

# Research on the Fuzzy Comprehensive Evaluation Method for Interior Design of Small and Medium-Sized Yacht Cabins based on the AHP Method

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## Abstract

To address the lack of scientific and objective evaluation standards for the interior design of small- and medium-sized yacht cabins, this study establishes an evaluation system that integrates the Analytic Hierarchy Process (AHP) with the fuzzy comprehensive evaluation method. Firstly, an evaluation index system is constructed from six dimensions: aesthetics, comfort, safety, functionality, cost, and sustainability. Subsequently, AHP is employed to determine the weights of each indicator, thereby reducing the influence of subjective judgments on the evaluation results. On this basis, the fuzzy comprehensive evaluation method is applied to conduct an empirical analysis and quantitative assessment of two yacht models, 500C and 500E. The results show that the interior design of both yachts reaches the “good” level. The study demonstrates that the combined application of AHP and the fuzzy comprehensive evaluation method effectively addresses the multi-level, multi-index, and fuzzy characteristics of yacht cabin design evaluation, providing a scientific and systematic technical approach and theoretical support for the assessment and optimization of yacht interior design.

## Keywords

Yacht Cabin Interior Design; Analytic Hierarchy Process (AHP); Fuzzy Comprehensive Evaluation Method.

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## 1. Introduction

In recent years, with the continuous advancement of industrialization, the yacht industry has experienced rapid growth and has gradually transitioned from a niche professional sector to a part of mainstream consumer life. Yachts have increasingly become high-end recreational products that combine functionality with luxury attributes. While exterior aesthetics play an important role in attracting consumers, the cabin interior—being the core space for user experience—has a more direct impact on the overall quality of a yacht. Consequently, the importance of interior design in yacht cabins has become increasingly prominent. However, how to scientifically and objectively evaluate the quality of cabin interior design after the design process is completed has emerged as a critical issue within the industry. In this context, establishing a systematic and objective evaluation framework that effectively integrates multidimensional evaluation indicators while minimizing subjective bias has become essential for promoting the standardization and development of yacht interior design. Identifying an appropriate evaluation methodology is therefore a key breakthrough for solving this challenge.

At present, comprehensive evaluation methods are primarily applied in scenarios characterized by high complexity and numerous influencing factors. The essence of these methods does not lie in

simply aggregating multiple indicators but rather in classifying them, constructing an appropriate evaluation model, and ultimately providing an objective and holistic assessment of the target. Among these methods, the Analytic Hierarchy Process (AHP) and the fuzzy comprehensive evaluation approach hold prominent positions and have been widely adopted in the maritime and shipbuilding fields in recent years. For example, Li Liang[1] et al. investigated large cruise ships operating along the Huangpu River in the Port of Shanghai and combined key factors influencing berth scheduling with AHP to evaluate optimal berthing windows. Li Junhua[2] et al. developed an evaluation index system for the layout design of a ship's command cabin, determined indicator weights using AHP, constructed a fuzzy evaluation matrix through linguistic scales and the centroid method, and ranked alternative layouts using the generalized distance method to complete the fuzzy comprehensive evaluation. Chang Yu[3] et al. established a quantitative evaluation model for the exterior design of street sweepers using a combination of AHP and fuzzy comprehensive evaluation. Wu Hao[4] applied the fuzzy comprehensive evaluation method to build an analytical model for assessing the overall competency of ship pilots, providing quantitative support for capability evaluation.

Given that the evaluation of yacht cabin interiors is a complex process involving numerous factors, this paper employs the Analytic Hierarchy Process in combination with the fuzzy comprehensive evaluation method to construct a scientific evaluation model for yacht cabin interior design.

## 2. Construction of the Evaluation Index System

Based on the principles of modern industrial design and in response to the evaluation needs of interior design for small- and medium-sized yacht cabins, six primary evaluation criteria are proposed. The overall evaluation index system is established in accordance with the Analytic Hierarchy Process (AHP). The main evaluation indicators for yacht cabin interior design are as follows:

### (1) Aesthetics

Yacht interior design refers to the layout and decorative design of both fixed and movable elements within the cabin space [5]. In interior design, attention must be paid not only to functional value but also to aesthetic value. The aesthetic evaluation of yacht interiors primarily considers the overall cabin style as well as the use of color and lighting. An interior should not only possess a unique yet harmonious style, but more importantly, the color scheme and lighting arrangement should be well-coordinated to create a visually pleasing environment that enhances the aesthetic experience of the yacht's cabin.

### (2) Comfort

Yacht comfort represents a comprehensive indicator reflecting the degree of comfort experienced by individuals during navigation, and serves as a standardized measure [6]. The comfort of a yacht's interior is not only determined by spatial layout and environmental control, but more importantly by users' overall perception of comfort within the cabin. Therefore, the evaluation of yacht comfort should be conducted from a holistic perspective. In addition to spatial organization and environmental regulation, factors such as the materials, tactile quality, and placement of furniture and equipment also significantly influence the comfort level of the interior environment.

### (3) Safety

In the comprehensive evaluation of yacht cabin interior design, both aesthetic presentation and living comfort must be considered. However, safety is a fundamental prerequisite for ensuring the protection of life and property during navigation, and thus its importance is particularly prominent. Therefore, when constructing an evaluation system for yacht cabin interior design, safety should be defined as a core evaluation criterion. Its essential meaning lies in employing systematic design strategies to prevent potential risks and enhance emergency response capabilities.

Safety can be assessed through three primary dimensions: structural safety, fire safety, and protective safety. Structural safety focuses on the secure installation and stability of interior materials and components, ensuring they can withstand vibrations and impacts during navigation without

detachment. Fire safety is reflected in the proper division of fire protection zones and the use of interior materials that comply with fire resistance and flame-retardant standards. Finally, protective safety involves ensuring that the layout of equipment and furniture follows ergonomic principles, provides adequate movement space, and minimizes collision hazards.

(4) Functionality

Function represents the essential value of a product. From conceptual design to practical implementation, functionality serves as the core foundation of all product development. As a high-end recreational product, a yacht expresses its aesthetic qualities largely through its functional performance. The functionality of a yacht is achieved through the integration of basic functions and specialized functions.

Basic functionality requires that the cabin is equipped with complete living facilities, sanitary installations, and sufficient storage space. In contrast, specialized functionality refers to the inclusion of additional features such as business facilities or entertainment systems, enabling the yacht to meet more diverse usage needs.

(5) Cost Efficiency

As a high-end product, the cost of a yacht encompasses not only hull construction but also the interior cabin design. Therefore, cost efficiency should be included as a key indicator in the evaluation of yacht cabin interiors, covering both production cost and user cost. The production cost of the cabin interior mainly consists of material manufacturing, transportation, and processing. In contrast, user cost is primarily reflected in equipment maintenance expenses and the residual or recyclable value of materials.

(6) Sustainability

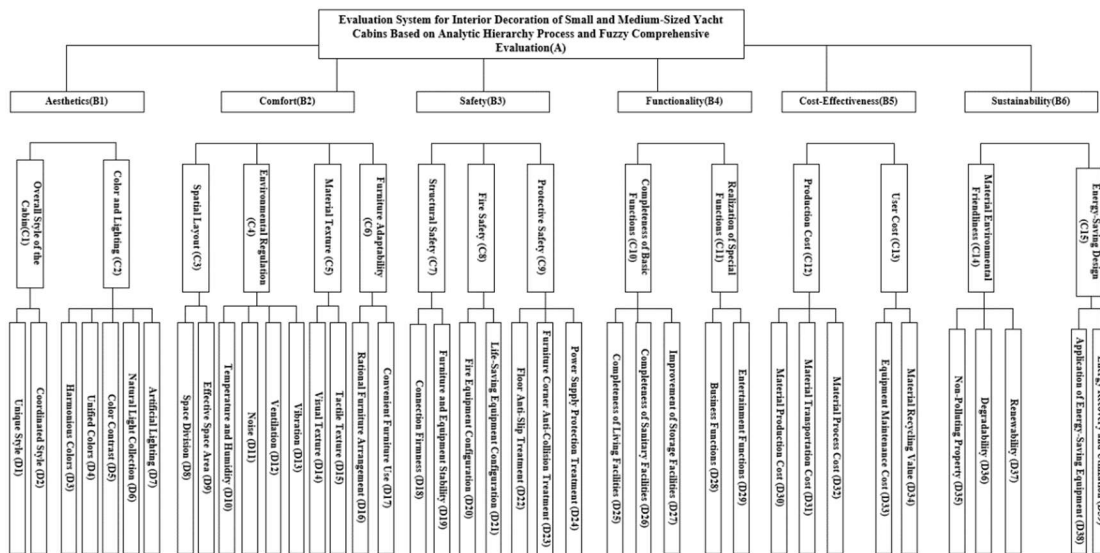


Fig. 1 Evaluation framework for yacht cabin interior design

With economic development and in response to national calls for green and sustainable growth, sustainability must be incorporated into the evaluation of yacht cabin interiors in addition to the existing five fundamental attributes. Integrating sustainability enables a more comprehensive and environmentally conscious assessment of yacht interior design.

Sustainability in yacht cabin interiors is primarily reflected in two aspects: environmentally friendly materials and energy-efficient design. The environmental performance of materials is evaluated based on their non-toxicity, biodegradability, and renewability. Energy-efficient design, on the other hand, is manifested through the application of energy-saving equipment and the utilization of energy recovery systems within the cabin.

The evaluation of yacht cabin design is not limited to assessing aesthetics and comfort alone; more importantly, it requires a comprehensive assessment of the cabin as a whole. Based on the above analysis, an evaluation system for yacht cabin interior design is constructed, as illustrated in Figure 1.

### 3. Fuzzy Comprehensive Evaluation based on the Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) [7] is a systematic analysis method proposed by American operations research scientist T. L. Saaty in the mid-1970s. It provides a structured, model-based, and quantitative approach to decision-making for complex problems. The fuzzy comprehensive evaluation (FCE) method is a decision-making technique that evaluates objects influenced by multiple interrelated and interacting factors. Based on the principles of fuzzy transformation and the maximum membership criterion, it constructs multi-level fuzzy subsets and quantifies the influence of factors using fuzzy indicators, thereby forming an evaluation model [8].

The fuzzy comprehensive evaluation based on AHP integrates both methods. Specifically, AHP is first employed to determine the weights of sub-objectives and evaluation indicators. Then, fuzzy mathematics and fuzzy statistical techniques are applied to conduct a comprehensive assessment of all influencing factors [9]. By combining these two methods, a systematic and objective evaluation of yacht cabin interior design can be achieved.

#### 3.1 Construction of Pairwise Comparison Matrices

The yacht interior evaluation system is a typical multi-level and multi-criteria assessment framework. In this study, a four-level hierarchical evaluation system is constructed, as illustrated in Figure 1. From the perspective of hierarchical structure, the overall evaluation objective is placed at the top level, referred to as the target layer (Level A). Directly beneath it is the criteria layer (Level B), where each criterion directly influences the achievement of the overall objective. Below this lies the sub-criteria layer (Level C), in which each sub-criterion exerts an impact on its corresponding criterion in the upper level. The lowest level is the alternative layer (Level D), which represents the candidate interior design schemes of yacht cabins, with at least one alternative included for evaluation.

It is important to note that, when constructing the hierarchical model, only the principal factors with significant weights are retained in Level C for each criterion in Level B, while secondary factors with negligible influence are excluded. To determine the relative importance of the factors within the same level (criteria or sub-criteria) with respect to a criterion in the adjacent upper level, pairwise comparisons are conducted to establish the judgment matrices.

During the construction of the judgment matrix, the relative importance of each element is assigned using the 1–9 scale method [10]. The meaning of each scale is shown in Table 1.

**Table 1.** Scale Interpretation

Scale	Meaning
1	The two factors are equally important.
3	The former is slightly more important than the latter.
5	The former is clearly more important than the latter.
7	The former is strongly more important than the latter.
9	The former is extremely more important than the latter.
2/4/6/8	Intermediate values between the adjacent judgments above.
	If the importance of factor $i$ over factor $j$ is $b_{ij}$ , then the importance of $j$ over $i$ is $1 / b_{ij}$ .

Based on the quantitative criteria defined in the scale interpretation table, when evaluating a single objective or indicator, the relative importance of its subordinate factors can be determined through

pairwise comparisons. This process leads to the construction of the corresponding judgment matrix, expressed as follows:

$$A=(a_{ij})_{n \times n}, (1, 2, \dots, n) \tag{1}$$

where  $n$  represents the number of influencing factors, and  $a_{ij}$  denotes the importance scale of factor  $i$  compared with factor  $j$ .

### 3.2 Calculation of Index Weights

(1) After constructing the judgment matrix, each column of the matrix must be normalized to process the indicator elements.

$$\bar{A}_{ij} = \frac{a_{ij}}{\sum_{k=1}^n a_{kj}}, (i, j = 1, 2, \dots, n) \tag{2}$$

(2) The normalized judgment matrix is then processed by summing the elements of each row, that is:

$$\bar{W}_i = \sum_{j=1}^n \bar{A}_{ij}, (i, j = 1, 2, \dots, n) \tag{3}$$

(3) Normalize  $W_i$ , that is:

$$\omega_i = \frac{\bar{W}_i}{\sum_{i=1}^n \bar{W}_i}, i = (1, 2, \dots, n) \tag{4}$$

Thus,  $\omega_i = (\omega_1, \omega_2, \dots, \omega_n)$  serves as the approximate eigenvector and represents the relative weights of the corresponding indicators.

(4) Calculation of the Maximum Eigenvalue of the Judgment Matrix

$$\lambda_{\max} = \sum_{i=1}^n \frac{(A\omega)_i}{n\omega_i} \tag{5}$$

(5) Consistency Test

In the Analytic Hierarchy Process (AHP), once the maximum eigenvalue and its corresponding eigenvector of the judgment matrix are obtained, a consistency test must be conducted to verify the logical rationality of the matrix. This is achieved by calculating the Consistency Ratio (CR), which quantitatively evaluates the degree of consistency.

$$CR = \frac{CI}{RI} \tag{6}$$

If  $CR < 0.1$ , the consistency of the judgment matrix is considered *acceptable*, indicating that the level of logical inconsistency is within the permissible range. In this case, the eigenvector can be used to calculate the indicator weights.

If  $CR \geq 0.1$ , the consistency of the judgment matrix is deemed *unacceptable*, meaning that significant logical contradictions exist. The judgment matrix must then be reconstructed and reassessed until  $CR < 0.1$  is satisfied. Here, **CI** denotes the Consistency Index.

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

The value of *RI*(Random Consistency Index) needs to be obtained from the corresponding average consistency index table. For  $n = 1, 2, \dots, 9$ , the values of *RI* are shown in Table 2.

**Table 2.** Random Index Values

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.45

### 3.3 Fuzzy Comprehensive Evaluation

#### 3.3.1 Determination of the Index Set

In conducting a fuzzy comprehensive evaluation of yacht interior design, the first step is to define the evaluation factor set. The evaluation indicators of the yacht interior collectively form this factor set. The set of primary indicators is denoted as  $B = \{B_1, B_2, \dots, B_m\}$ , the set of secondary indicators as  $C = \{C_1, C_2, \dots, C_n\}$ , and the set of tertiary indicators as  $D = \{D_1, D_2, \dots, D_u\}$ , where  $m$ ,  $n$ , and  $u$  represent the number of indicators at each respective level.

Based on the previous analysis, the Analytic Hierarchy Process (AHP) is employed to determine the weights of the indicators at each level, resulting in the corresponding weights for the primary, secondary, and tertiary indicators.

#### 3.3.2 Determination of Evaluation Grades

The evaluation grade set is defined as

$V = \{V_1, V_2, V_3, V_4, V_5, V_6\} = \{\text{Excellent}, \text{Good}, \text{Moderate}, \text{Fair}, \text{Poor}, \text{Very Poor}\}$ . Each grade in the evaluation set is assigned a corresponding quantitative value, forming the evaluation vector. Following the assignment, experts and scholars are invited to score each indicator on a percentage scale. The grading criteria are defined as follows: scores above 90 are classified as *Excellent*, scores between 80 and 90 as *Good*, scores between 70 and 79 as *Moderate*, scores between 60 and 69 as *Fair*, scores between 50 and 59 as *Poor*, and scores below 50 as *Very Poor*. The evaluation grades are summarized in Table 3.

**Table 3.** Evaluation Grades in Percentage Scale

Evaluation Grade	Excellent	Good	Moderate	Fair	Poor	Very Poor
Grade	(100~90)	(89~80)	(79~70)	(69~60)	(59~50)	(49~0)

#### 3.3.3 Construction of the Fuzzy Membership Matrix [11]

After establishing the fuzzy subsets of evaluation grades, each evaluation object must be quantified with respect to every factor. This involves determining the degree of membership of the evaluation object to each grade in the fuzzy subset from the perspective of a single factor. Consequently, the fuzzy relation matrix *R* is obtained.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \quad (8)$$

In matrix  $R$ , the element  $r_{ij}$  in the  $i$ -th row and  $j$ -th column represents the degree of membership of an evaluated object to the grade  $V_j$  under the influence of factor  $C_i$ . Therefore, matrix  $R$  is also referred to as the membership matrix.

### 3.3.4 Construction of the Fuzzy Comprehensive Evaluation

Based on the yacht cabin interior evaluation system shown in Figure 1, first-level, second-level, and third-level fuzzy transformations need to be constructed for the corresponding indicator system.

First-Level Fuzzy Transformation.

Assume that the  $i$ -th factor in the sub-criteria layer contains  $n$  indicators, and its corresponding weight vector is denoted as  $A_{Ci} = (a_{i1}, a_{i2}, \dots, a_{in})$ , the fuzzy evaluation matrix of the indicators is given

$$\text{by: } R_{Ci} = \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1n} \\ r_{i21} & r_{i22} & \cdots & r_{i2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{im1} & r_{im2} & \cdots & r_{imn} \end{bmatrix}$$

where  $r_{imn}$  represents the degree of membership of the  $m$ -th indicator under the  $i$ -th sub-criterion to the  $n$ -th evaluation grade. The comprehensive evaluation result of the sub-criteria layer can then be expressed as:

$$B_{Ci} = A_{Ci} \circ R_{Ci} \quad (9)$$

where “ $\circ$ ” denotes the weighted average fuzzy synthetic operation of the membership matrix.

(2) Second-Level Fuzzy Transformation.

Assume that the  $j$ -th factor in the criteria layer contains  $p$  sub-criteria, and its corresponding weight vector is denoted as  $A_{Bj} = (a_{j1}, a_{j2}, \dots, a_{jp})$ , the comprehensive evaluation matrix of the sub-criteria is

$$\text{given by: } R_{Bj} = \begin{bmatrix} B_{Cj1} \\ B_{Cj2} \\ \vdots \\ B_{Cjp} \end{bmatrix}. \text{ The comprehensive evaluation result of the criteria layer is therefore given by:}$$

$$B_{Bj} = A_{Bj} \circ R_{Bj} \quad (10)$$

where “ $\circ$ ” denotes the weighted average fuzzy synthetic operation of the membership matrix.

(3) Third-Level Fuzzy Transformation.

Assume that the target layer contains  $q$  criteria, and the corresponding weight vector is denoted as  $A_A = (a_1, a_2, \dots, a_q)$ , the comprehensive evaluation matrix of the criteria is given by:

$$B_A = A_A \circ R_A \tag{11}$$

where “ $\circ$ ” denotes the weighted average fuzzy synthetic operation of the membership matrix.

#### 4. Case Analysis

To establish a scientific evaluation system for yacht cabin interior design, this study employs a questionnaire survey to determine the weight coefficients of the evaluation indicators. Considering that engineering designers, process designers, high-end consumers, and experts in the shipbuilding field exhibit significant differences in functional requirements, perceptual experience, and professional judgment, a differentiated survey approach is adopted to ensure the comprehensiveness and rationality of the weight allocation.

A total of 200 questionnaires were distributed among these four key groups. The purpose of the survey was to collect multidimensional data in order to provide objective and reliable weighting references for the subsequent evaluation of yacht cabin interiors. The survey results were statistically analyzed, and based on the hierarchical evaluation model of yacht cabin interiors shown in Figure 1, along with AHP formulas (1)–(7), the judgment matrices and corresponding weight vectors for each evaluation level were calculated. The detailed results are presented in Tables 4 through 25.

**Table 4.** Hierarchical Ranking of Level B (Relative to Level A)

Indicator	B1	B2	B3	B4	B5	B6	$\omega$
B1	1	1/3	1/4	3	1	2	0.113071
B2	3	1	1/2	4	2	6	0.258868
B3	4	2	1	5	6	5	0.413733
B4	1/3	1/4	1/5	1	1	1/3	0.053413
B5	1	1/2	1/6	1	1	1	0.083880
B6	1/2	1/6	1/5	3	1	1	0.077034
$\lambda$ max	6.338055						
CI	0.067611						
RI	1.240000						
CR	0.054525						

**Table 5.** Hierarchical Ranking of Level C (under B1)

Indicator	C1	C2	$\omega$
C1	1	1/3	0.25
C2	3	1	0.75
$\lambda$ max	2.000000		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 6.** Hierarchical Ranking of Level C (under B2)

Indicator	C3	C4	C5	C6	$\omega$
C3	1	1	1	4	0.301960
C4	1	1	3	5	0.420202
C5	1	1/3	1	2	0.192936
C6	1/4	1/5	1/2	1	0.084902
$\lambda$ max	4.111975				
CI	0.037325				
RI	0.900000				
CR	0.041472				

**Table 7.** Hierarchical Ranking of Level C (under B3)

Indicator	C7	C8	C9	$\omega$
C7	1	2	4	0.558425
C8	1/2	1	3	0.319618
C9	1/4	1/3	1	0.121957
$\lambda$ max	3.018295			
CI	0.009147			
RI	0.580000			
CR	0.015771			

**Table 8.** Hierarchical Ranking of Level C (under B4)

Indicator	C10	C11	$\omega$
C10	1	3	0.75
C11	1/3	1	0.25
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ ,consistency test passed		

**Table 9.** Hierarchical Ranking of Level C (under B5)

Indicator	C12	C13	$\omega$
C12	1	4	0.80
C13	1/4	1	0.20
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ ,consistency test passed		

**Table 10.** Hierarchical Ranking of Level C (under B6)

Indicator	C14	C15	$\omega$
C14	1	2	0.666667
C15	1/2	1	0.333333
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 11.** Hierarchical Ranking of Level D (under C1)

Indicator	D1	D2	$\omega$
D1	1	1/2	0.333333
D2	2	1	0.666667
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 12.** Hierarchical Ranking of Level D (under C2)

Indicator	D3	D4	D5	D6	D7	$\omega$
D3	1	6	1/5	1/2	1/5	0.114485
D4	1/6	1	1/7	1/3	1/4	0.068755
D5	5	7	1	1	1	0.245127
D6	2	3	1	1	1/2	0.213395
D7	5	4	1	2	1	0.358238
$\lambda$ max	5.354550					
CI	0.088638					
RI	1.120000					
CR	0.079141					

**Table 13.** Hierarchical Ranking of Level D (under C3)

Indicator	D8	D9	$\omega$
D8	1	3	0.750000
D9	1/3	1	0.250000
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 14.** Hierarchical Ranking of Level D (under C4)

Indicator	D10	D11	D12	D13	$\omega$
D10	1	3	2	3	0.453085
D11	1/3	1	1/2	2	0.167140
D12	1/2	2	1	2	0.261589
D13	1/3	1/2	1/2	1	0.118186
$\lambda$ max	4.070868				
CI	0.023623				
RI	0.900000				
CR	0.026247				

**Table 15.** Hierarchical Ranking of Level D (under C5)

Indicator	D14	D15	$\omega$
D14	1	5	0.833333
D15	1/5	1	0.166667
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 16.** Hierarchical Ranking of Level D (under C6)

Indicator	D16	D17	$\omega$
D16	1	6	0.857143
D17	1/6	1	0.142857
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 17.** Hierarchical Ranking of Level D (under C7)

Indicator	D18	D19	$\omega$
D18	1	2	0.666667
D19	1/2	1	0.333333
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 18.** Hierarchical Ranking of Level D (under C8)

Indicator	D20	D21	$\omega$
D20	1	1/3	0.250000
D21	3	1	0.750000
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 19.** Hierarchical Ranking of Level D (under C9)

Indicator	D22	D23	D24	$\omega$
D22	1	3	1/3	0.268369
D23	1/3	1	1/4	0.117221
D24	3	4	1	0.614411
$\lambda$ max	3.073514			
CI	0.036757			
RI	0.580000			
CR	0.063374			

**Table 20.** Hierarchical Ranking of Level D (under C10)

Indicator	D25	D26	D27	$\omega$
D25	1	2	4	0.558425
D26	1/2	1	3	0.319618
D27	1/4	1/3	1	0.121957
$\lambda$ max	3.018295			
CI	0.009147			
RI	0.580000			
CR	0.015771			

**Table 21.** Hierarchical Ranking of Level D (under C11)

Indicator	D28	D29	$\omega$
D28	1	1/2	0.333333
D29	2	1	0.666667
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 22.** Hierarchical Ranking of Level D (under C12)

Indicator	D30	D31	D32	$\omega$
D30	1	3	1/2	0.308996
D31	1/3	1	1/5	0.109452
D32	2	5	1	0.581552
$\lambda$ max	3.003695			
CI	0.001847			
RI	0.580000			
CR	0.003185			

**Table 23.** Hierarchical Ranking of Level D (under C13)

Indicator	D33	D34	$\omega$
D33	1	4	0.800000
D34	1/4	1	0.200000
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

**Table 24.** Hierarchical Ranking of Level D (under C14)

Indicator	D35	D36	D37	$\omega$
D35	1	3	2	0.539615
D36	1/3	1	1/2	0.163424
D37	1/2	2	1	0.296961
$\lambda$ max	3.009203			
CI	0.004601			
RI	0.580000			
CR	0.007933			

**Table 25.** Hierarchical Ranking of Level D (under C15)

Indicator	D38	D39	$\omega$
D38	1	2	0.666667
D39	1/2	1	0.333333
$\lambda$ max	2.00		
CI	0		
RI	0		
CR	$\lambda_{\max} = n$ , consistency test passed		

In this study, yacht cabin interior evaluation serves as the core research focus. The 500C yacht model is selected as the primary evaluation object, while the 500E model is incorporated as a comparative

reference. A combined methodology of the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) is employed to conduct the assessment. The weights obtained from the AHP are utilized in the subsequent fuzzy comprehensive evaluation.

The fuzzy evaluation data are collected through a questionnaire survey. A total of 200 respondents participated, including high-end consumers, professional yacht interior designers, and experts in naval architecture and marine engineering. Based on the valid responses, the data were processed in accordance with formulas (8)–(11) of the fuzzy comprehensive evaluation method, thereby generating the membership degree matrices corresponding to each evaluation indicator, as shown in Tables 26–40.

Due to space limitations, this section presents only the complete data processing procedure and calculation steps for the cabin interior evaluation of the 500C yacht model.

**Table 26.** Membership Degrees of Overall Cabin Style ( $R_1$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Unique style	0.74	0.15	0.1	0.01	0	0
Coordinated Style	0.64	0.2	0.1	0.06	0	0

**Table 27.** Membership Degrees of Color and Lighting ( $R_2$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Harmonious Colors	0.39	0.23	0.26	0.12	0	0
Unified Colors	0.33	0.305	0.215	0.15	0	0
Color Contrast	0.41	0.265	0.245	0.08	0	0
Natural Light Collection	0.36	0.24	0.335	0.065	0	0
Artificial Lighting	0.43	0.27	0.27	0.03	0	0

**Table 28.** Membership Degrees of Spatial Layout ( $R_3$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Space Division	0.595	0.16	0.21	0.035	0	0
Effective Space Area	0.47	0.335	0.165	0.03	0	0

**Table 29.** Membership Degrees of Environmental Regulation ( $R_4$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Temperature and Humidity	0.445	0.21	0.27	0.075	0	0
Noise	0.39	0.225	0.285	0.1	0	0
Ventilation	0.55	0.165	0.235	0.05	0	0
Vibration	0.165	0.44	0.37	0.025	0	0

**Table 30.** Membership Degrees of Material Texture ( $R_5$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Visual Texture	0.22	0.4	0.32	0.06	0	0
Tactile Texture	0.69	0.2	0.075	0.035	0	0

**Table 31.** Membership Degrees of Furniture Arrangement Appropriateness ( $R_6$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Rational Furniture Arrangement	0.845	0.1	0.02	0.035	0	0
Convenient Furniture Use	0.215	0.445	0.24	0.1	0	0

**Table 32.** Membership Degrees of Structural Safety ( $R_7$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Connection Firmness	0.775	0.11	0.105	0.01	0	0
Furniture and Equipment Stability	0.535	0.21	0.22	0.035	0	0

**Table 33.** Membership Degrees of Fire Safety ( $R_8$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Fire Equipment Configuration	0.28	0.225	0.345	0.15	0	0
Life-Saving Equipment Configuration	0.175	0.225	0.435	0.165	0	0

**Table 34.** Membership Degrees of Protection Safety ( $R_9$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Floor Anti-Slip Treatment	0.34	0.375	0.215	0.07	0	0
Furniture Corner Anti-Collision Treatment	0.6	0.3	0.1	0	0	0
Power Supply Protection Treatment	0.49	0.28	0.2	0.03	0	0

**Table 35.** Membership Degrees of Basic Functionality Completeness ( $R_{10}$ )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Completeness of Living Facilities	0.48	0.39	0.1	0.03	0	0
Completeness of Sanitary Facilities	0.335	0.39	0.225	0.03	0	0
Improvement of Storage Facilities	0.145	0.51	0.325	0.02	0	0

**Table 36.** Membership Degrees of Special Function Realization (  $R_{11}$  )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Business Functions	0.24	0.33	0.28	0.15	0	0
Entertainment Functions	0.055	0.465	0.46	0.02	0	0

**Table 37.** Membership Degrees of Production Cost (  $R_{12}$  )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Material Production Cost	0.215	0.24	0.485	0.06	0	0
Material Transportation Cost	0.425	0.3	0.225	0.05	0	0
Material Process Cost	0.215	0.225	0.445	0.115	0	0

**Table 38.** Membership Degrees of User Cost (  $R_{13}$  )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Equipment Maintenance Cost	0.125	0.245	0.335	0.295	0	0
Material Recycling Value	0.22	0.24	0.425	0.115	0	0

**Table 39.** Membership Degrees of Material Environmental Friendliness (  $R_{14}$  )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Non-Polluting Property	0.385	0.425	0.17	0.02	0	0
Degradability	0.225	0.39	0.27	0.115	0	0
Renewability	0.445	0.225	0.28	0.05	0	0

**Table 40.** Membership Degrees of Energy-Efficient Design (  $R_{15}$  )

Indicator	Evaluation Grade					
	Excellent	Good	Moderate	Fair	Poor	Very Poor
Application of Energy-Saving Equipment	0.445	0.325	0.22	0.01	0	0
Energy Recovery and Utilization	0.325	0.225	0.43	0.02	0	0

#### 4.1 Fuzzy Comprehensive Evaluation Calculation

(1) First, the primary-level fuzzy comprehensive evaluation is calculated as follows:

$$\begin{aligned}
 B_{C1} &= A_{C1} \circ R_{C1} \\
 &= (0.33 \quad 0.667) \cdot \begin{bmatrix} 0.74 & 0.15 & 0.1 & 0.01 & 0 & 0 \\ 0.64 & 0.2 & 0.1 & 0.06 & 0 & 0 \end{bmatrix} \\
 &= [0.6733 \quad 0.1833 \quad 0.1 \quad 0.0433 \quad 0 \quad 0]
 \end{aligned}$$

Similarly, it can be obtained that:

$$\begin{bmatrix} B_{C2} \\ B_{C3} \\ \vdots \\ B_{C15} \end{bmatrix} = \begin{bmatrix} 0.3987 & 0.2602 & 0.2728 & 0.0683 & 0 & 0 \\ 0.5638 & 0.2037 & 0.1988 & 0.0338 & 0 & 0 \\ 0.4302 & 0.2279 & 0.2752 & 0.0667 & 0 & 0 \\ 0.2983 & 0.3667 & 0.2792 & 0.0558 & 0 & 0 \\ 0.755 & 0.1493 & 0.0514 & 0.0443 & 0 & 0 \\ 0.695 & 0.1433 & 0.1433 & 0.0183 & 0 & 0 \\ 0.2012 & 0.225 & 0.4125 & 0.1612 & 0 & 0 \\ 0.4626 & 0.3078 & 0.1923 & 0.0372 & 0 & 0 \\ 0.3992 & 0.4046 & 0.1674 & 0.0288 & 0 & 0 \\ 0.1167 & 0.42 & 0.4 & 0.0633 & 0 & 0 \\ 0.238 & 0.2378 & 0.4333 & 0.0909 & 0 & 0 \\ 0.144 & 0.244 & 0.353 & 0.259 & 0 & 0 \\ 0.3767 & 0.3599 & 0.219 & 0.0444 & 0 & 0 \\ 0.405 & 0.2917 & 0.29 & 0.0133 & 0 & 0 \end{bmatrix}$$

(2) The secondary evaluation process is as follows.

The secondary fuzzy comprehensive evaluation can be obtained from the formula as follows:

$$\begin{aligned} B_{B1} &= A_{B1} \circ R_{B1} \\ B_{B1} &= A_{B1} \circ R_{B1} = \\ (0.25 \quad 0.75) &\cdot \begin{bmatrix} 0.6733 & 0.1833 & 0.1 & 0.0433 & 0 & 0 \\ 0.3987 & 0.2037 & 0.1988 & 0.0683 & 0 & 0 \end{bmatrix} = [0.4674 \quad 0.241 \quad 0.2296 \quad 0.062 \quad 0 \quad 0] \end{aligned}$$

Similarly, it can be obtained that:

$$\begin{bmatrix} B_{B2} \\ B_{B3} \\ \vdots \\ B_{B5} \end{bmatrix} = \begin{bmatrix} 0.4727 & 0.2407 & 0.2339 & 0.0528 & 0 & 0 \\ 0.5089 & 0.1895 & 0.2353 & 0.0663 & 0 & 0 \\ 0.3286 & 0.4085 & 0.2255 & 0.0374 & 0 & 0 \\ 0.2192 & 0.2391 & 0.4172 & 0.1245 & 0 & 0 \\ 0.3861 & 0.3371 & 0.2427 & 0.0341 & 0 & 0 \end{bmatrix}$$

(3) Tertiary Fuzzy Comprehensive Evaluation:

$$\begin{aligned} B_A &= A_A \circ R_A \\ &= (0.113071 \quad 0.258868 \quad 0.413773 \quad 0.053413 \quad 0.08388 \quad 0.077034) \\ &\cdot \begin{bmatrix} 0.4674 & 0.241 & 0.2296 & 0.062 & 0 & 0 \\ 0.4727 & 0.2407 & 0.2339 & 0.0528 & 0 & 0 \\ 0.5089 & 0.1895 & 0.2353 & 0.0663 & 0 & 0 \\ 0.3286 & 0.4085 & 0.2255 & 0.0374 & 0 & 0 \\ 0.2192 & 0.2391 & 0.4172 & 0.1245 & 0 & 0 \\ 0.3861 & 0.3371 & 0.2427 & 0.0341 & 0 & 0 \end{bmatrix} \end{aligned}$$

$$=[0.4514 \quad 0.2358 \quad 0.2496 \quad 0.0632 \quad 0 \quad 0]$$

#### (4) Comprehensive Score

The calculated results are converted into a percentage system to obtain the final score of yacht 500C. Specifically, the percentage value is derived from the product of the tertiary fuzzy evaluation vector  $B_A$  and the evaluation grade vector  $\beta$ , that is:

$$M = B_A \cdot \beta = 80.75$$

Using the same evaluation method, the cabin interior of yacht 500E is quantitatively assessed, yielding a final score of 84.01. According to the grading criteria in Table 2, the cabin interiors of both the 500C and 500E yachts fall within the “Good” category.

Furthermore, a comparison of the comprehensive quantitative scores indicates that the interior score of yacht 500E is slightly higher than that of 500C, suggesting that the overall cabin interior performance of yacht 500E is superior to that of yacht 500C.

## 5. Conclusion

This study integrates the Analytic Hierarchy Process (AHP) with the Fuzzy Comprehensive Evaluation (FCE) method to establish a scientific and systematic evaluation framework for yacht interior design. By employing AHP, weight vectors of the evaluation indicators were calculated, effectively balancing the complexity of multi-criteria evaluation and minimizing the influence of subjective judgment. Meanwhile, the FCE method was used to construct the membership matrices, allowing for accurate handling of ambiguity and uncertainty within the evaluation process.

Two yachts, models 500C and 500E, were selected as empirical research cases. A comprehensive evaluation of their cabin interiors was conducted, and the final results were converted into quantitative scores on a percentage scale. The overall evaluation scores were 80.75 for the 500C and 84.01 for the 500E. From the perspective of sub-criteria assessment, both yachts achieved a “Good” rating in the dimension of interior styling and design.

The empirical findings demonstrate that the combination of AHP and the Fuzzy Comprehensive Evaluation method is both scientifically sound and practically feasible for yacht interior assessment. This hybrid approach provides a robust technical pathway and methodological support for quantitative evaluation in the field of yacht interior design.

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