

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{12}$$

Triangular fuzzy analytic hierarchy process (TFAHP) and fuzzy evaluation method can be used to obtain the comprehensive weight set $\omega$ and the fuzzy evaluation matrix $R$. The final result is the vector product of the first two items, that is, the fuzzy comprehensive evaluation model is obtained as follows.

$$B = \omega^T \bullet R = (\omega_1, \omega_2, \cdots, \omega_n) \bullet \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} = (b_1, b_2, \cdots, b_m) \tag{13}$$

According to the principle of maximum membership degree, the fuzzy comprehensive evaluation result vector $B = (b_i), i = 1, 2, \cdots, m$ indicates that the port shoreline use belongs to the comprehensive evaluation level of the port shoreline, so as to determine the $v_i$ as the finalized evaluation result.

# CASE STUDY

Nanjing is one of the four major cities in the Yangtze River Basin, and is the only city in Jiangsu Province with two coastlines of the Yangtze River. The south bank of Nanjing start from the south bank of the junction of the Soviet Union and the junction of the Cihu mouth, and stops at Ningzhen transfer of the new estuary; north shore from the junction of Jiangsu and Anhui Wujiangkou, stop at the junction of Yizheng Liuhe mouth. This paper chooses the resources of the Nanjing section of the Yangtze River as a case to analyze the correctness of the above model.

Through access to relevant literature, to convene relevant experts and scholars to carry out seminars and to the relevant departments and on-site field research to 2016 as the base year, and ultimately determine the port shoreline index system 11 quantitative indicators of the evaluation level standard. The weight values of the index based on triangular fuzzy analytic hierarchy process are shown in Table 3.

In the determination of qualitative indicators, the evaluation process by inviting a total of 24 experts in the field of 10 qualitative indicators to vote, according to the voting results combined with membership calculation formula to calculate the membership, as shown in Table 4.

Tab. 3. Nanjing port shoreline quantitative indicators grading evaluation criteria table

| index | unit | GREAT | GOOD | NORMAL | BED |
|---|---|---|---|---|---|
| Effective utilization rate of port shoreline$C_{21}$ | % | ≥ 60 | [50 – 60] | [40 – 50] | < 40 |
| Unit berth shoreline throughput$C_{22}$ | Million tons / m | ≥ 0.75 | [0.6 – 0.75] | [0.45 – 0.6] | < 0.45 |
| Shoreline public service rate$C_{31}$ | % | ≥ 80 | [60 – 80] | [40 – 60] | < 40 |
| Unit shoreline supply value$C_{32}$ | Million yuan / m | ≥ 1300 | [1000 – 1300] | [700 – 1000] | < 700 |
| Unit shoreline revenue$C_{33}$ | YUAN/M | ≥ 90000 | [70000 – 90000] | [50000 – 70000] | < 50000 |
| Unit shoreline employment$C_{34}$ | person/km | ≥ 180 | [130 – 180] | [80 – 130] | < 80 |
| Area of the same type of dock capacity ratio$C_{43}$ | 1 | ≥ 1.40 | [1.20 1.40] | [1.00 – 1.20] | < 1.00 |
| Unit throughput comprehensive energy consumption$C_{51}$ | Ton of standard coal / ten thousand tons | ≤ 2.00 | [2.0 – 3.0] | [3.0 – 4.0] | > 4.00 |
| Unit throughput CO2 emissions$C_{52}$ | Ton / tonne | ≤ 5.00 | [5.00 – 7.00] | [7.00 – 9.00] | > 9.00 |

Tab. 4. Nanjing coastline qualitative data

| index | great | | good | | normal | | bad | |
|---|---|---|---|---|---|---|---|---|
| | Number of votes | Membership | Number of votes | Membership | Number of votes | Membership | Number of votes | Membership |
| $C_{11}$ | 20 | 0.8333 | 4 | 0.1667 | 0 | 0 | 0 | 0 |
| $C_{12}$ | 22 | 0.9167 | 2 | 0.0833 | 0 | 0 | 0 | 0 |
| $C_{41}$ | 20 | 0.8333 | 3 | 0.1250 | 1 | 0.0417 | 0 | 0 |
| $C_{42}$ | 22 | 0.9167 | 2 | 0.0833 | 0 | 0 | 0 | 0 |
| $C_{61}$ | 19 | 0.7917 | 5 | 0.2083 | 0 | 0 | 0 | 0 |
| $C_{62}$ | 16 | 0.6667 | 6 | 0.2500 | 0 | 0 | 2 | 0.0833 |
| $C_{71}$ | 14 | 0.5833 | 8 | 0.3333 | 1 | 0.0417 | 1 | 0.0417 |
| $C_{72}$ | 23 | 0.9583 | 1 | 0.0417 | 0 | 0 | 0 | 0 |
| $C_{81}$ | 19 | 0.7917 | 4 | 0.1667 | 0 | 0 | 1 | 0.0416 |
| $C_{82}$ | 16 | 0.6667 | 7 | 0.2917 | 1 | 0.0416 | 0 | 0 |

According to the above data analysis results, available in Nanjing port shoreline comprehensive evaluation of the use of "great, good, normal, bad" membership degree $B = (0.444, 0.276, 0.240, 0.004)$. The evaluation results meet the principle of normalization, indicating the validity of the evaluation results. According to the principle of maximum membership, because the "good + great" = 0.72> 0.7, indicating that the year 2016 Nanjing port shoreline use in a better range.

## CONCLUSION

Port shoreline resource use level evaluation is a multi-criteria, multi-attribute problem, the effective evaluation of the level is a complex work. The results of this paper are as follows: 1) the method of calculating the weight of the index based on the triangular fuzzy analytic hierarchy process has overcome the problem that the decision maker has the deviation of the weight due to the mistake or preference, which provides the basis for the final port shoreline evaluation. 2) The fuzzy comprehensive evaluation model based on triangular fuzzy analytic hierarchy process (AHP) is used to evaluate the coastline of Nanjing port. It is concluded that the use of harbor coastline in Nanjing port is in a good evaluation range. From the calculation process and the results, it can be seen that the method not only can be scientific and rational evaluation of the status quo, and can reflect the level along the coast of the river, indicating that the method is effective.

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