

Article

Research on Service Quality for China's Ceramic Product Design Industry

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Abstract: As a part of the service industry, product design practitioners should possess an understanding of the multifaceted factors and solutions that contribute to delivering exceptional service quality. However, related research on the service quality factors and solutions for China's ceramic product design industry is still an important research gap. In view of this, an integrated approach based on multi-criteria decision making (MCDM), combining the fuzzy analytic hierarchy process (FAHP) and the measurement of alternatives and ranking according to compromise solution (MARCOS), was proposed in this research to analyse and evaluate the service quality factors and solutions for China's ceramic product design industry. Initially, the FAHP method determined the significance of the service quality dimensions and indicators. Subsequently, the MARCOS method ranked the alternatives based on their performance against these criteria. This research focuses on the growing subject of service quality in China's ceramic product design industry. The proposed model identifies essential service quality factors and solutions for China's ceramic product design industry. The findings of this study may assist ceramic product design practitioners in China in making strategic decisions to provide excellent service quality.

Keywords: SERVQUAL scale; fuzzy analytic hierarchy process (FAHP); the measurement of alternatives and ranking according to compromise solution (MARCOS); multi-criteria decision making (MCDM); integrated method

MSC: 68U35



Citation: Zhu, J.; Lin, C.-L. Research on Service Quality for China's Ceramic Product Design Industry. *Mathematics* **2024**, *12*, 2827. <https://doi.org/10.3390/math12182827>

Academic Editors: Yordanka Boneva, Boriana Vatchova and Alexander Gegov

Received: 10 August 2024
Revised: 6 September 2024
Accepted: 9 September 2024
Published: 12 September 2024



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1. Introduction

As one of the oldest civilisations, China has a rich history in ceramics. As a result, many studies on China's ceramic industry have been published in recent decades. For example, Li [1] mentioned that Chinese ceramic products are famous for their refined artistry and durable quality. Heimann [2] reported that the significant development of Chinese ceramic products occurred during the Ming Dynasty, when potters put more emphasis on quality and artistic expression. The world-famous Jingdezhen "Blue and White" porcelain displays a fusion of delicate artistry and technical mastery that set a benchmark for ceramic design. Many scholars [3–5] have noted that China's ceramic art continues to thrive in the modern era, combining ancient practices with the latest technologies. Mahendri et al. [6] added that contemporary artisans are incorporating cultural motifs into their wares to meet the needs of domestic and global markets and to emphasise continued relevance in an ever-connected world. In addition, Yu et al. [7] discussed the differences in opinions between Jingdezhen ceramic product manufacturers and consumers from the perspective of consumers' purchasing experience. Mirfakhradini et al. [8] studied the impact of consumer opinions on the new ceramic product development process. Duy et al. [9] discussed the factors related to promoting consumer satisfaction and loyalty in the ceramic industry.

Lin [10] and Guo et al. [11] studied the differences in consumer perspectives to find out the sustainable development factors and strategies for the Jingdezhen ceramic product industry.

Furthermore, some scholars have begun to consider the service capabilities of China's ceramic industry to meet future challenges. For example, Lo et al. [12] examined the competitive strategies of China's ceramic industry in the globalised economic environment. They found that the industry needs to evolve into a service industry by offering a range of customised design services to meet the changes and challenges of this environment. Ke [13] suggested that China's ceramic industry should transform towards the cultural and creative industry, enhancing the economic scale and influence of the ceramic industry by providing cultural and creative content services. Li et al. [14] explored the influence of information technology adoption on the ceramic design industry. They noted that technologies such as VR or intelligent manufacturing have the potential to significantly enhance the industry's capacity to deliver design services in the post-pandemic era. Tian et al. [15] reported that China's ceramic industry should strengthen its industrial production and design service capabilities, largely due to the challenges brought by the COVID-19 epidemic.

In 2023, Wang et al. [16] proposed a novel MCDM method that combines entropy-based objective weighting and the MARCOS method to evaluate 3PL providers' sustainable performance. Miškić et al. [17] developed an integrated MEREK–MARCOS evaluation model of the logistics performance index of European Union (EU) countries with an emphasis on sensitivity analysis, which implies a change in the importance of criteria. Badi [18] proposed a hybrid MCDM framework to analyse and evaluate wind farm locations in Libya.

In 2024, Ristić et al. [19] discussed the evaluation of pedestrian crossings based on pedestrian behaviour, particularly focusing on the start-up time. They employed an integrated fuzzy multi-criteria decision-making (MCDM) model to analyse how different age groups and genders influence pedestrian behaviour and the rankings of various cities regarding their pedestrian crossing characteristics.

In addition, Wan et al. [20] have presented a study investigating the service quality of Yue Kiln Celadon in China. The study examined service quality indicators and potential solutions for China's yue kiln celadon industry in the post-pandemic era through the use of a hybrid MCDM methodology. The authors argued that service quality is paramount in this new landscape. Key indicators of such excellent service quality, including robust safety mechanisms, high-calibre personnel and tailored service capabilities, were considered essential for China's ceramic-related industries to deliver exceptional service in the post-pandemic world. It is noteworthy that Lin et al. [21] conducted a study to evaluate service quality solutions within the design industry. Using an evaluation framework based on the SERVQUAL scale, they applied a hybrid MCDM method in a fuzzy environment to analyse and rank service quality indicators and solutions. The research undertaken by these two research teams represents some of the most recent findings concerning service quality within the ceramics and design industries during the post-COVID-19 era.

Despite this, there is still a lack of related research using the SERVQUAL scale to measure service quality in China's ceramic product design industry. Therefore, we first attempted to establish a service quality evaluation framework based on the SERVQUAL scale, specifically tailored to China's ceramic product design industry. Subsequently, the weights of service quality aspects and indicators relevant to this industry were analysed and calculated. Subsequently, service quality solutions were evaluated and ranked with the aim of providing relevant decision-making suggestions to promote the provision of exemplary service quality in China's ceramic product design industry. In view of this, we established a framework grounded in the SERVQUAL scale to measure service quality within China's ceramic product design industry. This was achieved through questionnaires distributed amongst experts in the field. Subsequently, the fuzzy analytic hierarchy process (FAHP) was employed to calculate the weights of dimensions and indicators. Finally, we utilised the measurement of alternatives and ranking according to the compromise solution (MARCOS) to rank all alternatives, thereby addressing the following research objectives:

- To construct the evaluation structure based on the SERVQUAL scale for China's ceramic product design service quality.
- To analyse and calculate the weight of dimensions and indicators using FAHP.
- To evaluate and rank all solutions using MARCOS.
- To provide related decision-making suggestions for China's ceramic product design industry for providing excellent service quality.

This paper begins with a review of the existing literature on the SERVQUAL scale FAHP and MARCOS (Section 2). Section 3 details the methodology, including the construction of the evaluation framework and the calculation processes of FAHP and MARCOS models. Section 4 presents the results of numerical analysis and research findings. Section 5 discusses the research findings. Lastly, Section 6 offers conclusions.

2. Literature Review

When multiple criteria influence a choice, the challenge is classified as multi-criteria decision-making (MCDM), requiring decision-makers to weigh numerous elements before choosing a course of action from a range of methodologies [22,23]. Li et al. [24] highlighted a key advantage of MCDM approaches: they empower decision-makers to prioritise risk and financial gain while minimising the weight given to other aspects. Similarly, Kou et al. [25] analysed and calculated data from small-scale studies and demonstrated the effectiveness of MCDM techniques in tackling a variety of MCDM-related problems.

In this research, the assessment framework of service quality for China's ceramic product design industry is constructed based on the SERVQUAL scale. In addition, two MCDM methods, namely FAHP and MARCOS, are employed to evaluate and rank service quality aspects, indicators and potential solutions.

The relevant research gaps are discussed in this section, and the SERVQUAL scale, FAHP and MARCOS are explored.

2.1. Research Gaps

In terms of methodology, this paper proposes a model that combines FAHP and MARCOS methods for the first time to evaluate the service quality of China's ceramic product design industry. In the MCDM process, the determination of the criterion weight is crucial, as it greatly affects the results [26]. Therefore, both Odu [27] and Deng et al. [28] mentioned that using mathematical methods to obtain weights is conducive to data-based structural analysis and improves the decision-making level.

Additionally, Kumar et al. [29] presented an application of upgraded arithmetic operations on fuzzy numbers to extend the reliability from point estimation to interval estimation. Also, Dhiman et al. [30] explored the reliability of Ultra-Low Temperature (ULT) freezers under a fuzzy environment, particularly in the context of their critical role during the COVID-19 pandemic for vaccine storage. They delved into how preventive maintenance and situational factors can influence the performance of these essential machines. Their findings aim to enhance our understanding of ULT freezers and ensure they operate effectively when needed most. Moreover, Kumar et al. [31] discussed the performance analysis of an "Injection Moulding Machine" under a fuzzy environment. The above research is one of the latest studies to apply fuzzy numbers to the field of MCDM, demonstrating the feasibility of fuzzy methods for solving MCDM problems.

Despite this, there is a lack of hybrid MCDM methods for service quality assessment in China's ceramic industry under a fuzzy environment. The hybrid method of FAHP and MARCOS proposed in this study helps to improve the robustness of the method. Although several studies focus on the ceramic product design industry, there are few studies on service quality in this industry. This highlights some new characteristics of China's ceramic product design industry that have received little attention in previous studies. Therefore, this article aims to fill this gap.

2.2. SERVQUAL Scale

The SERVQUAL scale, developed by Parasuraman, Zeithaml and Berry [32], is a multi-item scale used to measure customer perceptions of service quality. It assesses the gap between customer expectations and perceptions across five dimensions: tangibility, reliability, responsiveness, assurance and empathy, as shown in Table 1.

Table 1. Five main dimensions of the SERVQUAL scale.

Dimensions	Description
Tangibility	Appearance of physical facilities, personnel and written materials
Reliability	Reliable and correct performance of the promised service capabilities
Responsiveness	Willingness to help customers and provide prompt service
Assurance	The ability of employees to inspire trust and confidence in customers
Empathy	Give customers individualised treatment

The SERVQUAL scale examines five dimensions of service quality using 22 indicators [33–35]. Also, customer perception is gauged using a fuzzy-like Likert scale [36]. Moreover, the following equation is employed to determine the discrepancy between each dimension of service quality and customer expectations for analysing the specific characteristics of different industries and services [37].

$$O_j = \frac{\sum_{i=1}^n (P_{ij} - E_{ij})}{n_j} \tag{1}$$

where j is SERVQUAL scale dimension, n_j is the number of questions in j dimension, P_{ij} is the average of perceptions, E_{ij} is the average of expectations and O_j is the gap between every dimension.

If O_j is positive, the service quality level is higher in dimension than the customer expectations. On the contrary, the service quality level is lower than customer expectations. Accordingly, a reasonable score of service quality level can be calculated by weighting if the weight value of each industry indicator in the SERVQUAL scale is obtained.

The SERVQUAL scale’s robustness and accuracy have been substantiated by researchers across diverse disciplines [38–42]. Notably, several studies [43–48] have demonstrated the viability of integrating the SERVQUAL scale with MCDM techniques for assessing service quality.

Given this established efficacy, this paper utilises the SERVQUAL scale to analyse and categorise customer requirements.

2.3. Fuzzy Analytic Hierarchy Process (FAHP)

Analytic Hierarchy Process (AHP) was first introduced by Saaty [49]. It stands out as a comprehensive technique for addressing MCDM challenges across diverse fields, its efficacy confirmed by numerous studies [50–52]. This method excels at structuring complex problems and breaking them down into manageable levels for thorough evaluation and quantitative assessment.

However, AHP falls short in addressing uncertainties inherent in real-world scenarios. To overcome this limitation, Chang [53], in 1996, pioneered an integrated approach combining fuzzy logic with AHP, termed Fuzzy AHP (FAHP). This innovative method effectively handles and computes decision-making challenges arising from imprecise or ambiguous information.

Over recent decades, FAHP has gained widespread adoption and recognition as a highly dependable and robust research method for tackling MCDM problems, as evidenced by its successful application in various studies [54–58].

2.4. Measurement of Alternatives and Ranking According to Compromise Solution (MARCOS)

The measurement of alternatives and ranking according to compromise solution (MARCOS) was first proposed in 2020 [59]. It is an innovative and effective MCDM technique. It revolutionises the decision-making process by addressing several shortcomings of other methods. In particular, MARCOS tackles issues such as overlooking the relative importance of distances and reduces the burden of exhaustive calculations. The approach takes into account various parameters related to the performance of alternatives and uses utility-based functions to determine their final performance scores.

In recent years, Puška et al. [60] applied MARCOS to the performance assessment field of software project management. Chakraborty et al. [61] proposed a supplier selection model using an integrated method of D numbers and MARCOS. D numbers are a mathematical tool used to represent and manage uncertainty in decision-making processes. They are an extension of the Dempster–Shafer (D-S) theory [62]. They are particularly useful in situations where information is incomplete or ambiguous. Ali [63] developed a solid waste management model using MARCOS under a fuzzy environment. El-Araby [64] published a research work in 2023 and reported that MARCOS is a new method that is very suitable for application in the field of engineering decision-making because it is not easily affected by the rank reversal phenomenon (RRP). Badi et al. [65] developed a supplier selection model for the steelmaking industry using a hybrid approach of the grey system and the MARCOS method.

More recently, some scholars have started to apply the MARCOS method to the sustainability field. For example, Puška et al. [66] proposed a selection model of a sustainable supplier industry using MARCOS under an uncertain environment. Badi et al. [67] and Pamucar et al. [68] assessed sustainable performance indicators for the green innovation and road transportation industries using an integrated method of FUCOM and MARCOS. In 2023, two groups of scholars [69,70] established an assessment framework for zero-carbon mobility and fibre fabric recycling using the MARCOS methodology.

2.5. Summary

Based on the literature review, the methods of FAHP and MARCOS have proven effective in addressing MCDM problems within sustainability fields. Notably, Tešić et al. [71] highlighted the MARCOS method as a powerful and robust tool for multi-objective optimisation, employing both ratio and reference point methods to generate a comprehensive decision information scheme. Meanwhile, Ecer [72] argued that the MARCOS model exhibits remarkable flexibility and capability, particularly when handling MCDM models. Crucially, its ease of use is maintained even with an increasing number of criteria or options.

Also, the MARCOS method is characterised by its simplicity, effectiveness and ease of extension compared to other methods. For example, compared to the TOPSIS method, MARCOS demonstrates superior stability and robustness of results when adjustments are made to the measurement scales of decision attributes [73]. Moreover, the MARCOS method shows an exceptionally high-rank correlation with established MCDM methods such as MABAC, SAW, ARAS, WASPAS and EDAS [74].

Furthermore, the evaluation criteria for each alternative are obtained by integrating expert opinions into the FAHP model. Therefore, the disadvantage of such models is that they rely on expert experience and are prone to subjective opinions.

In view of this, many scholars [75–77] suggested utilising MARCOS as another way to assess the importance of evaluation indicators, thus avoiding interference with the result by the subjective opinion of experts.

Accordingly, in this paper, the service quality assessment framework of China's ceramic product design industry will be established based on the SERVQUAL scale. Subsequently, the overall weights of dimensions and indicators will be calculated by FAHP. Finally, the MARCOS method will then be used to rank the alternatives to meet the primary objectives of the research.

3. Materials and Methods

In this research, we present an integrated approach of FAHP and MARCOS that is based on the SERVQUAL scale to evaluate the service quality of China’s ceramic product design industry. The process of this research is shown in Figure 1.

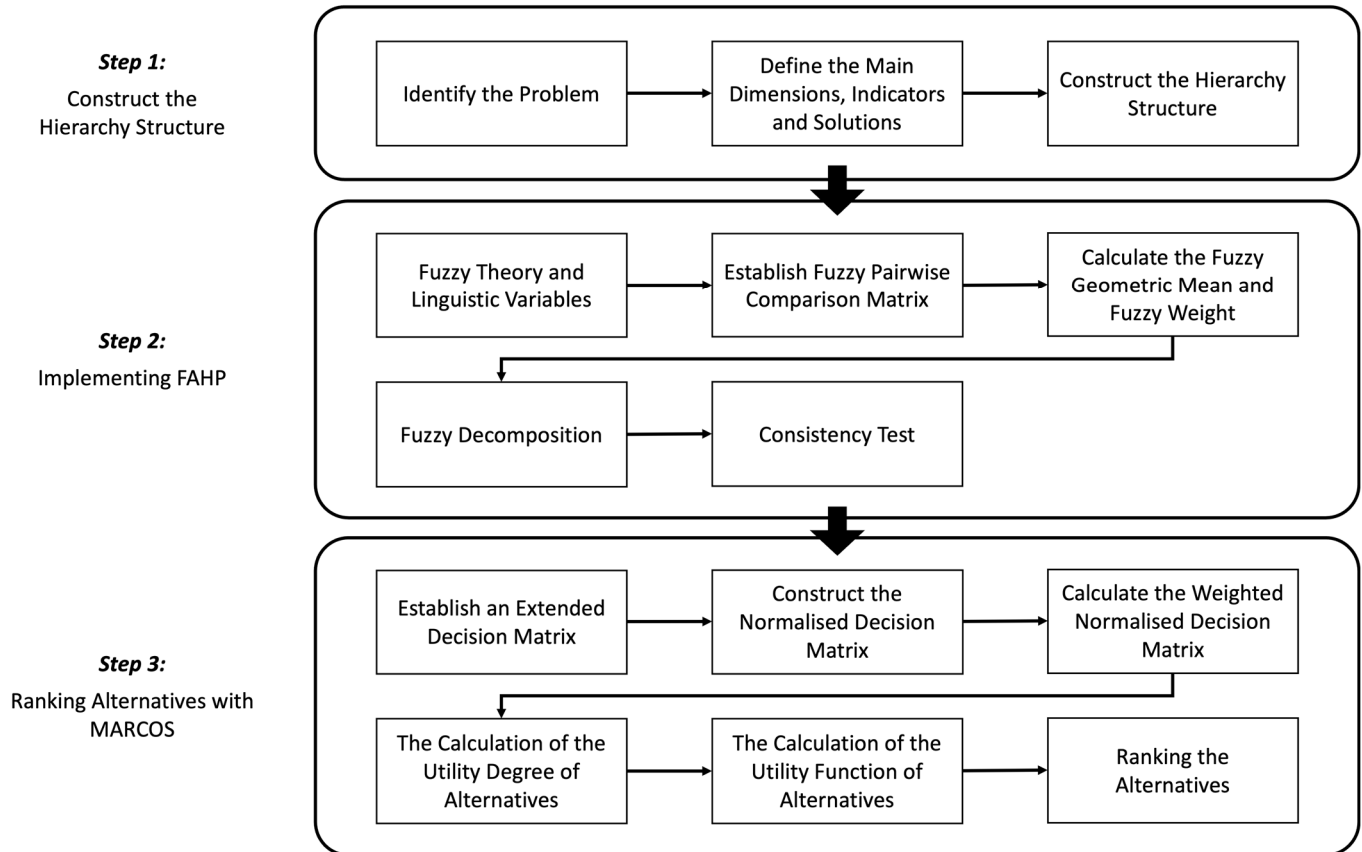


Figure 1. The process of this research.

3.1. The Construction of Hierarchy Structure

To construct the evaluation framework, we decomposed the problem into evaluation criteria and alternatives in accordance with the research methods. In addition, Tsai et al. [78] mentioned that the description of evaluation criteria and solutions should be reviewed and revised via expert discussion. Accordingly, a total of ten experts were invited to establish a focus group for this study. Among these, three are senior managers in ceramic product design-related industries, four are senior creative directors and the other three are senior ceramic product designers.

Subsequently, each focus group member independently scrutinised every dimension, indicator and potential solution, utilising their professional background and the SERVQUAL scale as guides. This assessment sought to ascertain whether the descriptions were congruent with the study’s aims. Thereafter, they engaged in an inductive examination for the assessment criteria and solutions to construct an initial hierarchy structure for the research, including 5 main dimensions, 14 indicators and 4 solutions, as shown in Figure 2.

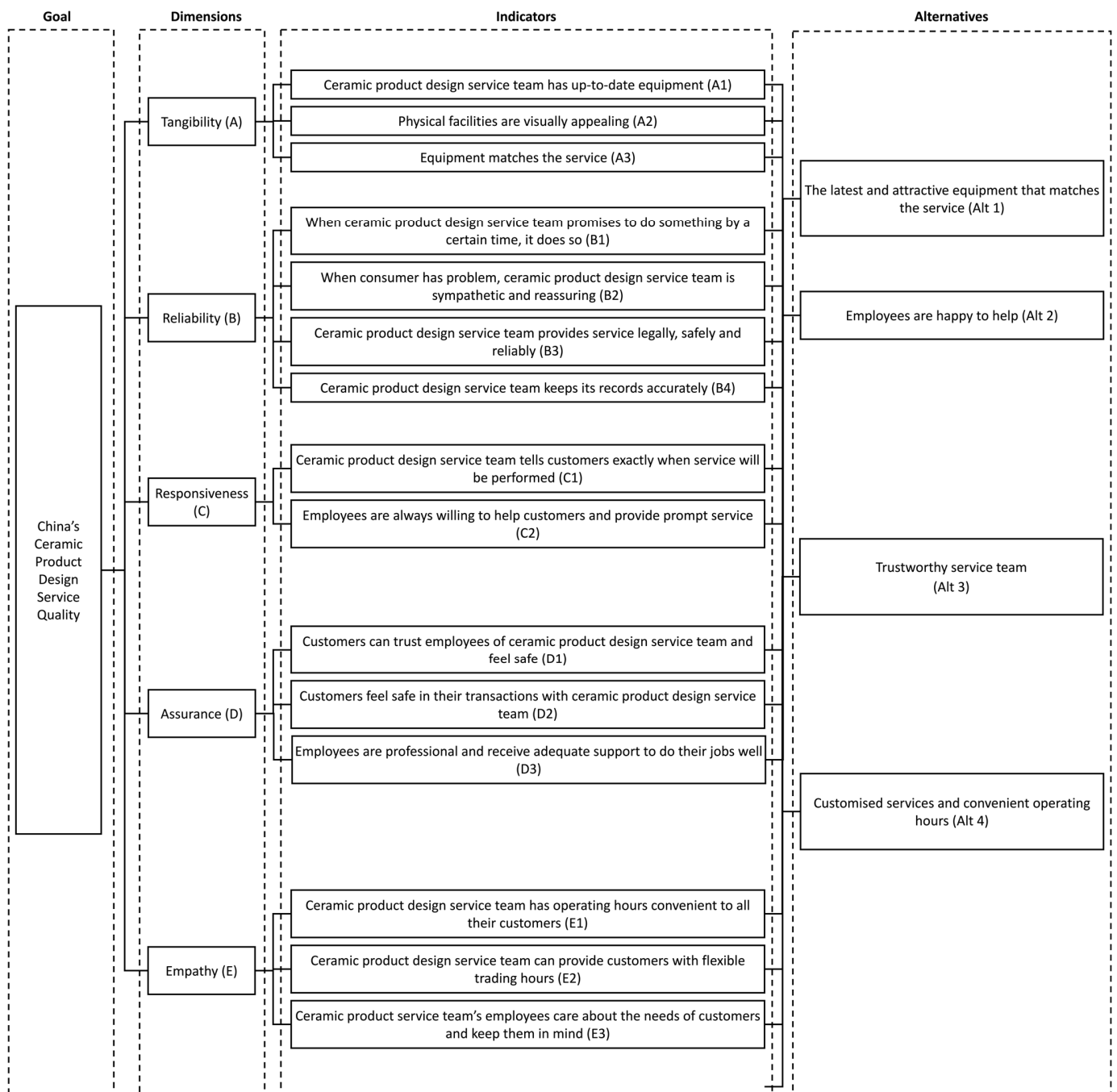


Figure 2. The initial hierarchy structure.

After an initial hierarchy structure was constructed, a preliminary test was conducted to ascertain the coherence and adequacy of the semantic portrayal. A total of 112 expert questionnaires were disseminated, with 73 valid responses retrieved. According to the results of the pre-test, most experts mentioned that the semantic meanings of some indicators were too close. Taking the dimension of assurance as an example, the semantics of the two indicators D1 and D2 will prevent the test subjects from correctly assessing the importance. Similarly, in the empathy dimension, the semantics of E1 and E2 were also very close, so appropriate modifications need to be made. Meanwhile, the number of indicators and solutions in the initial hierarchical structure was not sufficient to evaluate the service quality of the ceramic product design industry. In addition, solutions related to customer needs and employee quality should also be considered in this research.

Accordingly, we invited another ten experts to review and revise the description and phrasing of each dimension, indicator and potential solution in accordance with the SERVQUAL scale and the findings of the pre-test. For example, the experts reviewed each indicator in the assurance and empathy dimensions based on the pre-test results and revised them based on the SERVQUAL scale to ensure that the description of each indicator met the requirements of service quality assessment. In the meantime, the experts also mentioned that the number of indicators in the three dimensions of responsiveness, assurance and empathy was indeed insufficient. Therefore, they revised the number of indicators in these three dimensions. In addition, the experts added solutions related to potential customer needs and employee quality to the hierarchical structure.

Following this, the evaluation structure of service quality assessment for China’s ceramic product design industry based on the SERVQUAL scale was constructed, including 5 main dimensions, 17 indicators and 6 solutions, as shown in Figure 3.

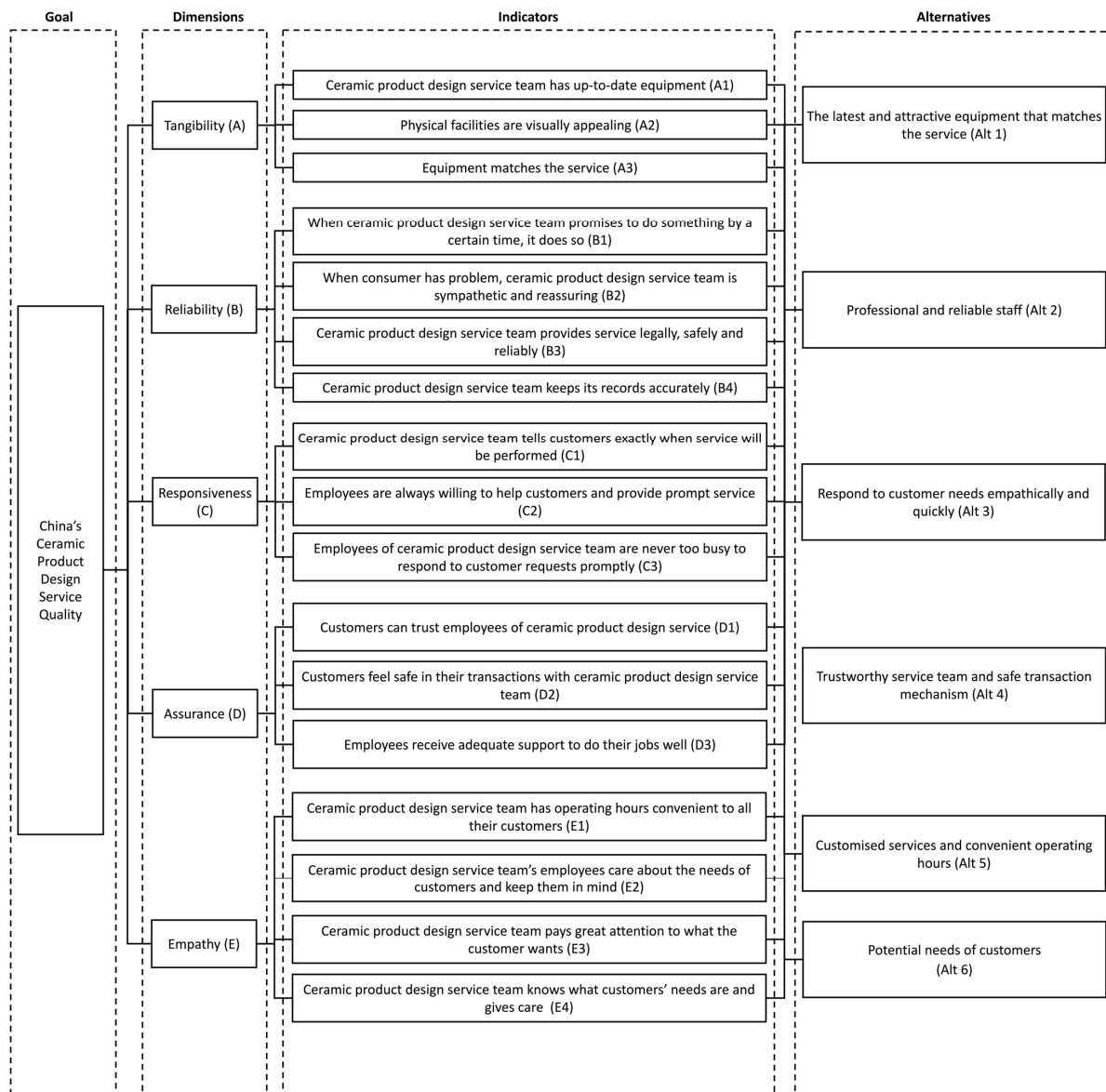


Figure 3. The evaluation structure of this research.

3.2. Questionnaire Development and Measurement

This research utilises an expert questionnaire method to obtain and gather research data for calculating the overall weight (OW) and the utility function of each dimension, in-

indicator and solution in the hierarchy structure, according to FAHP and MARCOS methods. Therefore, there is a need to consider validity before questionnaire development. In view of this, this study rewrites the questionnaire statement on the basis of expert advice and keeps the original representation of dimensions and indicators in order to maintain high content validity [79]. In addition, this study conducts a pre-test and revises the statements according to the results of the pre-test to check whether the meaning of the questionnaire was clear.

As for the number of experts, F. J. Parenté and J. K. Anderson-Parenté [80] suggested that there should be at least ten experts or more. Interestingly, Darko et al. [81] mentioned that a large sample size may not be helpful, because “cold-called” experts could profoundly affect the result of consistency examination. We found that much research [82–87] utilised a small sample size of four to nine experts to obtain a valuable and reliable decision-making basis.

Accordingly, a total of 30 experts were selected for this research to avoid the influence of opinions from “cold-called” experts on the consistency evaluation results, thus achieving our main research objectives. These experts were divided into two groups of 15. One group completed the pairwise comparison questionnaires and used the FAHP method for calculation and analysis. Another group of experts rated the solutions according to their relative importance, which was then calculated and ranked using the MARCOS method.

3.3. Fuzzy Analytic Hierarchy Process (FAHP)

3.3.1. Fuzzy Theory and Linguistic Variables

Herrera et al. [88] asserted that linguistic markers like “very important”, “somewhat important” and “not important” are frequently used to depict how individuals understand the significance of a specific issue. However, Zimmermann [89] observed that these linguistic markers, when employed to articulate the weight of human psychological understanding, often lack clarity. Therefore, it is crucial to integrate fuzzy theory to offer a more precise depiction of human interpretation of these matters.

Fuzzy theory was first proposed by Dr. Lotfi Zadeh [90], addressing problems encountered in uncertain environments. It is an algorithm that operates on fuzzy numbers, which incorporates a reasoning-like process to determine the outcome most aligned with human psychological perception.

In view of this, the fuzzy numbers were studied and it was discovered that their representation is often mathematical in nature [91–94]. For instance, a triangular fuzzy number A can be denoted as (L_{ij}, M_{ij}, U_{ij}) , where the parameters L_{ij} , M_{ij} and U_{ij} represent the smallest, most likely and largest values, respectively. Figure 4 illustrates a triangular fuzzy number $A (L_i, M_i, U_i)$ as defined by the following equation:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-L_{ij}}{M_{ij}-L_{ij}} & , L_{ij} \leq x \leq M_{ij} \\ \frac{x-U_{ij}}{M_{ij}-U_{ij}} & , M_{ij} \leq x \leq U_{ij} \\ 0 & , \text{otherwise} \end{cases} \quad (2)$$

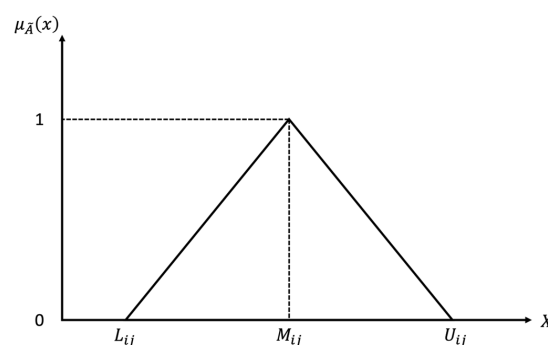


Figure 4. Fuzzy triangular numbers [95].

Meanwhile, much research [96–99] mentioned that the most likely evaluation value of triangular fuzzy numbers is the crisp value. The crisp value of triangular fuzzy numbers is given by the following equation.

$$A_a = [l^a, m^a] = [(m - l)a - (u - m)a + u] \tag{3}$$

Additionally, Buckley [100] reported that the characteristics of triangular fuzzy numbers are helpful in accurately presenting human fuzzy psychological perception variables by converting fuzzy numbers into clear and practical numbers. Moreover, triangular fuzzy numbers have been proven by Pedrycz [101] to be very suitable for expressing the degree of relative psychological perception and judgment of each criterion and alternative in the hierarchy and network structure. Accordingly, triangular fuzzy numbers are utilised to represent linguistic variable scales in this research.

Furthermore, AHP used a nine-point evaluation scale to indicate the importance of each evaluation criterion. Therefore, we integrate the triangular fuzzy number and AHP evaluation scale for assessing and measuring human psychological true preferences for specific options. The corresponding fuzzy numbers are provided in Table 2 [102].

Table 2. Fuzzy numbers and linguistic variables.

Linguistic Variables	Fuzzy Numbers	Triangular Fuzzy Scale			Reversed Triangular Fuzzy Scale		
Equally Preferred	$\tilde{1}$	1	1	1	1	1	1
Intermediate	$\tilde{2}$	1	2	3	1/3	1/2	1
Moderately Preferred	$\tilde{3}$	2	3	4	1/4	1/3	1/2
Intermediate	$\tilde{4}$	3	4	5	1/5	1/4	1/3
Strongly Preferred	$\tilde{5}$	4	5	6	1/6	1/5	1/4
Intermediate	$\tilde{6}$	5	6	7	1/7	1/6	1/5
Very Strongly Preferred	$\tilde{7}$	6	7	8	1/8	1/7	1/6
Intermediate	$\tilde{8}$	7	8	9	1/9	1/8	1/7
Extremely Preferred	$\tilde{9}$	9	9	9	1/9	1/9	1/9

3.3.2. The Construction of Fuzzy Pairwise Comparison Matrix

In this step, a fuzzy pairwise comparison matrix is performed and presented as follows:

$$\tilde{A}^k = \begin{bmatrix} \tilde{a}_{11}^k & \tilde{a}_{12}^k & \cdots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & \tilde{a}_{22}^k & \cdots & \tilde{a}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1}^k & \tilde{a}_{n2}^k & \cdots & \tilde{a}_{nn}^k \end{bmatrix}, \tag{4}$$

where \tilde{A}^k represents the fuzzy pairwise comparison matrix and \tilde{a}_{nn}^k is the triangular fuzzy mean value for comparing priority pairs among elements.

3.3.3. The Calculation of Fuzzy Geometric Mean (\tilde{r}_i) and Fuzzy Weight (\tilde{w}_i)

The calculation of fuzzy geometric mean and fuzzy weight is as follows:

$$\tilde{r}_i = \left[\left(L_{ij1} \otimes L_{ij2} \otimes \cdots \otimes L_{ijk} \right)^{\frac{1}{i}}, \left(M_{ij1} \otimes M_{ij2} \otimes \cdots \otimes M_{ijk} \right)^{\frac{1}{i}}, \left(U_{ij1} \otimes U_{ij2} \otimes \cdots \otimes U_{ijk} \right)^{\frac{1}{i}} \right] \tag{5}$$

$$\tilde{w}_i = \tilde{r}_i \otimes \left(\tilde{r}_1 \oplus \tilde{r}_2 \oplus \cdots \oplus \tilde{r}_n \right)^{-1} \tag{6}$$

where \otimes represents the operation of Kronecker product.

3.3.4. Defuzzification

In terms of fuzzy decomposition, the optimism index (α, β) is utilised to combine the smallest and largest values of triangular fuzzy numbers (L_{ij}, U_{ij}) for defuzzification [103–105]. Thus, the process of fuzzy decomposition is as follows:

$$t_{\alpha,\beta}(\bar{a}_{ij}) = [\beta f_a(L_{ij}) + (1 - \beta)f_a(U_{ij})], \alpha \in [0, 1], \beta \in [0, 1], \tag{7}$$

where

$$f_a(L_{ij}) = (M_{ij} - L_{ij})\alpha + L_{ij}, \tag{8}$$

$$f_a(U_{ij}) = U_{ij} - (M_{ij} - L_{ij})\alpha, \tag{9}$$

When the diagonal matrix is matching, we have

$$t_{\alpha,\beta}(\bar{a}_{ij}) = \frac{1}{t_{\alpha,\beta}(\bar{a}_{ij})}, \alpha \in [0, 1], \beta \in [0, 1], i > j \tag{10}$$

where \bar{a}_{ij} is the value of fuzzy decomposition.

3.3.5. Consistency Check

Saaty [106] proposed adopting the consistency index (C.I.) and consistency ratio (C.R.) to verify the consistency of the comparison matrix. The C.I. and C.R. are defined as follows:

$$C.I. = \frac{\lambda_{max} - n}{n - 1}, \tag{11}$$

where λ_{max} is the maximum value of the matrix and n is the number of criteria.

$$C.R. = \frac{C.I.}{R.I.}, \tag{12}$$

Random index (R.I.) is a consistency index produced by positive reciprocal matrices of different orders 2 to 14 generated from the integer set 1 to 9 [107]. It depends on the number of involved criteria [108]. Table 3 shows the values of the random index.

Table 3. Random index (R.I.) values.

The Order of Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	-	-	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

When $C.I. \leq 0.1$, it refers to the best acceptable error. When $C.R. \leq 0.1$, it means that the consistency of the matrix is satisfactory.

3.4. Measurement of Alternatives and Ranking According to Compromise Solution (MARCOS)

3.4.1. Establish an Extended Decision Matrix

The extended decision matrix is performed as follows:

$$X' = \begin{matrix} (AAI) \\ A_1 \\ A_2 \\ \dots \\ A_m \\ (AI) \end{matrix} \begin{matrix} C_1 & C_2 & \dots & C_n \\ \left[\begin{matrix} x_{aa1} & x_{aa1} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \\ x_{ai1} & x_{ai2} & \dots & x_{ain} \end{matrix} \right] \end{matrix}, \tag{13}$$

The ideal (AI) solution represents an alternative with the highest performance, whereas the anti-ideal (AAI) solution denotes the least desirable alternative. Depending on the characteristics of the criteria, the AI and AAI sets are established as follows:

$$AI = \max_i x_{ij} \text{ if } j \in B \text{ and } \min_i x_{ij} \text{ if } j \in C \tag{14}$$

$$AAI = \min_i x_{ij} \text{ if } j \in B \text{ and } \max_i x_{ij} \text{ if } j \in C \tag{15}$$

where B denotes a benefit group of criteria while C denotes a group of cost criteria.

3.4.2. Construct the Normalised Decision Matrix

The normalised decision matrix can be calculated using the following equations.

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ if } j \in B \tag{16}$$

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ if } j \in C \tag{17}$$

where x_{ij} and x_{ai} represent the elements of the matrix X' .

3.4.3. Calculate the Weighted Normalised Decision Matrix

The weighted matrix V is obtained by multiplying the normalised matrix N with the weight coefficient of each criterion ω_j using the following equation.

$$v_{ij} = n_{ij} \times \omega_j \tag{18}$$

3.4.4. The Calculation of the Utility Degree of Alternatives

The utility degrees of an alternative in relation to the ideal (K_i^+) and anti-ideal (K_i^-) solution are calculated as follows:

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{19}$$

$$K_i^- = \frac{S_i}{S_{aai}} \tag{20}$$

where $S_i (i = 1, 2, \dots, m)$ signifies the summation of the elements within the weighted matrix V , illustrated in the following equation.

$$S_i = \sum_{i=1}^n v_{ij} \tag{21}$$

3.4.5. The Calculation of the Utility Function of Alternatives

The utility function of alternatives is calculated as follows:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \tag{22}$$

where the utility functions concerning the ideal $f(K_i^+)$ and anti-ideal $f(K_i^-)$ solutions are determined using the following equations.

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{23}$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{24}$$

3.4.6. Ranking the Solutions

Within the MARCOS model, all potential solutions are ranked according to the final values of the utility function, denoted as $f(K_i)$. The most favourable alternative is identified as the one that is closest to the ideal and at the same time furthest from the anti-ideal reference point. This implies that potential solutions with higher utility function values are considered more desirable.

4. Results

4.1. Numerical Analysis

4.1.1. Fuzzy Analytic Hierarchy Process (FAHP)

As for the construction of a fuzzy pairwise comparison matrix, we gathered the opinions and integrated the perspectives of 15 experienced ceramic product design experts. Subsequently, the fuzzy pairwise comparison matrix was established using Equation (4), as shown in Table 4.

Table 4. The fuzzy pairwise comparison matrix of the five main dimensions from the FAHP model.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	(1,1,1)	(4,5,6)	(5,6,7)	(3,4,5)	(6,7,8)
Reliability (B)	(1/6,1/5,1/4)	(1,1,1)	(1,2,3)	(1/3,1/2,1)	(3,4,5)
Responsiveness (C)	(1/7,1/6,1/5)	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)	(1,2,3)
Assurance (D)	(1/5,1/4,1/3)	(1,2,3)	(2,3,4)	(1,1,1)	(3,4,5)
Empathy (E)	(1/8,1/7,1/6)	(1/5,1/4,1/3)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1,1,1)

Subsequently, the fuzzy geometric mean values of the five main dimensions are calculated through the use of Equation (5), as shown in Table 5.

Table 5. The calculation of fuzzy geometric mean values for the main dimensions.

Dimensions	Computation Process	Results
Tangibility (A)	$[(1 \times 4 \times 5 \times 3 \times 6)^{\frac{1}{5}}, (1 \times 5 \times 6 \times 4 \times 7)^{\frac{1}{5}}, (1 \times 6 \times 7 \times 5 \times 8)^{\frac{1}{5}}]$	3.245 3.845 4.416
Reliability (B)	$[(1/6 \times 1 \times 1 \times 1/3 \times 3)^{\frac{1}{5}}, (1/5 \times 1 \times 2 \times 1/2 \times 4)^{\frac{1}{5}}, (1/4 \times 1 \times 3 \times 1 \times 5)^{\frac{1}{5}}]$	0.699 0.956 1.303
Responsiveness (C)	$[(1/7 \times 1/3 \times 1 \times 1/4 \times 1)^{\frac{1}{5}}, (1/6 \times 1/2 \times 1 \times 1/3 \times 2)^{\frac{1}{5}}, (1/5 \times 1 \times 1 \times 1/2 \times 3)^{\frac{1}{5}}]$	0.412 0.561 0.786
Assurance (D)	$[(1/5 \times 1 \times 2 \times 1 \times 3)^{\frac{1}{5}}, (1/4 \times 2 \times 3 \times 1 \times 4)^{\frac{1}{5}}, (1/3 \times 3 \times 4 \times 1 \times 5)^{\frac{1}{5}}]$	1.037 1.431 1.821
Empathy (E)	$[(1/8 \times 1/5 \times 1/3 \times 1/5 \times 1)^{\frac{1}{5}}, (1/7 \times 1/4 \times 1/2 \times 1/4 \times 1)^{\frac{1}{5}}, (1/6 \times 1/3 \times 1 \times 1/3 \times 1)^{\frac{1}{5}}]$	0.278 0.339 0.450
	Total	5.672 7.132 8.776

The calculation process of fuzzy weight (\tilde{w}_i) for each dimension using Equation (6) is shown in Table 6.

Table 6. The calculation of fuzzy weight for the main dimensions.

Dimensions	Computation Process	Results
Tangibility (A)	$(3.245, 3.845, 4.416) \otimes \left(\frac{1}{8.776}, \frac{1}{7.132}, \frac{1}{5.672} \right)$	0.370 0.539 0.779
Reliability (B)	$(0.699, 0.956, 1.303) \otimes \left(\frac{1}{8.776}, \frac{1}{7.132}, \frac{1}{5.672} \right)$	0.080 0.134 0.230
Responsiveness (C)	$(0.412, 0.561, 0.786) \otimes \left(\frac{1}{8.776}, \frac{1}{7.132}, \frac{1}{5.672} \right)$	0.047 0.079 0.139
Assurance (D)	$(1.037, 1.431, 1.821) \otimes \left(\frac{1}{8.776}, \frac{1}{7.132}, \frac{1}{5.672} \right)$	0.118 0.201 0.321
Empathy (E)	$(0.278, 0.339, 0.450) \otimes \left(\frac{1}{8.776}, \frac{1}{7.132}, \frac{1}{5.672} \right)$	0.032 0.048 0.079

As for fuzzy decomposition, this study utilises $\alpha = 0.5$ and $\beta = 0.5$ during the defuzzification [109–111]. The process of fuzzy decomposition for dimensions between tangibility (A) and reliability (B) is as follows:

$$t_{0.5,0.5}(\overline{a_{A,B}}) = [0.5 \times 5.5 + (1 - 0.5) \times 4.5] = 5$$

$$f_a(L_{A,B}) = (5 - 4) \times 0.5 + 4 = 4.5$$

$$f_a(U_{A,B}) = 6 - (5 - 4) \times 0.5 = 5.5$$

$$t_{0.5,0.5}(\overline{a_{B,A}}) = \frac{1}{5}$$

The processes of fuzzy decomposition for the remaining main dimensions are like the above calculation. Subsequently, the de-fuzzified pairwise comparison matrix for the five main dimensions from the FAHP model is shown in Table 7.

Table 7. The de-fuzzified pairwise comparison matrix of five dimensions from the FAHP model.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	1	5	6	4	7
Reliability (B)	1/5	1	2	1/2	4
Responsiveness (C)	1/6	1/2	1	1/3	2
Assurance (D)	1/4	2	3	1	4
Empathy (E)	1/7	1/4	1/2	1/4	1

The calculation of the maximum individual value (AM) for each dimension is shown in Table 8.

Table 8. The maximum individual value calculation process.

Dimensions	The Calculation Process	Maximum Individual Value
Tangibility (A)	$(1 \times 5 \times 6 \times 4 \times 7)^{\frac{1}{5}}$	3.8446
Reliability (B)	$(\frac{1}{5} \times 1 \times 2 \times \frac{1}{2} \times 4)^{\frac{1}{5}}$	0.9564
Responsiveness (C)	$(\frac{1}{6} \times \frac{1}{2} \times 1 \times \frac{1}{3} \times 2)^{\frac{1}{5}}$	0.561
Assurance (D)	$(\frac{1}{4} \times 2 \times 3 \times 1 \times 4)^{\frac{1}{5}}$	1.431
Empathy (E)	$(\frac{1}{7} \times \frac{1}{4} \times \frac{1}{2} \times \frac{1}{4} \times 1)^{\frac{1}{5}}$	0.3388
	Total	7.1317

The calculation process of weight (ω) for each dimension is shown in Table 9.

Table 9. The calculation of weight for the five dimensions.

Dimensions	The Calculation Process	Weight (ω)
Tangibility (A)	$\frac{3.8446}{7.1317}$	0.5391
Reliability (B)	$\frac{0.9564}{7.1317}$	0.1341
Responsiveness (C)	$\frac{0.561}{7.1317}$	0.0787
Assurance (D)	$\frac{1.431}{7.1317}$	0.2006
Empathy (E)	$\frac{0.3388}{7.1317}$	0.0475
	Total	1

The calculation of the normalised matrix is shown in Table 10.

Table 10. Normalised matrix calculation.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	1×0.5391	5×0.1341	6×0.0787	4×0.2006	7×0.0475
Reliability (B)	$1/5 \times 0.5391$	1×0.1341	2×0.0787	$1/2 \times 0.2006$	4×0.0475
Responsiveness (C)	$1/6 \times 0.5391$	$1/2 \times 0.1341$	1×0.0787	$1/3 \times 0.2006$	2×0.0475
Assurance (D)	$1/4 \times 0.5391$	2×0.1341	3×0.0787	1×0.2006	4×0.0475
Empathy (E)	$1/7 \times 0.5391$	$1/4 \times 0.1341$	$1/2 \times 0.0787$	$1/4 \times 0.2006$	1×0.0475

The calculation of the maximum eigenvector (W_1) is shown in Table 11.

Table 11. The calculation of the maximum eigenvector for the five main dimensions.

Dimensions	A	B	C	D	E	Total	ω	W_1
A	0.5391	0.6705	0.4720	0.8026	0.3325	2.8167	0.5391	$2.8167/0.5391 = 5.2249$
B	0.1078	0.1341	0.1573	0.1003	0.1900	0.6896	0.1341	$0.6896/0.1341 = 5.1424$
C	0.0898	0.0670	0.0787	0.0669	0.0950	0.3975	0.0787	$0.3975/0.0787 = 5.0528$
D	0.1348	0.2682	0.2360	0.2006	0.1900	1.0296	0.2006	$1.0296/0.2006 = 5.1315$
E	0.0770	0.0335	0.0393	0.0502	0.0475	0.2475	0.0475	$0.2475/0.0475 = 5.2105$

Since the numbers of main dimensions are 5, we obtain $n = 5$. Therefore, λ_{max} and $C.I.$ are calculated as follows:

$$\lambda_{max} = \frac{(5.2249 + 5.1424 + 5.0528 + 5.1315 + 5.2105)}{5} = 5.1524$$

$$C.I. = \frac{\lambda_{max} - n}{n - 1} = \frac{5.1524 - 5}{5 - 1} = 0.0381$$

For $C.R.$, with $n = 5$, we have $R.I. = 1.12$.

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.0381}{1.12} = 0.034$$

The calculation results of the de-fuzzified pairwise comparison matrix between five main dimensions are shown in Table 12.

Table 12. The pairwise comparison matrix for five main dimensions from the FAHP model.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)	ω
Tangibility (A)	1	5	6	4	7	0.566
Reliability (B)	1/5	1	2	1/2	4	0.1408
Responsiveness (C)	1/6	1/2	1	1/3	2	0.0826
Assurance (D)	1/4	2	3	1	4	0.2107
Empathy (E)	1/7	1/4	1/2	1/4	1	0.0499
Total						1
$\lambda_{max} = 5.1524, C.I. = 0.0381, C.R. = 0.034$						

The calculation processes of defuzzification, maximum eigenvalue (λ_{max}), consistency index ($C.I.$) and consistency ratio ($C.R.$) for all indicators are like the above calculations. Subsequently, the de-fuzzified pairwise comparison matrix for all sub-criteria is shown in Tables A1–A5.

As shown in Tables A1–A5, values of the consistency index ($C.I.$) and consistency ratio ($C.R.$) for all criteria are less than 0.1. This means that the result of the consistency tests is acceptable.

After passing the consistency test, the overall weight (OW) of all indicators in the FAHP model was calculated using Super Decisions software 3.2. This software was developed by Prof. Saaty [112], the inventor of the analytic hierarchy process (AHP), and is suitable for

obtaining the OW of all criteria. The OW of all indicators in the FAHP model is shown in Table 13.

Table 13. The overall weight of all indicators in the FAHP model.

Indicators	Description	OW
A1	Ceramic product design service team has up-to-date equipment	0.0042
A2	Physical facilities are visually appealing	0.0076
A3	Equipment matches the service	0.0276
B1	When ceramic product design service team promises to do something by a certain time, it does so	0.0154
B2	When consumer has a problem, ceramic product design service team is sympathetic and reassuring	0.0895
B3	Ceramic product design service team provides service legally, safely and reliably	0.0395
B4	Ceramic product design service team keeps its records accurately	0.011
C1	Ceramic product design service team tells customers exactly when service will be performed	0.0355
C2	Employees are always willing to help customers and provide prompt service	0.1625
C3	Employees of ceramic product design service team are never too busy to respond to customer requests promptly	0.062
D1	Customers can trust employees of ceramic product design service team	0.0422
D2	Customers feel safe in their transactions with ceramic product design service team	0.0119
D3	Employees receive adequate support to do their jobs well	0.05
E1	Ceramic product design service team has operating hours convenient to all their customers	0.0207
E2	Ceramic product design service team’s employees care about the needs of customers and keep them in mind	0.1013
E3	Ceramic product design service team pays great attention to what the customer wants	0.269
E4	Ceramic product design service team knows what customers’ needs are and gives care	0.0503

4.1.2. Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS)

After obtaining the overall weight of all indicators from the FAHP model, the MARCOS method was applied to rank all alternatives. The ideal (AI) and anti-ideal (AAI) solutions in relation to each criterion are determined. The ideal (AI) is the highest value of each criterion while the lowest value is the anti-ideal (AAI).

The extended decision-making matrix was established using Equation (13), as shown in Table 14.

Table 14. Extended decision-making matrix of the MARCOS model.

Alternatives	Indicators																
	A1	A2	A3	B1	B2	B3	B4	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4
AAI	1.26	1.26	1.91	3.98	3.63	3.11	2.52	2.08	1.82	3.17	3.27	2.88	3.48	2.88	2.88	1.82	1.59
ALT 1	5.13	5.04	8.28	3.98	3.63	4.16	3.68	2.52	1.82	3.56	3.83	3.04	4.58	3.00	2.88	2.00	1.59
ALT 2	2.29	2.15	3.63	6.54	5.01	6.65	6.32	4.93	5.65	6.60	3.27	4.48	3.48	6.54	7.27	5.65	2.29
ALT 3	1.26	1.26	2.41	4.93	5.43	3.17	2.52	2.08	4.58	7.11	6.32	3.63	3.56	5.19	4.16	5.52	3.42
ALT 4	2.88	3.30	4.48	4.58	3.63	3.11	2.88	3.30	4.48	4.31	4.38	2.88	3.56	2.88	2.88	1.82	2.29
ALT 5	1.71	1.82	1.91	4.76	4.38	4.16	4.64	3.30	3.78	3.17	3.78	3.91	3.63	4.82	3.78	2.71	2.15
ALT 6	2.08	2.00	3.98	7.56	6.95	6.65	6.54	8.65	7.96	9.00	8.32	7.96	7.61	6.95	7.56	8.65	8.32
AI	5.13	5.04	8.28	6.54	5.43	6.65	6.32	4.93	5.65	7.11	6.32	4.48	4.58	6.54	7.27	5.65	3.42

Subsequently, the normalised decision-making matrix was constructed using Equations (16) and (17), as shown in Table A6.

The values of the weighted normalised decision-making matrix shown in Table A7 were obtained by applying Equation (18): $v_{ij} = n_{11} \times \omega_1 = 1 \times 0.0042 = 0.0042$.

The calculations of utility degrees for all alternatives (S_i) in the MARCOS model using Equations (19)–(21) are shown in Table A8.

4.2. Research Result

4.2.1. Fuzzy Analytic Hierarchy Process (FAHP)

In the FAHP model, all dimensions and indicators are ranked based on overall weight (OW). As for the calculation of the OW, all data in the de-fuzzified pairwise comparison matrix were input into Super Decisions software. Subsequently, the OW of main dimensions and indicators were obtained, as shown in Figures 5 and 6.

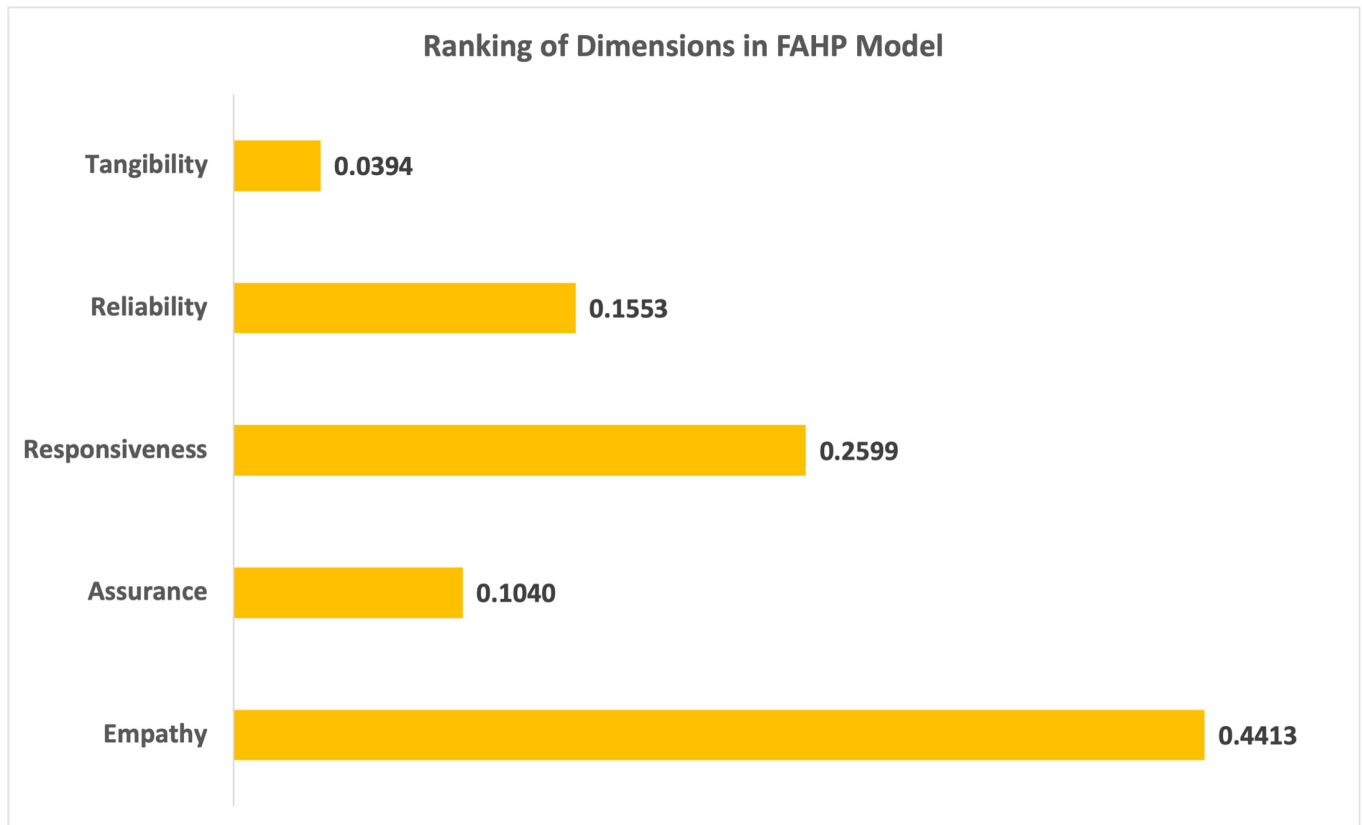


Figure 5. The ranking of all the dimensions in the FAHP model.

As shown in Figure 5, the dimensions were ordered by OW as empathy (0.4413), responsiveness (0.2599), reliability (0.1553), assurance (0.104) and tangibility (0.0394).

As shown in Figure 6, the top three indicators in terms of OW were “Ceramic product design service team pays great attention to what the customer wants” (E3, 0.269), “Employees are always willing to help customers and provide prompt service” (C2, 0.1625) and “Ceramic product design service team’s employees care about the needs of customers and keep them in mind” (E2, 0.1013).

The OWs of indicators ranked fourth to sixth were “When consumer has problem, ceramic product design service team is sympathetic and reassuring” (B2, 0.0895), “Employees of ceramic product design service team are never too busy to respond to customer requests promptly” (C3, 0.062) and “Ceramic product design service team knows what customers’ needs are and gives care” (E4, 0.053).

4.2.2. Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS)

In the MARCOS model, the ranking of all alternatives was determined by the value of the final utility function ($f(K_i)$). The final utility function value of all alternatives was calculated using Equations (22)–(24), as shown in Table 15.

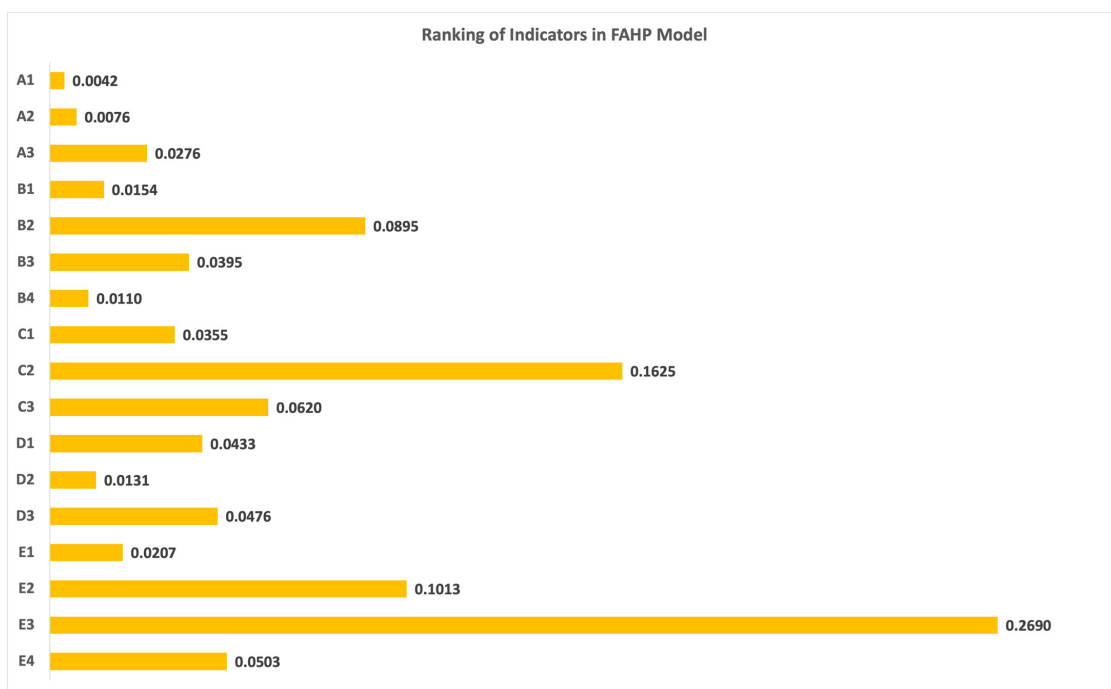


Figure 6. The ranking of all the indicators in the FAHP model.

Table 15. The final utility function value of all alternatives.

Alternatives	Utility Degrees		
	$f(K_i^+)$	$f(K_i^-)$	$f(K_i)$
ALT 1	0.7698	0.2302	5.156
ALT 2	0.7698	0.2302	6.4636
ALT 3	0.7698	0.2302	6.1711
ALT 4	0.7698	0.2302	5.3384
ALT 5	0.7698	0.2302	5.458
ALT 6	0.7698	0.2302	7.9213

The ranking result of all alternatives based on the final utility function value in the MARCOS model is shown in Figure 7.

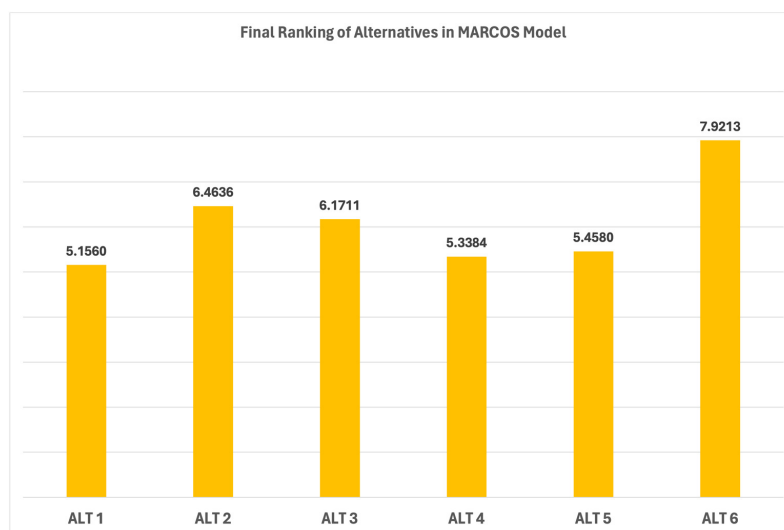


Figure 7. The ranking of all alternatives in the MARCOS model.

In Figure 7, “Potential needs of customers” (ALT 6, 7.9213) ranked first, followed by “Professional and reliable staff” (ALT 2, 6.4636), “Respond to customer needs empathically and quickly” (ALT 3, 6.1711) and “Customised services and convenient operating hours” (ALT 5, 5.458). In addition, “Trustworthy service team and safe transaction mechanism” (ALT 4, 5.3384) and “The latest and attractive equipment that matches the service” (ALT 1, 5.156) were ranked fourth and fifth.

5. Discussion

5.1. Sensitivity Analysis of Criteria Weight

In MCDM problems, the input data are often fluid and constantly changing, as opposed to being consistent and stable. Therefore, sensitivity analysis is essential to support the decision-making process. In this study, sensitivity analysis in the context of MCDM problems is used to assess the impact of changes in the weighting of a single criterion on the overall results. These changes include adjustments to the weighting of other criteria and variations in the final ranking of options [113].

For this purpose, each criterion is removed in turn, resulting in 18 scenarios for sensitivity analysis of criteria weight. The weight of all criteria and the prospect value of alternatives in all scenarios are shown in Tables A9 and A10. The ranking is visualised in Figure 8.

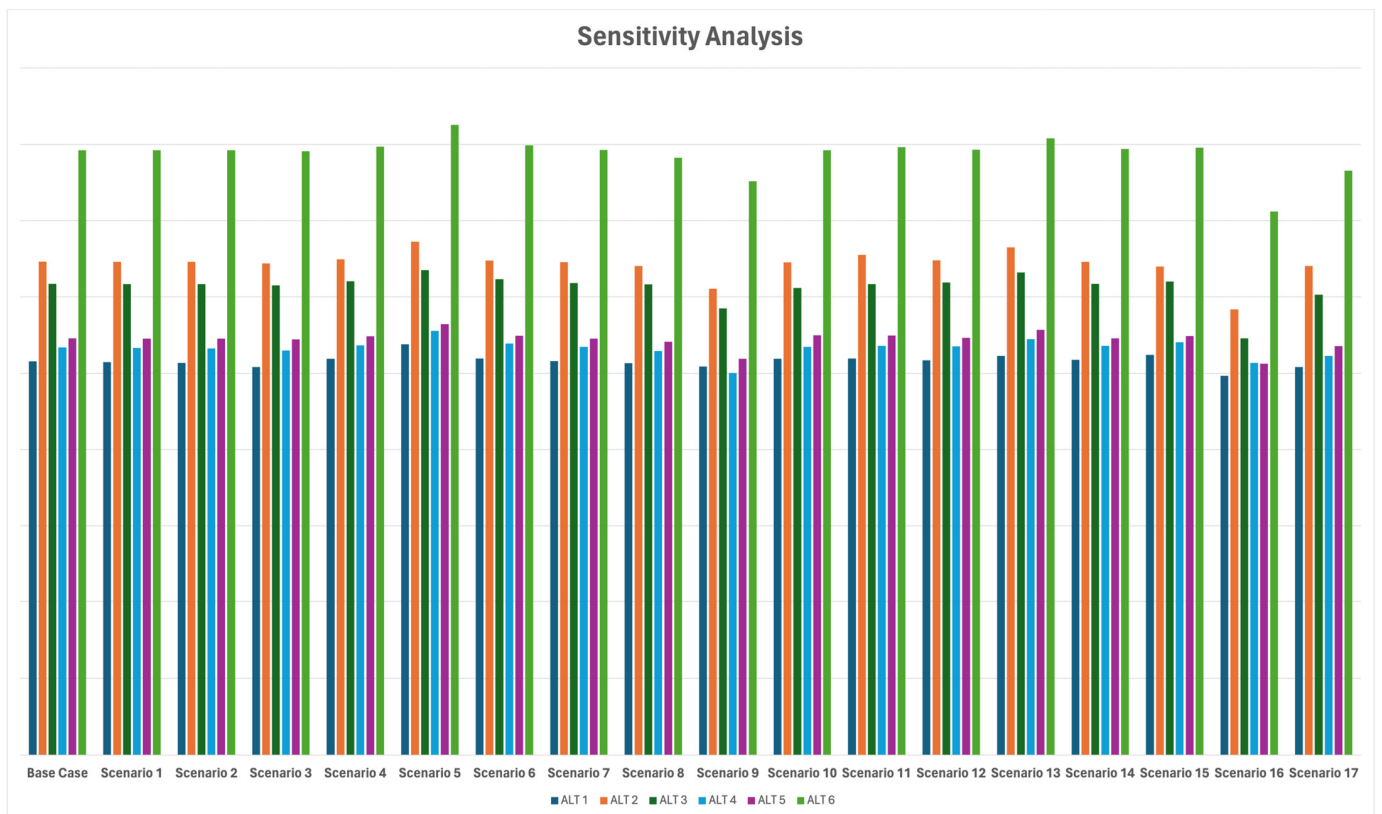


Figure 8. The ranking of alternatives in all scenarios.

While the prospect values changed, the final ranking remains largely consistent, identifying “Potential needs of customers” (ALT 6) as the optimal solution. These results from the sensitivity phase indicate a robust alternative ranking that is insensitive to changes in criteria weights. This demonstrates the high stability and applicability of the proposed FAHP-MARCOS model.

5.2. Implications for Research

In this research, a hybrid MCDM method was proposed to exploit the strengths of both FAHP and MARCOS, thereby increasing robustness and mitigating the limitations of each method. Meanwhile, by applying this hybrid MCDM method to real-world data, the study ensures greater objectivity and reduces bias, providing more practical insights for decision making by practitioners in China's ceramic product design industry.

Also, the hybrid MCDM method proposed in this study will positively help practitioners in the ceramic product design industry to understand the service quality index and solutions to provide excellent service quality. Therefore, China's ceramic product design practitioners can use the proposed priorities of the indicator to compare their own industry's priorities with the ideal proposed rankings.

Moreover, the main criteria, including empathy, responsiveness and reliability, emerge as the three most significant in the FAHP model. In terms of indicator ranking, "Ceramic product design service team pays great attention to what the customer wants" ranks first, followed by "Employees are always willing to help customers and provide prompt service" and "Ceramic product design service team's employees care about the needs of customers and keep them in mind". Thus, practitioners in the ceramic product design industry should give priority to these identified indicators for providing good service quality. It is important to note that while relevant indicators such as "Ceramic product design service team keeps its records accurately", "Physical facilities are visually appealing" and "Ceramic product design service team has up-to-date equipment" may appear lower in the ranking, this reflects their relative priority within the context of this study's decision model. It should not be interpreted as meaning that these indicators are not important at all.

In addition, this research makes a scientific contribution by demonstrating the effectiveness of the proposed hybrid MCDM method. It shows how the FAHP and MARCOS methods can help in understanding the factors and solutions related to Chinese ceramic product design. Furthermore, the relative priority of service quality factors was analysed, evaluated and presented in the outcome of this study.

5.3. Implications for Management

For China's ceramic product design industry, understanding these solutions of excellent service quality for making the right choices is a major decision-making challenge. Making this choice is critical to helping companies achieve their service goals. According to the findings of this study, the potential needs of customers, well-qualified staff and the response speed to customer needs will contribute to the service quality of the ceramic product design industry. Therefore, the ceramic product design industry should work with suppliers to develop new standards to meet the requirement of excellent service quality.

Finally, this fundamental change in approach has implications for management across related sectors. The proposed model is tailored to China's ceramic product design industry, offering valuable perspectives for ceramic product designers as well as for business, management and industry professionals in related fields.

5.4. Research Limitations

This research proposed an integrated MCDM method by combining FAHP and MARCOS. In the FAHP model, the pairwise comparison of the importance of the indicators and the values of C.I. and C.R. were used to verify the indicators' progression and consistency. As for the ranking of solutions, it was analysed and calculated using MARCOS.

The research results were obtained based on the opinions of experts. Therefore, the research findings are contingent upon expert opinions, constituting a limitation of this study. To mitigate this, the research involved the participation of highly experienced experts in completing the questionnaire.

In addition, more than half of the experts involved in completing the questionnaire were Chinese professionals within the ceramic design industry, aged between 34 and 56 years. Of these participants, 72.68% were male, with the remaining identifying as female.

Consequently, the findings of this study hold relevance for China’s ceramic product design sector, offering valuable insights to enhance understanding and alignment with customer preferences. Thus, these insights serve as a crucial reference and guide for the industry to offer good service quality that aligns closely with customer expectations.

6. Conclusions

In this research, an integrated method of FAHP and MARCOS is proposed and applied to assess and calculate the importance of the service quality index and solutions for China’s ceramic design industry. This work makes a scientific contribution by evidencing the effectiveness of the proposed hybrid MCDM method. It shows how the FAHP and MARCOS methods can assist in comprehending the dimensions, indicators and solutions concerning the service quality of China’s ceramic product design industry. Practically, this research suggests that companies involved in China’s ceramic product design industry can employ the decision-making model put forward to better address service quality index and solutions for diminishing risks and enhancing informed decision-making.

The most three important dimensions in the FAHP model were empathy, responsiveness and reliability. Moreover, indicators related to accurately recognising the priority of customer needs, willingness to serve customers and memorising customer needs were among the top three in the FAHP model.

According to the MARCOS model, solutions related to the customers’ potential needs, professional staff and the ability to empathise with the customer are the key points in providing excellent service quality.

Furthermore, the originality of this article lies in the following. (1) This study is the first to consider service quality index and solutions in China’s ceramic product design field under a fuzzy environment. The research can provide valuable insights into the service quality criteria of the ceramic product design industry. (2) Using the merits of both FAHP and MARCOS methods, the proposed integrated method can conveniently express the real condition of the decision-making problem, providing a better representation of experts’ evaluation with simplified calculations. (3) The implementation of sensitivity analysis will allow decision-makers to test the method’s stability, while findings can be effectively adapted to related sectors.

Finally, the integrated operations performed in this study were logically coherent, practical and functional. In addition to establishing a systematic and objective general model of selection in the context of this study and reflecting the characteristics of the conditions to meet practical needs, it can also serve as a reference for future studies in similar fields.

Author Contributions: All authors contributed equally. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. The pairwise comparison matrix for tangibility criteria.

Indicators	A1	A2	A3	ω
A1	1	2	6	0.588
A2	1/2	1	4	0.323
A3	1/6	1/4	1	0.089
		Total		1
	$\lambda_{max} = 3.0092, C.I. = 0.0046, C.R. = 0.0079$			

Table A2. The pairwise comparison matrix for reliability criteria.

Indicators	B1	B2	B3	B4	ω
B1	1	5	4	1/2	0.334
B2	1/5	1	1/4	1/5	0.059
B3	1/4	4	1	1/4	0.133
B4	2	5	4	1	0.473
Total					1
$\lambda_{max} = 4.2338, C.I. = 0.0779, C.R. = 0.0866$					

Table A3. The pairwise comparison matrix for responsiveness criteria.

Indicators	C1	C2	C3	ω
C1	1	4	2	0.558
C2	1/4	1	1/3	0.122
C3	1/2	3	1	0.32
Total				1
$\lambda_{max} = 3.0183, C.I. = 0.0091, C.R. = 0.0158$				

Table A4. The pairwise comparison matrix for assurance criteria.

Indicators	D1	D2	D3	ω
D1	1	1/3	1	0.185
D2	3	1	5	0.659
D3	1	1/5	1	0.156
Total				1
$\lambda_{max} = 3.0291, C.I. = 0.0145, C.R. = 0.0251$				

Table A5. The pairwise comparison matrix for empathy criteria.

Indicators	E1	E2	E3	E4	ω
E1	1	6	8	3	0.589
E2	1/6	1	5	1/3	0.123
E3	1/8	1/5	1	1/4	0.048
E4	1/3	3	4	1	0.24
Total					1
$\lambda_{max} = 4.2446, C.I. = 0.0815, C.R. = 0.0906$					

Table A6. Normalised decision-making matrix of the MARCOS model.

Alternatives	Indicators																
	A1	A2	A3	B1	B2	B3	B4	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4
ALT 1	1.00	1.00	1.00	0.61	0.67	0.63	0.58	0.51	0.32	0.50	0.61	0.68	1.00	0.46	0.40	0.35	0.46
ALT 2	0.45	0.43	0.44	1.00	0.92	1.00	1.00	1.00	1.00	0.93	0.52	1.00	0.76	1.00	1.00	1.00	0.67
ALT 3	0.25	0.25	0.29	0.75	1.00	0.48	0.40	0.42	0.81	1.00	1.00	0.81	0.78	0.79	0.57	0.98	1.00
ALT 4	0.56	0.65	0.54	0.70	0.67	0.47	0.46	0.67	0.79	0.61	0.69	0.64	0.78	0.44	0.40	0.32	0.67
ALT 5	0.33	0.36	0.23	0.73	0.81	0.63	0.73	0.67	0.67	0.45	0.60	0.87	0.79	0.74	0.52	0.48	0.63
ALT 6	0.41	0.40	0.48	1.16	1.28	1.00	1.03	1.75	1.41	1.27	1.32	1.78	1.66	1.06	1.04	1.53	2.43

Table A7. Weighted normalised decision-making matrix of the MARCOS model.

Alternatives	Indicators																
	A1	A2	A3	B1	B2	B3	B4	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4
ALT 1	0.004	0.008	0.028	0.009	0.060	0.025	0.006	0.018	0.052	0.031	0.026	0.009	0.048	0.010	0.040	0.095	0.023
ALT 2	0.002	0.003	0.012	0.015	0.083	0.039	0.011	0.035	0.162	0.058	0.022	0.013	0.036	0.021	0.101	0.269	0.034
ALT 3	0.001	0.002	0.008	0.012	0.090	0.019	0.004	0.015	0.132	0.062	0.043	0.011	0.037	0.016	0.058	0.263	0.050
ALT 4	0.002	0.005	0.015	0.011	0.060	0.018	0.005	0.024	0.129	0.038	0.030	0.008	0.037	0.009	0.040	0.087	0.034
ALT 5	0.001	0.003	0.006	0.011	0.072	0.025	0.008	0.024	0.109	0.028	0.026	0.011	0.038	0.015	0.053	0.129	0.032
ALT 6	0.002	0.003	0.013	0.018	0.115	0.039	0.011	0.062	0.229	0.078	0.057	0.023	0.079	0.022	0.105	0.412	0.122

Table A8. The utility degrees of all alternatives.

Alternatives	Utility Degrees		
	K_i^+	K_i^-	S_i
ALT 1	0.3483	1.1646	0.4922
ALT 2	0.6493	2.1713	0.9175
ALT 3	0.5820	1.9461	0.8224
ALT 4	0.3903	1.3051	0.5515
ALT 5	0.4178	1.3971	0.5904
ALT 6	0.9849	3.2934	1.3917

Table A9. The criteria weights in all scenarios.

Sub-Criteria	Scenarios																	
	Base	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A1	0.004	0.000	0.005	0.006	0.005	0.009	0.006	0.005	0.006	0.014	0.008	0.007	0.005	0.007	0.005	0.010	0.020	0.007
A2	0.008	0.008	0.000	0.009	0.008	0.013	0.010	0.008	0.010	0.017	0.011	0.010	0.008	0.010	0.009	0.014	0.023	0.011
A3	0.028	0.028	0.028	0.000	0.028	0.033	0.030	0.028	0.030	0.037	0.031	0.030	0.028	0.030	0.029	0.034	0.043	0.031
B1	0.015	0.016	0.016	0.017	0.000	0.021	0.018	0.016	0.017	0.025	0.019	0.018	0.016	0.018	0.017	0.021	0.031	0.018
B2	0.090	0.090	0.090	0.091	0.090	0.000	0.092	0.090	0.092	0.099	0.093	0.092	0.090	0.092	0.091	0.095	0.105	0.092
B3	0.039	0.040	0.040	0.041	0.040	0.045	0.000	0.040	0.042	0.049	0.043	0.042	0.040	0.042	0.041	0.045	0.055	0.042
B4	0.011	0.011	0.011	0.013	0.012	0.016	0.013	0.000	0.013	0.021	0.015	0.014	0.012	0.014	0.012	0.017	0.027	0.014
C1	0.035	0.036	0.036	0.037	0.036	0.041	0.038	0.036	0.000	0.045	0.039	0.038	0.036	0.038	0.037	0.041	0.051	0.038
C2	0.162	0.163	0.163	0.164	0.163	0.168	0.165	0.163	0.165	0.000	0.166	0.165	0.163	0.165	0.164	0.168	0.178	0.165
C3	0.062	0.062	0.062	0.064	0.063	0.067	0.064	0.063	0.064	0.072	0.000	0.065	0.063	0.065	0.063	0.068	0.078	0.065
D1	0.043	0.044	0.044	0.045	0.044	0.049	0.046	0.044	0.045	0.053	0.047	0.000	0.044	0.046	0.045	0.049	0.059	0.046
D2	0.013	0.013	0.014	0.015	0.014	0.018	0.015	0.014	0.015	0.023	0.017	0.016	0.000	0.016	0.014	0.019	0.029	0.016
D3	0.048	0.048	0.048	0.049	0.049	0.053	0.050	0.048	0.050	0.057	0.051	0.050	0.048	0.000	0.049	0.054	0.063	0.051
E1	0.021	0.021	0.021	0.022	0.022	0.026	0.023	0.021	0.023	0.030	0.024	0.023	0.021	0.024	0.000	0.027	0.037	0.024
E2	0.101	0.102	0.102	0.103	0.102	0.107	0.104	0.102	0.103	0.111	0.105	0.104	0.102	0.104	0.103	0.000	0.117	0.104
E3	0.269	0.269	0.269	0.271	0.270	0.274	0.271	0.270	0.271	0.279	0.273	0.272	0.270	0.272	0.270	0.275	0.000	0.272
E4	0.050	0.051	0.051	0.052	0.051	0.056	0.053	0.051	0.052	0.060	0.054	0.053	0.051	0.053	0.051	0.056	0.066	0.000

Table A10. The prospect value of alternatives in all scenarios.

Sub-Criteria	Scenarios																	
	Base	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ALT 1	5.156	5.145	5.136	5.080	5.189	5.378	5.193	5.159	5.131	5.088	5.191	5.194	5.170	5.228	5.178	5.240	4.966	5.082
ALT 2	6.464	6.461	6.459	6.439	6.493	6.724	6.478	6.457	6.407	6.108	6.453	6.552	6.480	6.651	6.461	6.399	5.838	6.406
ALT 3	6.171	6.169	6.168	6.150	6.205	6.352	6.234	6.181	6.164	5.849	6.117	6.168	6.188	6.322	6.173	6.203	5.456	6.031
ALT 4	5.338	5.333	5.326	5.297	5.366	5.557	5.390	5.344	5.291	5.003	5.344	5.360	5.353	5.447	5.359	5.407	5.135	5.227
ALT 5	5.458	5.455	5.453	5.444	5.485	5.643	5.491	5.454	5.412	5.188	5.499	5.495	5.464	5.569	5.459	5.489	5.126	5.357
ALT 6	7.921	7.922	7.923	7.910	7.970	8.256	7.988	7.926	7.826	7.515	7.924	7.962	7.931	8.077	7.941	7.956	7.119	7.656

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