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Ranking of Service Quality Index and Solutions for Online English Teaching in the Post-COVID-19 Crisis

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Abstract: Online English teaching remains prevalent post-pandemic, yet there is a significant research gap in assessing service quality during this period. Thus, this study employs a hybrid FANP and GRA method to evaluate critical factors sustaining high service quality in online English teaching in the post-coronavirus era. The FANP model highlights key contributors like professional employees, trustworthy staff, flexible transaction times, and a secure transaction environment. In contrast, GRA identifies personnel quality, responsiveness to customer needs, and a secure transaction mechanism as top factors. Individual customer needs and service facilities are of less importance in both models. This study's primary contribution is proposing an integrated FANP and GRA approach to rank potential solutions for online English teaching service quality in the post-COVID-19 fuzzy context. The findings guide the online English teaching industry in maintaining service quality in future similar scenarios.

Keywords: online English teaching; service quality; fuzzy analytic network process (FANP); grey rational analysis (GRA); multi-criteria decision-making (MCDM)

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1. Introduction

1.1. Research Background

The COVID-19 pandemic has had an impact on the education industry; in particular, the lockdown has resulted in the inability of people to move, thus changing the learning method from traditional face-to-face learning to online learning [1]. Meanwhile, scholars such as Ria [2] and Sarnoto et al. [3] mentioned that online learning is an effective way to deal with the challenges of the epidemic in developing countries. Aso, la Velle et al. [4] mentioned that learning disruption is the biggest challenge during the COVID-19 pandemic. Therefore, they proposed a new online learning framework to reduce the impact of learning interruptions. Hoofman et al. [5] reported that online learning has become normal due to the COVID-19 lockdown. Hazaymeh [6] pointed out that over 88% of students had a positive perception of online learning. Dhawan [7] proposed an importance analysis model for e-learning in India. Agarwal et al. [8] investigated the effectiveness of online learning from the perspective of students. They discovered that online learning was enjoyable and helpful during the period of the COVID-19 pandemic. Interestingly, some researchers [9–11] reported similar research results, demonstrating that online educational methods were effective in response to the development of the COVID-19 epidemic. Moreover, Ibrahim et al. [12] proposed a case study of online foreign language learning from the perspective of Russian students. They found that these characteristics of usefulness, comfort, and acceptability were important factors for students in the digital learning environment. Laili et al. [13] argued that applications of online learning should be easy to access, motivating, and in the form of a combination among various online learning media for providing the best way during the process of teaching and learning. Rifiyanti [14] indicated that shifting to online learning, particularly for English classes, was also an effective way during the pandemic. Almusharraf et al. [15] revealed that students were satisfied with the online learning environment during the pandemic. Furthermore, some researchers [16–18] provided advice on online education strategies and useful tools for teachers during this period.

1.2. Motivation

In addition, some scholars [19–22] paid attention to the trend of online English education in the post-coronavirus era. Among them, Younesi et al. [20] reported a case study of online language teaching in India in the post-COVID-19 era. Likewise, Kaoud et al. [21] investigated the perceptions of Egyptian universities' students toward online English learning.

Interestingly, much research [23–27] mentioned that the service quality of online education was a major research need during the post-coronavirus era. Among them, Camilleri [23] proposed a systematic review of service quality measurement for online education in 2021. His research work was the first study related to service quality measurement in the post-epidemic era. Lin et al. [24] reported that service quality is the key factor in EFL students' learning performance for the online educational industry in the post-coronavirus crisis. Additionally, some studies [25–27] reported that service quality assessment is also a research need for the blended educational industry during the post-COVID-19 era.

Despite this, the related research of service quality for online English teaching industry using SERVQUAL scale is insufficient in the post coronavirus era. Accordingly, the evaluation of service quality for online English teaching industry is needed for providing decision-making suggestions for online English industry in similar scenario in the future.

1.3. Objectives

In view of this, this research will establish a framework based on the SERVQUAL scale for measuring the quality of online English teaching services through expert questionnaires. Afterwards, a fuzzy analytic network process (FANP) will be implemented to calculate the weights of dimensions and indicators. Finally, gray rational analysis (GRA) will be applied to rank all alternatives, thereby achieving the following research purposes:

1. To construct the evaluation structure based on the SERVQUAL scale for the online English teaching service quality;
2. To integrate expert consensus for analyzing the weight of dimensions and indicators for online English teaching service quality using FANP;
3. To evaluate and rank alternatives to online English teaching service quality by applying GRA;
4. To provide suggestions for the online English teaching industry to maintain good service quality in similar scenarios in the future based on the research findings.

2. Literature Review

2.1. SERVQUAL Scale

The SERVQUAL scale is a multi-item scale for service quality measurement that evolved from the conceptual model of service quality proposed by Parasuraman et al. [28] in 1985. Meanwhile, it has also been verified by many scholars to summarize five main aspects and 22 evaluation indicators and has become the most widely known service quality measurement method [29–31]. The five main dimensions are 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

Meanwhile, Arambewela et al. [32] proposed a case study of higher educational service quality assessment in Australia based on the SERVQUAL scale. Stodnick et al. [33] mentioned that the SERVQUAL scale is superior to the traditional evaluation scales. It can effectively evaluate the quality of educational services and has positive advantages for the measurement of service quality in the education industry. Yousapronpaiboon et al. [34] applied the SERVQUAL scale to investigate the service quality of private higher education institutions in Thailand. This study found that the five major aspects of the SERVQUAL scale can effectively express Thai consumers' expectations for higher education service quality.

Also, Aboubakr et al. [35] proposed a case study of educational service quality among dentistry and nursing students in the post-COVID-19 era. Lizarelli et al. [36] proposed a hybrid model of SERVQUAL scale and fuzzy approaches for educational service quality assessment in the post-coronavirus crisis period.

Moreover, some studies [37–42] have pointed out that a hybrid method of SERVQUAL and multi-criteria decision-making (MCDM) techniques can effectively examine service quality.

The above research results revealed the feasibility of applying the SERVQUAL scale to service quality assessment in the education field and integrating it with other MCDM methods. Accordingly, this research will integrate the SERVQUAL scale with FANP and GRA to assess customer needs in the post-COVID-19 period and provide a decision-making basis for online English teaching practitioners.

2.2. Fuzzy Analytic Network Process Model

The Analytic Network Process (ANP) proposed by Saaty [43] in 1996 has been confirmed by many studies and recognized as one of the most complete MCDM research methods nowadays [44–50]. Meanwhile, ANP is well suited to solve problems with special structures between identified nonlinear links.

Unfortunately, ANP does not provide a good explanation for problems involving uncertain phenomena. Therefore, it is necessary to introduce fuzzy approaches.

Fuzzy theory, first proposed by Dr. Lotfi Zadeh in 1965 [51]. It is a method to describe the fuzzy phenomenon of human psychology using mathematical language [52]. Since the variables of human psychological perception are often difficult to accurately estimate, the use of fuzzy theory can make the statistical results closer to the perceived state of human psychology [53].

Also, Kahraman et al. [54] considered that a relatively new research approach is needed in the face of decision analysis problems raised by imprecise variables of psychological perception. Therefore, an integrated approach consisting of fuzzy theory and ANP, called Fuzzy ANP (FANP), was proposed to deal with decision-making problems related to such imprecise psycho-perceptual variables [54].

For decades, FANP has been widely used in the research field of MCDM problems and has proven to be a highly reliable and valid research method for MCDM problems. For example, Lupo [55] proposed an integrated framework of fuzzy logic and ANP to measure the service quality of the healthcare industry. Chang et al. [56] and Ozdemir et al. [57] applied FANP to the e-book and aircraft industries for aircraft selection and business strategy formulation. In addition, Parameshwaran et al. [58] proposed a framework for product development factor evaluation in a fuzzy environment. Lin et al. [59] proposed a hybrid fuzzy approach for the service quality evaluation of the blended design teaching industry. Their research results demonstrated the feasibility of applying fuzzy methods to the industries of product development and education. Moreover, it was a major inspiration for this study's application of the FANP method to the measurement of service quality in the online English teaching industry.

2.3. Grey Rational Analysis

Grey Rational Analysis (GRA) was proposed by Deng [60]. This method is mainly aimed at system models with uncertainty or incomplete information. It can effectively deal with uncertainty, multivariate input information, or discrete data through the use of system correlation analysis, model building, prediction, and decision-making methods [61]. Such properties make the GRA a suitable method for solving multi-attribute and multi-scenario MCDM problems [62–65].

In the meantime, many scholars [66–69] combined the GRA with other MCDM research methods (such as AHP and ANP) to deal with multi-domain MCDM problems. Also, some researchers [70,71] also point to the mixed use of FAHP, FANP, and GRA to evaluate energy storage and ERP.

Moreover, some scholars [72–74] applied GRA to research works in education-related fields before and after the COVID-19 pandemic. For example, Ertugrul et al. [72] presented a case study in 2016, applying the GRA to assess the academic performance of Turkish higher education institutions. Zhang et al. [73] proposed an algorithm for teaching evaluation based on GRA in the post-coronavirus era. Similarly, Wan et al. [74] proposed a study of the service quality evaluation for online art education based on FANP and GRA in the post-COVID-19 era.

2.4. Summary

According to the chapter of the literature review, it is known that FANP and GRA are effective techniques for solving MCDM problems in many fields. Meanwhile, the integrated approaches of FANP and GRA contribute to interdisciplinary research. However, the evaluation criteria for each alternative are obtained by integrating expert opinions into the FANP model. Therefore, the disadvantage of such models is that they rely on expert experience and are prone to subjective opinions.

With this perspective, some scholars [75,76] have advocated the use of GRA to rank all alternatives in the later stages of such research, thus mitigating any potential bias introduced by expert subjectivity.

Hence, this study will be grounded in the SERVQUAL scale to construct a framework for evaluating the service quality of online English teaching through expert interviews. Subsequently, FANP will be employed to determine the weights of dimensions and indicators. Finally, GRA will be applied to compute gray rational grades (GRGs) to identify potential optimal solutions that align with our primary research objectives using this integrated approach.

3. Materials and Methods

In this paper, an integrated method of FANP and GRA based on the SERVQUAL scale was proposed for the service quality estimation of online English teaching in the post-COVID-19 era. The research process is shown in Figure 1.

3.1. The Establishment of Hierarchy and Network Structure

Firstly, this study decomposed the research problem into dimensions, indicators, and alternatives based on the ANP and SERVQUAL scales. Then, a hierarchical structure was established by grouping them to discover the relationship between indicators. Meanwhile, Tsai et al. [77] suggested that the content used for evaluation should be revised through expert discussion. Therefore, expert questionnaires were utilized to gather the opinions of experts in this research. Afterwards, dimensions, indicators, and alternatives were revised according to the suggestions of all experts, thereby making the description and semantics of dimensions, indicators, and alternatives conform to the particularity of online English teaching in the post-coronavirus era.

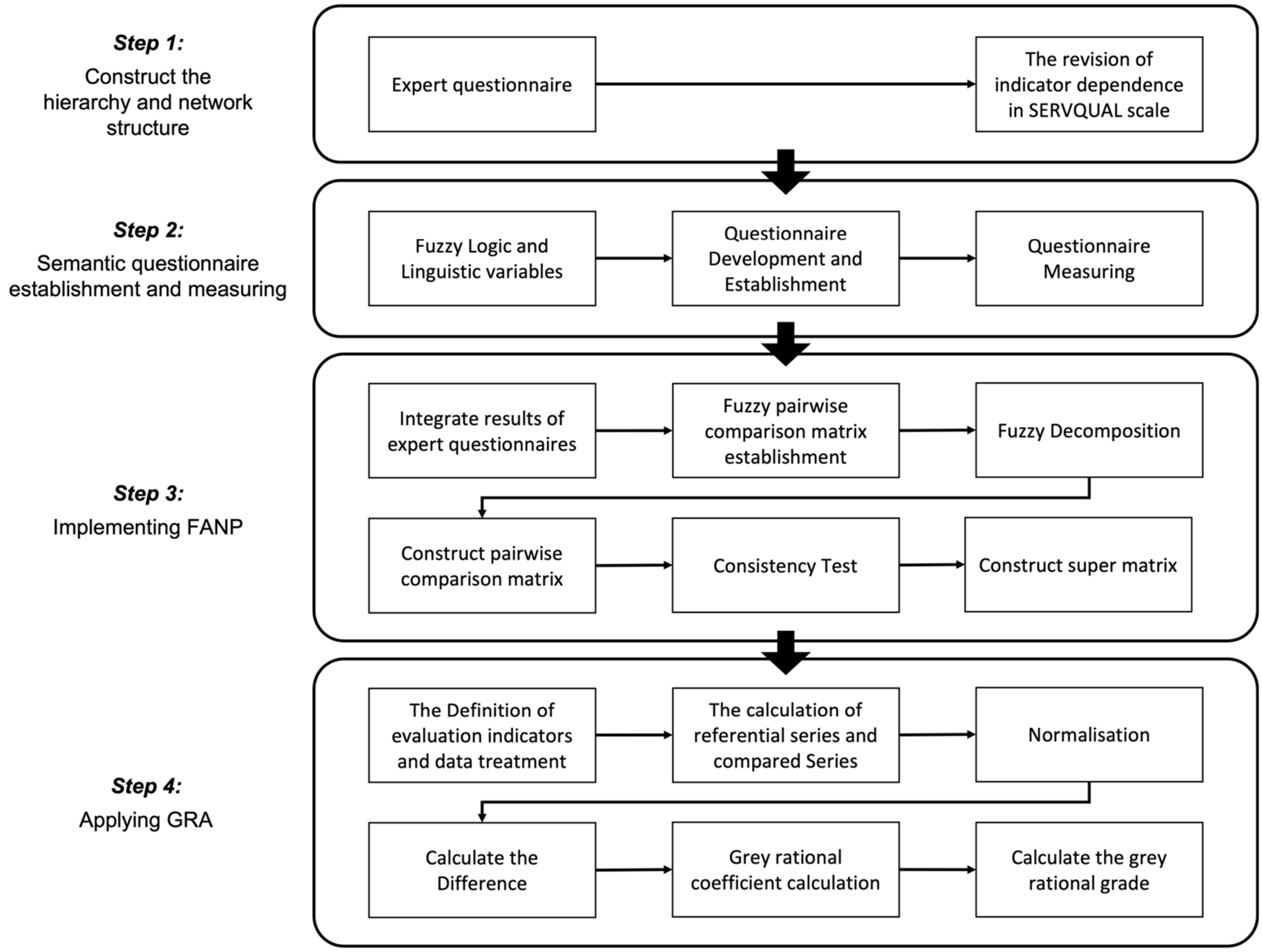

Figure 1. The research process of this study.

3.2. Fuzzy Logic and Linguistic Variables

Linguistic variables, such as "Very important", "Somewhat important", and "Unimportant", are seen as useful tools for service quality evaluation and measurement [78]. However, such linguistic variables indicating importance are often ambiguous. Thus, fuzzy logic is a useful method for clarifying mental perception when the state of human mental perception is unclear [79].

Fuzzy logic was proposed by Zadeh in 1975 [80]. It is an algorithm with fuzzy numbers that introduces a similar concept of reasoning to find the result that is closest to the variable of human psychological perception, further improving the content of fuzzy theory.

In view of this, fuzzy numbers were studied, and it was discovered that fuzzy numbers are generally expressed in mathematical ways [81–88]. For example, the triangular fuzzy number A (L, M, U) given by the following equation is shown in Figure 2.

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-L}{M-L} & , \quad L \le x \le M \\ \frac{x-U}{M-U} & , \quad M \le x \le U \\ 0 & , \quad \text{otherwise} \end{cases} \tag{1}$$

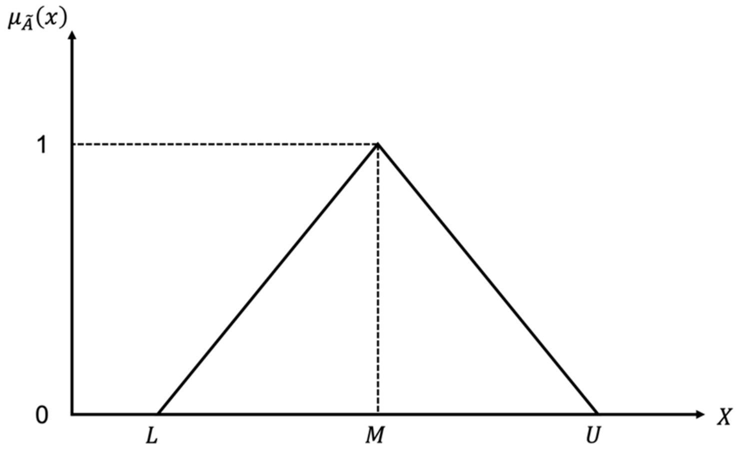

Figure 2. Fuzzy triangular number.

In the meantime, much research [81–88] has reported 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:

$$A_a = [L^a, M^a] = [(M - L)a - (U - M)a + U] \quad (2)$$

Also, Buckley [89] reported that triangular fuzzy numbers transform fuzzy language into practical numbers and accurately measure psychological perception. Moreover, Pedrycz [90] proved that triangular fuzzy numbers are suitable for representing the relative judgment strengths of criteria and alternatives in a hierarchy.

Accordingly, triangular fuzzy numbers are used to express linguistic variables in this research. Moreover, Saaty [91] proposed a 9-point evaluation scale for ANP. Therefore, we combine the two to assess the true human preference for options. The corresponding fuzzy numbers are provided in Table 2.

Table 2. Fuzzy numbers and scales.

Triangular Fuzzy Number	Linguistic Variables
$\tilde{1}$ = (1,1,1)	Equally Preferred
$\tilde{2}$ = (1,2,3)	Intermediate
$\tilde{3}$ = (2,3,4)	Moderately Preferred
$\tilde{4}$ = (3,4,5)	Intermediate
$\tilde{5}$ = (4,5,6)	Strongly Preferred
$\tilde{6}$ = (5,6,7)	Intermediate
$\tilde{7}$ = (6,7,8)	Very Strongly Preferred
$\tilde{8}$ = (7,8,9)	Intermediate
$\tilde{9}$ = (9,9,9)	Extremely Preferred

3.3. Questionnaire Development and Establishment

As for the questionnaire development, it is necessary to consider the validity of the questionnaire before questionnaire measurement. Based on expert advice, this study revises the questionnaire description on the premise of retaining the original semantics for dimensions and indicators in the SERVQUAL scale, thereby maintaining the high efficiency of the questionnaire content [92]. Then, a pre-test is conducted to understand whether the meaning of the questionnaire is clear. Afterwards, the statement of questionnaires is revised according to the results of the pre-test. Finally, this study uses the expert questionnaire method to assess the weight of dimensions and indicators for online English teaching service quality in the post-COVID-19 era according to the FANP method.

As for the number of expert questionnaires, F. J. Parenté and J. K. Anderson-Parenté [93] suggested that there should be at least ten or more experts. Interestingly, we found that much research [94–103] used a small sample size of four to nine to obtain a valuable decision-making basis. In the meantime, Darko et al. [104] reported that a large sample size may not be helpful due to "cold-called" experts, which could profoundly affect the result of the consistency assessment.

In view of this, a total of 20 experts in online English teaching are selected by this research as the survey objects, thereby avoiding the influence of opinions from "cold-called" experts on the consistency evaluation results to achieve our main research objectives.

3.4. Fuzzy Analytic Network Process

3.4.1. Synthesize Opinions of All Experts

In this paper, the method of geometric mean is utilizes to generalize the results of expert questionnaires, largely because Saaty [105] considered that the geometric mean method is not easily affected by extreme values. Therefore, the consolidation result of all expert opinions is calculated by the following equation:

$$\left(\prod_{i=1}^{n} x_i\right)^{\frac{1}{n}} = \sqrt[n]{x_1 x_2 \dots x_n}, \tag{3}$$

where

n is the number of experts.

3.4.2. Set up the Fuzzy Pairwise Comparison Matrix

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

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

where

$\tilde{A}^k$ represents the fuzzy pairwise comparison matrix.

$\tilde{a}^k_{nn}$ is triangular fuzzy mean value for comparing priority pairs among elements.

3.4.3. Fuzzy Decomposition

As for fuzzy decomposition, the process of defuzzification is presented as follows [106–108]:

$$t_{\alpha,\beta}(\bar{a}_{ij}) = \left[\beta f_a(L_{ij}) + (1-\beta) f_a(U_{ij})\right], \alpha \in [0,1],\ \beta \in [0,1], \tag{5}$$

where

$$f_a(L_{ij}) = (M_{ij} - L_{ij})\alpha + L_{ij}, \tag{6}$$

$$f_a(U_{ij}) = U_{ij} - (M_{ij} - L_{ij})\alpha, \tag{7}$$

where

L_{ij} is the lower bound value of the triangular fuzzy number.
M_{ij} represents the median value of the triangular fuzzy number.
U_{ij} is the upper bound value of the triangular fuzzy number.

When the diagonal matrix is matching, we have

$$t_{\alpha,\beta}(\bar{a}_{ij}) = \frac{1}{t_{\alpha,\beta}(\bar{a}_{ij})}, \alpha \in [0,1],\ \beta \in [0,1], i > j \tag{8}$$

3.4.4. Set up the De-Fuzzified Pairwise Comparison Matrix

After the process of fuzzy decomposition. The de-fuzzified pairwise comparison matrix is expressed as follows:

$$A = (a_{ij})_{n\times n} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{9}$$

3.4.5. Consistency Test

The consistency index (*C.I.*) and consistency ratio (*C.R.*) were proposed by Saaty [109] to assess the consistency of the comparison matrix. The *C.I.* and *C.R.* are calculated as follows:

$$C.I. = \frac{\lambda max - n}{n-1}, \tag{10}$$

where

λmax is the maximum value of the matrix,

n is the number of indicators.

When checking the consistency ratio (*C.R.*), it must first find the consistency index (*C.I.*). The consistency index is defined as follows:

$$C.R. = \frac{C.I.}{R.I.}, \tag{11}$$

where

C.I. is the consistency index.

R.I. represents the random index.

The random index (*R.I.*) is a consistency index that produced by positive reciprocal matrices of different orders. Table 3 shows values of random index. As suggested by Saaty [109], 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.

Table 3. Random indexes (*R.I.*).

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

3.4.6. The Super Matrix Construction

After completing the above steps, the super matrix is formed as follows:

$$W_N = \begin{bmatrix} 0 & 0 & 0 \\ w_1 & W_3 & 0 \\ 0 & W_2 & W_4 \end{bmatrix}, \tag{12}$$

where

W_N represents the weight of indicators in the super matrix.

w_1 is the vector of the feature.

W_2 means the vector of the criterion.

W_3 represents the dependency of dimensions.

W_4 is the dependency of criteria.

Afterwards, the weight of indicators in the super matrix (W_N) is calculated as follows:

$$\left.\begin{array}{r} W_3 \times w_1 = W_c \\ W_4 \times W_2 = W_e \end{array}\right\rangle \Rightarrow W_e \times W_c = W_N, \tag{13}$$

where

W_C is the weight matrix of main criteria considering the interdependence degree.

W_e is the evaluation weight matrix of indicators considering the interdependence degree.

3.5. Grey Rational Analysis

3.5.1. The Definition of Evaluation Indicators and Data Treatment

Firstly, the five alternatives in the study correspond to the 18 indicators of the SERVQUAL scale. Then, the direct evaluation (with a rating from 1 to 9, with the higher value indicating better ability) is implemented for the assessment. Afterwards, the experts score the 18 indicators and take the average as the score of the five alternatives.

3.5.2. The Calculation of Referential Series and Compared Series

Firstly, the referential series (x_0) with the number of indicators (n) is defined as follows:

$$x_0 = (x_0(1), x_0(2), \ldots, x_0(n)) \tag{14}$$

Then, the compared series (x_i) is defined as follows:

$$x_i = (x_i(1), x_i(2), \ldots, x_i(n)), \ \ i = 1, 2, \ldots, m \tag{15}$$

3.5.3. Normalization

Afterwards the data of referential series and compared series should be normalized, thereby making them comparable.

In this research, scores of all criteria are larger-the-better. Thus, the process of normalisation for referential series and compared series is expressed as follows [110]:

$$x_i^*(k) = \frac{x_i(k) - \underset{k}{\min} x_i(k)}{\underset{k}{\max} x_i(k) - \underset{k}{\min} x_i(k)}, \tag{16}$$

where

$\underset{k}{\max} x_i(k)$ is the maximum value of k indicator.

$\underset{k}{\min} x_i(k)$ represents the minimum value of k indicator.

3.5.4. Calculate the Difference between Referential Series and Compared Series

The series difference is calculated as follows:

$$\Delta_{0i}(k) = |x_0(k) - x_i(k)|, \ \ k = 1, 2, \ldots, 18, \tag{17}$$

where

$x_0(k)$ is the referential series of 18 evaluation indicators.

$x_i(k)$ represents the compared series of 18 evaluation indicators.

3.5.5. Calculate the Gray Rational Coefficient

The gray relational coefficient between the compared series (x_i) and the referential series (x_0) at the jth indicator is defined as follows:

$$\gamma_{0i}(k) = \frac{\Delta\text{min} + \zeta\Delta\text{max}}{\Delta_{0i}(k) + \zeta\Delta\text{max}} \tag{18}$$

3.5.6. The Calculation the Gray Rational Grade

The gray rational grade (GRG) of a series (x_i) is calculated as follows:

$$\Gamma_{0i} = \sum_{k=1}^{n} \omega_k \gamma_{0i}(k) \tag{19}$$

Finally, the alternatives are prioritised based on the magnitude of GRG values (Γ_{0i}). The alternative with the largest GRG value represents the best alternative and so on.

4. Result

4.1. The Construction of Hierarchy and Network Structure

This research engaged ten experts in online English teaching, comprising four senior industry managers and six senior online English instructors, to review and refine dimensions, indicators, and alternatives. Subsequently, ten expert consultation questionnaires were administered to these experts to check the clarity of indicators within the SERVQUAL scale, yielding ten valid responses. Based on these inputs, a questionnaire assessing the quality of online English teaching services was developed.

Despite the questionnaire's creation, a pre-test was conducted with ten additional experts to assess its semantic clarity. For example, the dimension of tangibility in the SERVQUAL scale originally refers to the material conditions such as the equipment, the personnel, or the appearance of the service provider. In the meantime, most experts argue that the tangibility dimensions represent the material conditions possessed by service providers in the post-epidemic era. Thus, they recommended retaining tangibility to evaluate whether the material conditions possessed by service providers will affect the service quality of online English education service providers in the post-epidemic era.

In terms of indicators, A2, for example, refers to the various equipment owned by online English language learning service providers that can be used by service providers and consumers. Meanwhile, all experts believed that online English teaching services involved online transactions of money or services. Therefore, experts recommend adding security-related descriptions to the D1 statement. Also, experts suggest that customized service delivery times should be provided in the indicators to meet customer needs. Therefore, this study modified the indicator description of E1 based on the experts' suggestions.

Then, another ten experts revised the statements and added auxiliary descriptions to the semantics of the questionnaires based on the results of the pre-test survey. Afterwards, the evaluation structure of online English teaching service quality based on the SERVQUAL scale, including 5 main dimensions, 18 indicators, and 5 alternatives, was constructed and shown in Figure 3.

In addition, this study collected expert opinions on the interrelationships among various indicators through relevant questionnaires. While most expert-approved correlations confirm the interdependence of indicators, there is a chance that some correlated indicators might be overlooked. Conversely, this study could select indicators with low expert recognition, but this would significantly increase the interdependence among indicators, resulting in a larger number of questions in the comparison questionnaire. For instance, if more than six experts reach a consensus on the interdependence of indicators, the questionnaire would contain over 50 questions.

In light of this, the researchers have chosen to require the approval of over nine out of ten experts to prevent excessive questionnaire length. This approach allows the network relationships among indicators to be preserved, signifying that the majority of experts determine the interdependency of all indicators. For instance, if more than nine out of ten experts concur that indicator B1 impacts A1, it indicates a relationship between the two indicators, B1 and A1.

Finally, this research has condensed the viewpoints of all experts into a hierarchical and networked structure for evaluating the service quality of online English teaching in the post-COVID-19 era, as depicted in Figure 4.

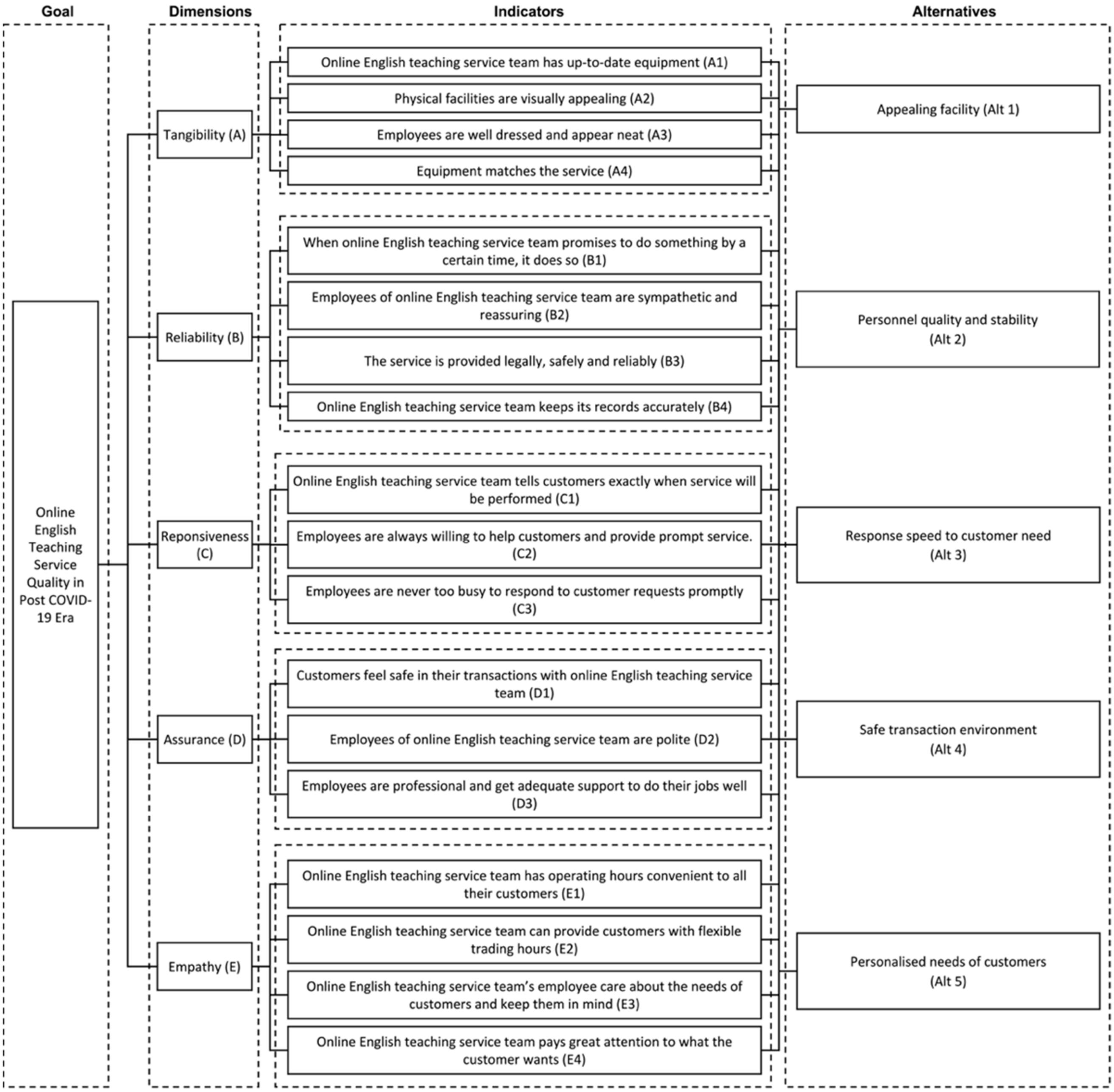

Figure 3. The evaluation structure of online English teaching service quality.

4.2. Questionnaire Establishment and Measurement

After the hierarchy and network structure were obtained, we inputted the associated evaluation indicators in the hierarchy and network structure into the Super Decision software to create a pairwise comparison questionnaire on a nine-point evaluation scale. The results of pairwise comparison questionnaires were integrated using Equation (3) and analyzed by fuzzy ANP. Meanwhile, this study established a direct rating scale questionnaire with five alternatives. The results of direct rating scale questionnaires were analyzed using GRA.

Then, in this study, a total of 24 expert questionnaires were sent to the online English teaching experts from 10 March 2022 to 31 May 2022. Subsequently, a total of 20 valid questionnaires were recovered, including 10 valid pairwise comparison questionnaires and 10 valid direct rating scale questionnaires.

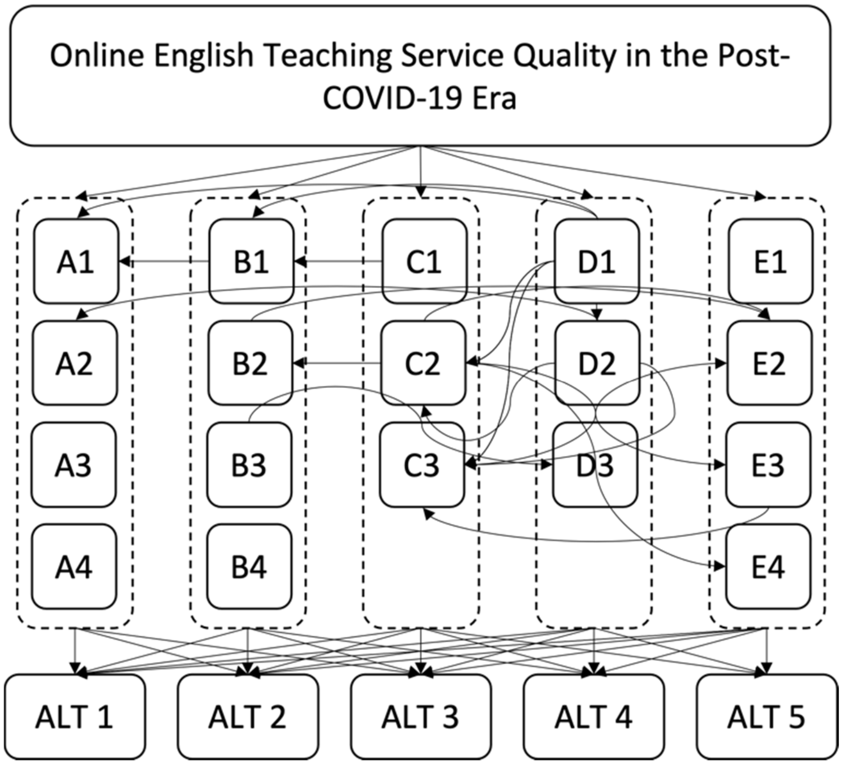

Figure 4. The hierarchy and network structure of this research.

4.3. Numerical Analysis

4.3.1. Fuzzy Analytic Network Process Model

After collecting valid expert questionnaires, Equation (3) was used to integrate experts' opinions. Afterwards, the fuzzy pairwise comparison matrix for all criteria from the FANP model was established.

Table 4 demonstrates the fuzzy pairwise comparison matrix for five dimensions.

Table 4. The fuzzy pairwise comparison matrix for five dimensions from the FANP model.

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

Afterwards, $\alpha = 0.5$ and $\beta = 0.5$ are used during the defuzzification [111–113]. The process of fuzzy decomposition for dimensions between tangibility (A) and reliability (B) is as follows:

$$t_{0.5,0.5}(\overline{a_{A,B}}) = [0.5 \times 4.5 + (1 - 0.5) \times 3.5] = 4$$

$$f_a(L_{A,B}) = (4 - 3) \times 0.5 + 3 = 3.5$$

$$f_a(U_{A,B}) = 5 - (4 - 3) \times 0.5 = 4.5$$

$$t_{0.5,0.5}(\overline{a_{B,A}}) = \frac{1}{4}$$

The remaining process of fuzzy decomposition for other dimensions is similar to the above calculation. The de-fuzzified pairwise comparison matrix for five dimensions from the FANP model is shown in Table 5.

Table 5. The de-fuzzified pairwise comparison matrix for five dimensions from the FANP model.

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

The calculation of the maximum individual value for each dimension (AM) is shown in Table 6.

Table 6. The maximum individual value calculation.

Dimensions	Maximum Individual Value (AM)
Tangibility (A)	$\left(1 \times 4 \times 4 \times 4 \times \frac{1}{2}\right)^{\frac{1}{5}} = 2$
Reliability (B)	$\left(\frac{1}{4} \times 1 \times \frac{1}{4} \times \frac{1}{2} \times \frac{1}{4}\right)^{\frac{1}{5}} = 0.3789$
Responsiveness (C)	$\left(\frac{1}{4} \times 4 \times 1 \times 3 \times \frac{1}{2}\right)^{\frac{1}{5}} = 1.0845$
Assurance (D)	$\left(\frac{1}{4} \times 2 \times \frac{1}{3} \times 1 \times \frac{1}{4}\right)^{\frac{1}{5}} = 0.5296$
Empathy (E)	$(2 \times 4 \times 2 \times 4 \times 1)^{\frac{1}{5}} = 2.2974$
$\sum AM = 2 + 0.3789 + 1.0845 + 0.5296 + 2.2974 = 6.2904$	

The calculation of weight (ω) for each dimension is shown in Table 7.

Table 7. The calculation of weight for five dimensions.

Dimensions	The Calculation of Weight (ω)
Tangibility (A)	$\frac{2}{6.2904} = 0.3179$
Reliability (B)	$\frac{0.3789}{6.2904} = 0.0602$
Responsiveness (C)	$\frac{1.0845}{6.2904} = 0.1724$
Assurance (D)	$\frac{0.0842}{6.2904} = 0.0842$
Empathy (E)	$\frac{2.2974}{6.2904} = 0.3652$

The calculation of the normalized matrix is shown in Table 8.

Table 8. Normalized matrix calculation.

Dimensions	Tangibility (A)	Reliability (B)	Responsiveness (C)	Assurance (D)	Empathy (E)
Tangibility (A)	1×0.3179	4×0.0602	4×0.1724	4×0.0842	$1/2 \times 0.3652$
Reliability (B)	$1/4 \times 0.3179$	1×0.0602	$1/4 \times 0.1724$	$1/2 \times 0.0842$	$1/4 \times 0.3652$
Responsiveness (C)	$1/4 \times 0.3179$	4×0.0602	1×0.1724	3×0.0842	$1/2 \times 0.3652$
Assurance (D)	$1/4 \times 0.3179$	2×0.0602	$1/3 \times 0.1724$	1×0.0842	$1/4 \times 0.3652$
Empathy (E)	2×0.3179	4×0.0602	2×0.1724	4×0.0824	1×0.3652

The calculation of maximum eigenvector (W_1) and eigenvalue (λmax) is shown in Table 9.

Table 9. The calculation of maximum eigenvector and eigenvalue for five dimensions.

	A	**B**	**C**	**D**	**E**	**Total**	ω	W_1
A	0.3179	0.2410	0.6896	0.3368	0.1826	1.7679	0.3179	1.7679/0.3179 = 5.5604
B	0.0795	0.0602	0.0431	0.0421	0.0913	0.3162	0.0602	0.3162/0.0602 = 5.2495
C	0.0795	0.2410	0.1724	0.2526	0.1826	0.928	0.1724	0.928/0.1724 = 5.383
D	0.0795	0.1205	0.0575	0.0842	0.0913	0.4329	0.0842	0.4329/0.0842 = 5.1421
E	0.6359	0.2410	0.3448	0.3368	0.3652	1.9236	0.3652	1.9236/0.3652 = 5.2671
$\sum W_1 = 5.4658 + 5.2462 + 5.5111 + 5.1452 + 5.2338 = 26.6021$								
$\lambda max = 26.6021/5 = 5.3204$								

Since numbers of dimensions are 5, we obtain n = 5; *C.I.* is calculated as follows:

$$C.I. = \frac{\lambda max - n}{n-1} = \frac{5.3204}{5-1} = 0.0801$$

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

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.0801}{1.12} = 0.0715$$

The final calculation result of de-fuzzified pairwise comparison matrix between five dimensions is shown in Table 10.

Table 10. The pairwise comparison matrix of five dimensions from FANP model.

Dimensions	**Tangibility (A)**	**Reliability (B)**	**Responsiveness (C)**	**Assurance (D)**	**Empathy (E)**	**Weights**
Tangibility (A)	1	1/4	1/4	1/4	2	0.0783
Reliability (B)	4	1	4	2	4	0.4133
Responsiveness (C)	4	1/4	1	1/3	2	0.1444
Assurance (D)	4	1/2	3	4	3	0.2957
Empathy (E)	1/2	1/4	1/2	1/4	1	0.0682
Total						1
C.I. = 0.0801, *C.R.* = 0.0715						

The calculation method of the de-fuzzified pairwise comparison matrix for the remaining dimensions and indicators is analogous to the above calculation method. Finally, *C.I.* and *C.R.* values for the remaining dimensions and indicators are shown in Table 11

Table 11. *C.I.* and *C.R.* values for remaining dimensions and indicators.

	Compare Respect to	**Group**	**Pairwise Comparison**	***C.I.***	***C.R.***
Dimensions	B		A and D, A and E, D and E	0.0429	0.0739
	C		B and E	0.0000	0.0000
	D		A and B, A and C, A and D, B and C, B and D, C and D	0.054	0.0601
Indicators	Goal	A	A1 and A2, A1 and A3, A1 and A4, A2 and A3, A2 and A4, A3 and A4	0.0069	0.0076
		B	B1 and B2, B1 and B3, B1 and B4, B2 and B3, B2 and B4, B3 and B4	0.0262	0.0292
		C	C1 and C2, C1 and C3, C2 and C3	0.0046	0.0079
		D	D1 and D2, D1 and D3, D2 and D3	0.0091	0.0158
		E	E1 and E2, E1 and E3, E1 and E4, E2 and E3, E2 and E4, E3 and E4	0.0201	0.0224
	C2	E	E2 and E3, E2 and E4, E3 and E4	0.0368	0.0634
	D1	C	C2 and C3	0.0000	0.0000
	D2	C	C2 and C3	0.0000	0.0000

Since both *C.I.* and *C.R.* are less than 0.1, the result of the consistency tests is acceptable.

After passing the consistency test, the super matrix is calculated using Super Decision software. The value of each column in the limit super matrix is the weight of each indicator, as shown in Table 12.

Table 12. The super matrix of experts' opinions.

Dimensions		**Tangibility**				**Reliability**				**Responsiveness**			**Assurance**			**Empathy**			
Indicator		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4
Tangibility	A1	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	A2	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	A3	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	A4	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
Reliability	B1	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	B2	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	B3	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	B4	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
Responsiveness	C1	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	C2	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	C3	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
Assurance	D1	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	D2	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	D3	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
Empathy	E1	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	E2	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	E3	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013
	E4	0.003	0.006	0.018	0.016	0.129	0.051	0.114	0.056	0.046	0.040	0.063	0.100	0.049	0.151	0.008	0.123	0.015	0.013

4.3.2. Gray Rational Analysis

In this study, scores of all alternatives given by experts are larger-the-better. Therefore, the largest value of each sub-criteria is considered as a referential series (x_0), and the value of each indicator is considered a compared series (x_i). Table 13 reveals the referential series (x_0) and compared series (x_i).

Table 13. Referential series and compared series.

Indicators	**Referential Series (x_0)**	**Compared Series (x_i)**				
		Alt 1	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**
A1	6.20	1.00	1.41	6.20	4.86	4.45
A2	6.20	1.23	1.41	6.20	4.77	3.52
A3	6.57	1.23	6.57	6.20	4.77	3.52
A4	7.12	1.23	7.12	6.20	4.86	3.52
B1	7.12	1.23	7.12	3.87	4.77	4.45
B2	7.12	1.00	7.12	4.70	4.77	4.45
B3	6.06	1.32	6.06	3.87	3.90	3.52
B4	7.35	1.32	7.35	3.87	4.45	2.08
C1	6.06	1.74	6.06	3.87	3.52	2.88
C2	7.23	1.41	7.23	4.70	3.52	2.08
C3	7.12	1.52	7.12	4.79	3.52	2.08
D1	6.12	1.41	6.12	4.79	4.45	2.08
D2	6.84	1.52	6.84	4.79	3.52	2.88
D3	7.12	1.74	7.12	4.70	4.45	2.08
E1	6.10	1.52	6.10	4.70	3.52	2.88
E2	6.10	1.41	6.10	4.70	3.52	2.17
E3	6.20	1.41	6.20	4.70	3.52	2.17
E4	6.20	1.41	6.20	4.77	3.52	2.17

The normalized data is calculated using Equation (16), as shown in Table 14.

Table 14. Normalized data.

Indicators	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
A1	0.0000	0.0788	1.0000	0.7423	0.6635
A2	0.0000	0.0362	1.0000	0.7123	0.4608
A3	0.0000	1.0000	0.9307	0.6629	0.4288
A4	0.0000	1.0000	0.8438	0.6163	0.3888
B1	0.0000	1.0000	0.4482	0.6010	0.5467
B2	0.0000	1.0000	0.6046	0.6160	0.5637
B3	0.0000	1.0000	0.5380	0.5443	0.4641
B4	0.0000	1.0000	0.4229	0.5191	0.1260
C1	0.0000	1.0000	0.4931	0.4120	0.2639
C2	0.0000	1.0000	0.5653	0.3625	0.1151
C3	0.0000	1.0000	0.5839	0.3571	0.1000
D1	0.0000	1.0000	0.7176	0.6454	0.1423
D2	0.0000	1.0000	0.6147	0.3759	0.2556
D3	0.0000	1.0000	0.5502	0.5037	0.0632
E1	0.0000	1.0000	0.6943	0.4367	0.2969
E2	0.0000	1.0000	0.7015	0.4499	0.1620
E3	0.0000	1.0000	0.6868	0.4405	0.1587
E4	0.0000	1.0000	0.7015	0.4405	0.1587

The calculation of deviation sequences using Equation (17) is shown in Table 15.

Table 15. Deviation sequences.

Indicators	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
A1	1.0000	0.9212	0.0000	0.2577	0.3365
A2	1.0000	0.9638	0.0000	0.2877	0.5392
A3	1.0000	0.0000	0.0693	0.3371	0.5712
A4	1.0000	0.0000	0.1562	0.3837	0.6112
B1	1.0000	0.0000	0.5518	0.3990	0.4533
B2	1.0000	0.0000	0.3954	0.3840	0.4363
B3	1.0000	0.0000	0.4620	0.4557	0.5359
B4	1.0000	0.0000	0.5771	0.4809	0.8740
C1	1.0000	0.0000	0.5069	0.5880	0.7361
C2	1.0000	0.0000	0.4347	0.6375	0.8849
C3	1.0000	0.0000	0.4161	0.6429	0.9000
D1	1.0000	0.0000	0.2824	0.3546	0.8577
D2	1.0000	0.0000	0.3853	0.6241	0.7444
D3	1.0000	0.0000	0.4498	0.4963	0.9368
E1	1.0000	0.0000	0.3057	0.5633	0.7031
E2	1.0000	0.0000	0.2985	0.5501	0.8380
E3	1.0000	0.0000	0.3132	0.5595	0.8413
E4	1.0000	0.0000	0.2985	0.5595	0.8413

The calculation of gray rational coefficient using Equation (18) is shown in Table 16.

Table 16. Gray rational coefficient.

Indicators	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
A1	0.3333	0.3518	1.0000	0.6599	0.5977
A2	0.3333	0.3416	1.0000	0.6347	0.4811
A3	0.3333	1.0000	0.8783	0.5973	0.4668
A4	0.3333	1.0000	0.7620	0.5658	0.4500
B1	0.3333	1.0000	0.4754	0.5562	0.5245
B2	0.3333	1.0000	0.5584	0.5656	0.5340
B3	0.3333	1.0000	0.5197	0.5232	0.4827
B4	0.3333	1.0000	0.4642	0.5097	0.3639
C1	0.3333	1.0000	0.4966	0.4596	0.4045
C2	0.3333	1.0000	0.5349	0.4396	0.3610
C3	0.3333	1.0000	0.5458	0.4375	0.3571
D1	0.3333	1.0000	0.6391	0.5851	0.3683
D2	0.3333	1.0000	0.5648	0.4448	0.4018
D3	0.3333	1.0000	0.5264	0.5019	0.3480
E1	0.3333	1.0000	0.6206	0.4702	0.4156
E2	0.3333	1.0000	0.6262	0.4761	0.3737
E3	0.3333	1.0000	0.6149	0.4719	0.3728
E4	0.3333	1.0000	0.6261	0.4719	0.3728

4.4. Research Result

4.4.1. Fuzzy Analytic Network Process Model

As for the ranking of all dimensions, it ranked according to their overall weight as reliability (0.402), assurance (0.303), responsiveness (0.139), tangibility (0.082), and empathy (0.074).

The overall weight of all dimensions in the FANP model is shown in Table 17.

Table 17. The overall weight of all dimensions in the FANP model.

Dimensions	Description	Overall Weight	Rank
Tangibility	Appearance of physical facilities, personnel and written materials	0.082	4
Reliability	Reliable and correct performance of the promised service capabilities	0.402	1
Responsiveness	Willingness to help customers and provide prompt service	0.139	3
Assurance	The ability of employees to inspire trust and confidence in customers	0.303	2
Empathy	Give customers individualised treatment	0.074	5

As for the ranking of indicators, the top 3 weights of indicators are "Employees are professional and obtain adequate support to do their jobs well" (D3, 0.151), "When online English teaching service team promises to do something by a certain time, it does so" (B1, 0.129), and "Online English teaching service team can provide customers with flexible trading hours" (E2, 0.123).

Meanwhile, weights of indicators ranked fourth to sixth are "The service is provided legally, safely and reliably" (B3, 0.114), "Customers feel safe in their transactions with online English teaching service team" (D1, 0.100), and "Employees are never too busy to respond to customer requests promptly" (C3, 0.063).

Also, the seventh to eighth important indicators are "Online English teaching service team keeps its records accurately" (B4, 0.056) and "Employees of online English teaching service team are sympathetic and reassuring" (B2, 0.051).

The overall weight of all indicators in the FANP model is shown in Figure 5.

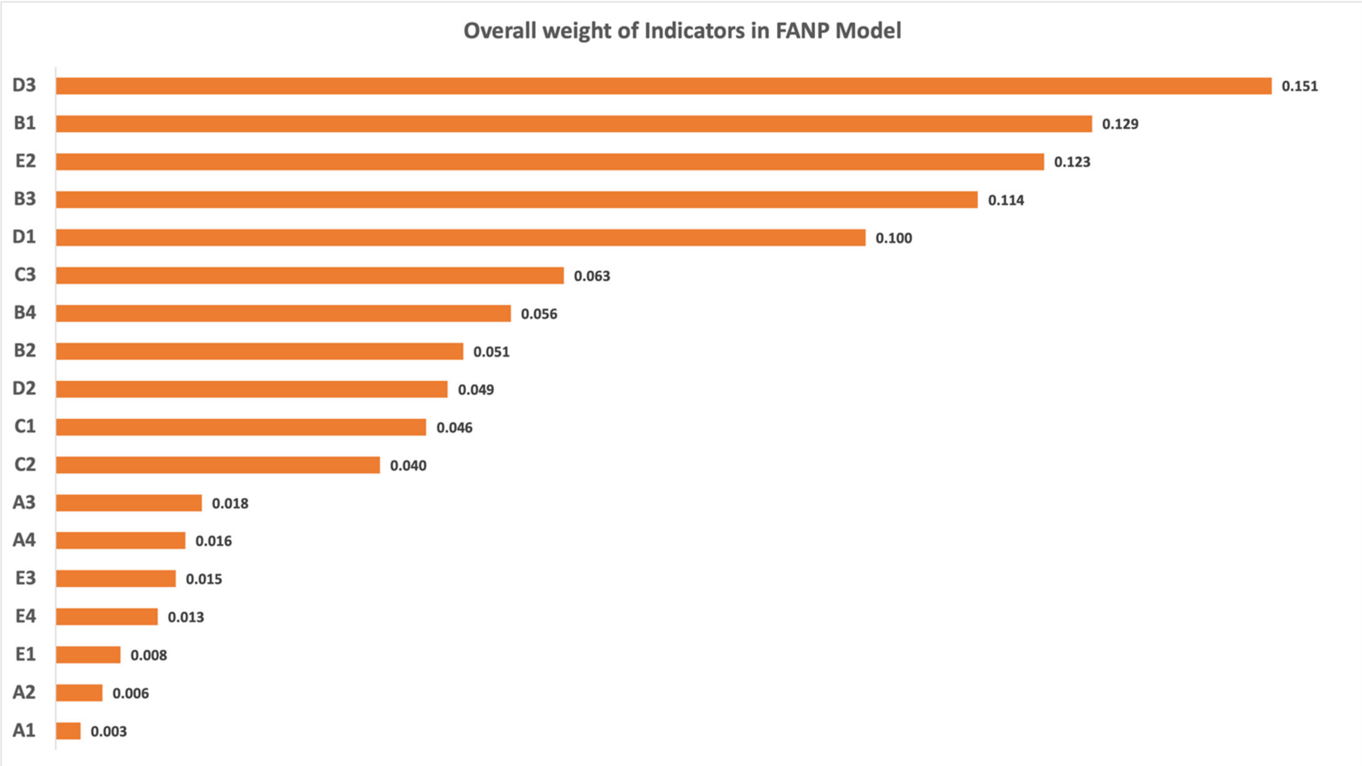

Figure 5. The overall weight of all indicators in the FANP model.

4.4.2. Gray Rational Analysis

The priority of all alternatives is based on the gray rational grade (Γ_{0i}). The calculation of the gray rational grade using Equation (19) is shown in Table 18.

Table 18. Gray rational grade.

Alternatives	Description	Grey Rational Grade (Γ_{0i})	Rank
Alt 1	Appealing facility	0.3	5
Alt 2	Personnel quality and stability	0.8347	1
Alt 3	Response speed to customer need	0.5727	2
Alt 4	Safe transaction environment	0.4686	3
Alt 5	Personalised needs of customers	0.3838	4

The larger value of gray rational grade represents that the alternative is closer to the optimal solution. Accordingly, rankings of all alternatives based on gray rational grade are "Personnel quality and stability" (Alt 2, 0.8347), "Response speed to customer need" (Alt 3, 0.5943), "Safe transaction environment" (Alt 3, 0.4855), "Personalised needs of customers" (Alt 5, 0.391), and "Appealing facility" (Alt 1, 0.3).

5. Discussion and Research Limitation

5.1. Discussion

Matzler et al. [114] found that customer satisfaction evaluation comprises three factors: basic, performance, and excitement factors. They emphasized the importance of identifying and fulfilling customers' fundamental needs. In this study, the analysis of expert questionnaires revealed that reliability emerged as the most crucial dimension, while tangibility was identified as the least significant in the FANP model. Meanwhile, the top alternative in the GRA model is "Personnel quality and stability", followed by "Response speed to customer need" and "Safe transaction environment". Also, the indicators in order of overall weight in the reliability dimension are "When online English teaching service team promises to do something by a certain time, it does so", "The service is provided legally, safely and reliably" and "Online English teaching service team keeps its records accurately". This means that in the FANP and GRA models, experts believe that the basic needs of customers include the quality of employees, speed of response to customer needs, safe transaction environment, service team emphasis on commitment, legal service content, and correct customer record demand.

Moreover, experts are of the opinion that factors like the equipment and appearance of service providers will be less significant in the post-pandemic era. This primarily stems from the fact that consumers opt for online learning and frequently need to acquire their own equipment, resulting in a reduced emphasis on the service provider's own equipment.

In addition, Kim et al. [115] and Uppal et al. [116] put forth research prior to the COVID-19 pandemic. They indicated that dimensions within the SERVQUAL scale, including reliability, responsiveness, assurance, and empathy, have a significant impact on the assessment of online learning and e-learning satisfaction. Furthermore, Sumi [117] and Ma et al. [118] stated that the dimensions and indicators in the SERVQUAL scale are suitable for assessing the service quality of the online teaching industry amidst the COVID-19 pandemic.

It is worth noting that the results of the previous research are very similar to those of the current study. For example, Kim et al. [115] found that the dimension of empathy has an impact on service quality. However, the dimension of empathy is relatively less important than the three dimensions of reliability, responsiveness, and assurance. Ma et al. [118] reported that the empathy aspect is a relatively low-ranking aspect from the perspective of online English educational service providers and consumers. In the meantime, indicators in the empathy facet, such as E1 and E2, also rank low from the perspective of online English teaching service providers and consumers. Thus, the dimensions and indicators used to assess the quality of educational services remain consistent, whether in the post-COVID-19 era, during the COVID-19 pandemic, or before the coronavirus pandemic.

Accordingly, service providers of online English teaching should address basic consumer needs, such as high-quality personnel, reliable service content, and a safe transactional environment, to deliver high-quality service in the post-COVID-19 era.

5.2. Research Limitation

This research approach integrates FANP and GRA methods. Within the hierarchy and network structure, over 90% of experts concur on the relationships, indicating a substantial consensus. Pairwise comparisons of indicator importance employ *C.I.* and *C.R.* values for validation. In the GRA model, 10 experts assessed the indicators and plans. It is important to note that this research relies on expert opinions, which constitutes a limitation of this study and the ANP and GRA methodologies. As such, experienced experts were specifically engaged to complete the questionnaires.

6. Conclusions

This research established the hierarchy and network structure of a crisis management plan for the online English teaching industry based on the SERVQUAL scale. Then, the weights of all dimensions and indicators were analyzed and calculated using FANP. Afterwards, all alternatives were ranked using GRA.

The main contribution of this study is to introduce a hybrid approach of FANP and GRA to assess the service quality of online English teaching in the post-COVID-19 era in a fuzzy environment. In the meantime, our findings highlight that having competent and reliable staff, legal and trustworthy service content, flexible business hours, and a secure transaction environment are crucial factors for providing quality services in the online English education industry in the post-coronavirus pandemic era.

As for the result of GRA in this study, it was reported that well-qualified teachers, low-mobility employees, and instant response speed to customer needs are also important factors in establishing optimized crisis management plan for online English teaching in the post-epidemic era.

Moreover, this study has an indicative role for the online English teaching industry to maintain excellent service quality in the post-COVID-19 era. Finally, the research findings of this study provide guidance for the online English teaching industry in future related scenarios.

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