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Evaluation of Student-Perceived Service Quality in Higher Education for Sustainable Development: A Fuzzy TODIM-ERA Method

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Abstract: Evaluating and prioritizing the service quality of higher education is an essential issue for the successful implementation of Education for Sustainable Development (ESD). This study investigates an evaluation framework to assess the performances of higher education institutes (HEIs) within the context of ESD based on student-perceived service quality. First, a conceptual model of the evaluation indicator system is explored by embedding sustainability-related indicators into the fuzzy SERVQUAL scale. Then, the evaluation of student-perceived service quality can be thought of as a problem of multicriteria decision-making (MCDM) that involves uncertainty and bounded rationality. Thus, an evaluation technique called hybrid fuzzy TODIM-ERA is proposed to address such evaluation problems by synthesizing the theoretical strengths of the intuitionistic fuzzy set theory, the evidential reasoning algorithm (ERA), and the TODIM (an acronym in Portuguese for interactive and multicriteria decision-making). Finally, a case study of five Chinese HEIs in maritime transportation is used to demonstrate the effectiveness and robustness of the proposed framework. Results provide the ranking order of all the alternative HEIs and the improvement strategies of each HEI for student-perceived service quality dimensions.

Keywords: MCDM; service quality evaluation; sustainability; higher education; intuitionistic fuzzy theory; evidence theory; TODIM

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1. Introduction

The concept of sustainable development has been discussed intensively in academia since the 1970s [1]. Recently, global environmental issues, such as climate change, environmental pollution, and natural resource scarcity, have changed how we live, think, and act [2]. To ensure a better world, the United Nations approved the 2030 Agenda for Sustainable Development in 2015, which refines the new global sustainable framework that outlines how the international community can work together to achieve 17 Sustainable Development Goals (SDGs) [3,4]. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), Education for Sustainable Development (ESD), which is the essence of SDG 4, plays a critical role in the achievement of all SDGs in the 2030 Agenda for Sustainable Development [5,6]. Specifically, SDG target 4.7 seeks to "ensure that all learners acquire the knowledge and skills required to promote sustainable development" [7]. This goal embodies the vision and ambitions of ESD for 2030, which emphasizes the provision of inclusive and equitable quality education and lifelong learning opportunities for all [8–10].

In academia, ESD is widely understood to integrate sustainability into education programs' teaching, research, and operations, presenting new challenges in education development [11,12]. In recent decades, ESD has also attracted increasing attention from strategic decision makers in many countries [13]. As an important international power, China has always given priority to development. In 2016, the Chinese government issued China's National Plan on Implementation of the 2030 Agenda for Sustainable Development, which integrates the 2030 Agenda's SDGs into domestic mid- and long-term development strategies [10,14]. Later, China's Education Modernization 2035 was published in 2019 to improve education quality, promote equitable education, and optimize the educational system [15,16]. Higher education institutions (HEIs) foster and promote sustainability competencies [17,18]. Despite the considerable academic progress in ESD [19–21], more research is necessary to address the challenges posed by sustainability implementation in higher education, particularly in terms of student-perceived service quality. Sustainability can only be achieved if students are satisfied with the education service provided by their host institutions [9].

Because students can be considered the primary customers of education, the student-perceived service quality of higher education refers to the students' overall impression of the educational functionality of HEIs and their delivery systems [22]. To better satisfy students in an increasingly competitive environment, HEIs must actively monitor the quality of the services they provide and commit to the continuous improvement of service levels [23]. To this end, there is a strong need for a valid and reliable evaluation of student-perceived service quality in higher education for sustainable development. In general, there are two critical issues in evaluating service quality: identifying reasonable quality indicators and using appropriate evaluation methods [24].

Considering the first issue, academics have become increasingly interested in the identification of educational quality indicators based on a variety of classical models or measurements, such as total quality management [25], the 5Qs model [26,27], the ISO 9001 standards [28], the service quality (SERVQUAL) scale [29], and the performance-based measure of service quality (SERVPERF) scale [30]. As one of the most widely used and mature conceptual models, the SERVQUAL scale has been modified in the evaluation of higher education service quality [23,31–34]. The SERVQUAL scale focuses on five dimensions, including tangibility, reliability, responsiveness, assurance, and empathy. Due to the urgent needs of ESD, sustainability-related indicators are incorporated into the five dimensions of the SERVQUAL scale in this study to measure student-perceived service quality in higher education more accurately.

Considering the second issue, evaluating student-perceived service quality within the context of sustainable development can belong to the scope of multicriteria decision-making (MCDM) [10]. In recent years, a variety of classic MCDM techniques, such as the analytic hierarchy process (AHP) [34,35] and the technique of order preference by similarity to ideal solution (TOPSIS) [33], have been used to evaluate educational performance, curriculum quality, and student satisfaction [23,32]. Due to the diversity of student characteristics and the complexities of decision-making scenarios, the student-perceived service quality can be plagued with vagueness and uncertainty [32]. Additionally, subjective evaluation behavior is more akin to bounded rationality [22,36,37]. According to the literature [34–39], fuzzy set theory can reasonably describe the subjective uncertainty related to educational quality evaluation [34]; ERA (evidential reasoning algorithm) can minimize the loss of uncertainty in the fusion process of evaluation information [38,39]; and TODIM (an acronym in Portuguese for interactive and multicriteria decision-making) can express the psychological behavior of decision makers in MCDM problems [36,37]. Therefore, this study develops the MCDM method based on fuzzy set theory, TODIM, and ERA for student-perceived service quality evaluation with uncertain information and bounded rationality of decision makers.

Inspired by the challenges of the above two issues, the primary objective of this study is to answer two research questions:

RQ1: How can a comprehensive evaluation indicator system be established by linking the goals of ESD to student-perceived service quality in higher education?

RQ2: How can an appropriate MCDM method be developed by fully considering the uncertainty of evaluation information and the bounded rationality of student perceptions?

In addition, integrating sustainability into transportation education is a pivotal subtopic to achieving the Sustainable Development Goals, which has gained growing attention from academia [21,40,41]. Maritime transportation is widely recognized as one of the significant pillars anchored to economic growth, social stability, and environmental issues. According to the UNCTAD reports, about 80% of the world's trade volume is transported by sea [42]. Moreover, maritime transportation enables the delivery of oversized cargo volumes with low costs and less environmental pollution [43]. In recent years, the prevalence of global sustainable development has put forward new requirements for the education of maritime transportation. In 2019, the State Council of China issued the Outline of Building China's Strength in Transportation [44]. Therefore, cultivating high-quality maritime talents with sustainability is one of the crucial components of maritime transportation education and the foundation of the maritime industry.

Based on these considerations, this study proposes an evaluation framework of student-perceived service quality in higher education for sustainable development, including a conceptual model of an evaluation indicator system and an evaluation technique called hybrid fuzzy TODIM-ERA. First, a conceptual model is designed by embedding sustainability-related indicators into the fuzzy SERVQUAL scale. Specifically, there are five dimensions and 22 indicators, of which seven indicators are related to sustainability. Then, a hybrid technique to evaluate student-perceived service quality is devised by integrated intuitionistic fuzzy set theory, ERA, and TODIM. This technique has solid theoretical advantages when managing uncertain information and bounded rationality during student-perceived service quality evaluation. Then, the evaluation of student-perceived service quality for five HEIs related to maritime transportation is conducted to demonstrate the effectiveness and performance of the proposed framework.

The remainder of this paper is organized as follows. Section 2 briefly reviews recent literature on student-perceived service quality in higher education for sustainable development. Section 3 outlines the proposed evaluation method, including a conceptual model and a hybrid fuzzy TODIM-ERA method. In Section 4, the implementation of the proposed method is detailed in five Chinese HEIs. The results and discussion are analyzed in Section 5, and conclusions are summarized in Section 6.

2. Literature Review

In this study, relevant literature can be roughly divided into three themes: higher education for sustainable development, service quality in higher education, and related MCDM methods.

2.1. Higher Education for Sustainable Development

As early as the 1980s, sustainable development attracted the attention of academia. The widely accepted definition of sustainable development was proposed based on the Brundtland Report: "the one that satisfies the needs of the present generation without compromising the capacity to satisfy those of the future generations" [4]. In terms of education for sustainable development (ESD), the Talloires Declaration in 1990 pioneered the critical role of higher education in promoting global sustainable development [10]. In 1992, Agenda 21 elaborated by the United Nations (UN) declared that education provides an essential path for advancing individual capability to deal with sustainability problems [15,18]. Then, the UNESCO Decade of ESD (2005–2014) encouraged a shift in public consciousness, values, and knowledge to promote equitable education and lifelong learning [18]. In 2015, the 2030 Agenda described the urgency to embed the goals of ESD into all levels of education [45].

Currently, higher education institutions (HEIs) are trying to incorporate the concept of ESD into their systems and subsystems, operations, and curricula [1]. Higher education plays a significant role in sustainable development. HEIs have a mission to serve societies to achieve a sustainable life. Conversely, the achievement of the SDGs is also conducive to promoting education quality and increasing student satisfaction. Many scholars have devoted themselves to investigating themes related to higher education for sustainable development in recent years. First, some scholars focus on successfully implementing ESD and addressing sustainability issues in HEIs, such as the evolution, challenges, and strategies of higher education in the ESD framework [3]; the interdisciplinary teaching-learning sequence [2]; and the experiences of sustainability-related courses [21,46]. These ESD practices can effectively promote and enhance the sustainability competencies of teachers and students in higher education. Then, some studies have attempted to identify sustainability competencies in higher education based on the rough-dominance set approach [15] and the questionnaire survey [47]. In addition, the sustainability evaluation of higher education has also attracted the attention of academia. For example, Elmassah et al. introduced a framework for HEIs' sustainable development assessment in three countries, i.e., Germany, Japan, and Egypt [48]. Weng et al. proposed an evaluation model for the improvement of teachers in the context of sustainable development [10]. Staniskis et al. applied the QUESTE-SI evaluation system to analyze educational sustainability at the Kaunas University of Technology [12]. Yuan et al. studied the awareness of sustainability among students based on a questionnaire survey with 53 elements in seven groups [13]. Regarding sustainable transportation education, Lukman et al. elaborated on integrating sustainable development within logistics-oriented programs at European universities [21]. Putz et al. applied field trips to enhance students' knowledge of sustainable transport based on a longitudinal panel study [40]. Wu et al. provided the current state of the major transportation-related departments and programs in North America and Europe based on exploratory empirical content [41].

2.2. Service Quality in Higher Education

The definition of service quality is derived from marketing [23,26] and can be described as a measure of customer satisfaction and perceived service level concerning the factors that characterize service and customer expectations [26,34,49]. The provision of high-quality service is one of the crucial factors affecting the satisfaction level of students [9]. For example, Chen et al. used data mining techniques to analyze the current status of teaching quality in high vocational education through student satisfaction surveys [50]. In addition, high-quality education is also essential for the advancement of maritime transportation. In this view, Koh et al. identified six quality dimensions and 29 measurement items for maritime programs from students' perspectives based on exploratory factor analysis [42]. Liu et al. surveyed maritime undergraduate students' perceptions of associated programs to better understand education and career paths [43]. Bao et al. identified four principal factors affecting the quality of maritime education and training in China by employing an exploratory factor analysis technique [51].

Perceived service quality evaluation is the core component of service quality management. Higher education exhibits the four peculiar characteristics of service, including being intangible, inseparable, heterogeneous, and perishable [23,34]. Therefore, it is common to generalize and apply classic service quality models and methods to higher education, such as total quality management [25], the American Customer Satisfaction Index [31], the ISO 9001 standards [28], the SERVQUAL scale [29], and the SERVPERF scale [30]. As the most prevalent service quality measurement, the SERVQUAL scale was developed based on the discrepancy or gap between perceptions and expectations of service [29]. This scale has been shown to be effective and applicable to evaluate service quality in a wide range of domains, including higher education. For example, Nojavan et al. developed a hybrid evaluation approach based on fuzzy SERVQUAL questionnaires to study the service quality performance of education units [32]. Cheng et al. modified the SERVQUAL instrument by considering the characteristics of hospitality, tourism, and leisure undergraduate programs [23]. Choudhury investigated a modified SERVQUAL instrument with four dimensions, including competence, tangibility, responsiveness, and convenience, to capture customers' perceptions of service quality [33]. Lupo proposed a reliable model based on an extension of the SERVQUAL method for measurements of education services related to the management engineering program [34].

2.3. Related MCDM Methods

Multiple-criteria decision-making (MCDM) is the methodology of prioritizing all available alternatives by comprehensively considering multiple criteria [38,52]. Recently, some researchers have explored various MCDM methods in higher education, such as the DEMATEL (a decision-making trial and evaluation laboratory) method, the DEMATEL-based analytical network process (DANP) [10], importance-performance analysis (IPA), quality function deployment (QFD) [23], and TOPSIS [33]. In order to improve the quality and level of transportation engineering education, Luo et al. studied a teaching system based on CDIO education philosophy and talent training evaluation by using the combination of AHP and expert survey method [53].

Because indicators of service quality evaluation tend to be qualitative or formulated in linguistic terms, uncertainties inevitably exist in the evaluation process. Recently, some scholars have introduced the fuzzy set theory to express epistemic and subjective uncertainty in educational evaluation. For example, Menon et al. developed a conceptual assessment model using the fuzzy logic method to analyze environmental sustainability initiatives in higher education [54]. Nojavan et al. devised a hybrid approach based on fuzzy SERVQUAL questionnaires [32]. Puente et al. proposed a methodology using FDEMATEL and FDAHP for quality assessment in European HEIs [55]. Lupo proposed a combined procedure using fuzzy set theory and AHP for measurements of education services [34]. However, fuzzy set can only describe the preference of "either one or the other" [56]. Intuitionistic fuzzy sets (IFSs) are characterized by membership and non-membership functions [57], can provide more auxiliary decision information, and are useful when representing uncertainty [38,39,52,58]. In terms of evaluating information aggregation, evidence theory is one of the best solutions to fuse uncertain information and is well-known for making the maximum use of all available information [38,39,52].

In addition, previous methods have primarily been developed on the hypothesis that decision makers act completely rationally [10,23,32–34,55]. However, in the real case, the decision behavior with bounded rationality is more in line with the practical characteristics of perceived service quality evaluation. As a popular method of behavioral decision-making, TODIM (an acronym in Portuguese for interactive and multicriteria decision-making) [59] has been successfully applied in various domains [58]. For example, Liu et al. proposed a multiple criteria group decision-making method based on evidence theory and TODIM under double hierarchy hesitant fuzzy linguistic term sets for the application of postgraduate course evaluation [37]. Zuo et al. developed a linear programming technique for multidimensional analysis of a preference model based on prospect theory and the TOPSIS method [22]. Chen et al. designed a hybrid method to analyze sustainable development indicators in the construction minerals industry by combining fuzzy set theory, the Delphi method, and the TODIM [60].

3. Methodology

To evaluate student-perceived service quality in higher education for sustainable development, this study proposes an integrated methodology consisting of two parts. First, a conceptual model with a hierarchical structure can be constructed by incorporating fuzzy SERVQUAL and sustainability-related indicators. According to this model, students' perceptions of higher education can be surveyed and collected. Next, a hybrid fuzzy TODIM-ERA method is developed for the information uncertainty and individual bounded rationality in the real evaluating process. The overall framework of this methodology is shown in Figure 1.

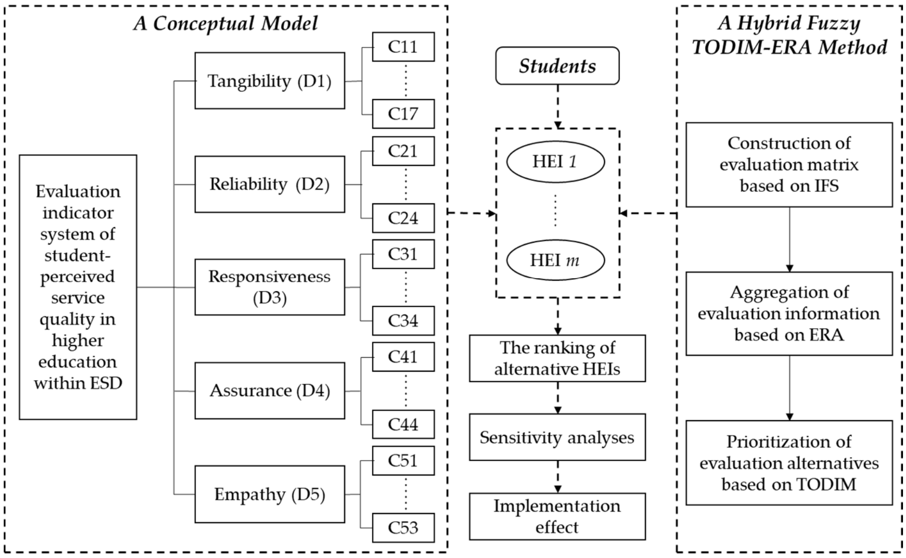

Figure 1. The overall framework of the proposed methodology.

3.1. A Conceptual Model Based on Fuzzy SERVQUAL and Sustainable Development

Establishing a conceptual model with multiple criteria is undoubtedly the foundation for reasonable evaluation. To assess students' perceptions about the service quality of HEIs in this study, the fuzzy SERVQUAL considering uncertainty is an appropriate instrument [32,34]. The method involves five dimensions [1,29]:

(1) Tangibility is concerned with physical facilities, personnel appearance, etc.
(2) Reliability is related to the capacity to deliver the promised service consistently and precisely.
(3) Responsiveness is linked to employee behaviors and attitudes, motivation to work, and willingness to assist customers.
(4) Assurance is related to employees' security, credibility, faith, and confidence.
(5) Empathy refers to specific attention to and communication with consumers.

In higher education, students are typically regarded as the customers of the service, while staff (academic and other) are the primary providers of the service. The level of service quality is affected by physical campus conditions and virtual education policies. In addition, the goals of ESD make the service of higher education more complex. Thus, indicators related to sustainability must be introduced into each of the five dimensions. Therefore, it is necessary to identify the evaluation indicators in the five dimensions of the fuzzy SERVQUAL scale based on the characteristics of higher education practices and the requirements of sustainable development.

Via a thorough literature review on ESD and service quality evaluation, 22 indicators in the five dimensions are shown to constitute the hierarchy of the proposed conceptual model, as shown in Table 1 and Figure 1. Motivated by the literature [1,6,13], seven sustainability-related indicators are introduced into the conceptual model. For example, indicators C16 and C17 are included in the tangibility dimension to describe the sustainability of education infrastructures and student activities. The indicator C24 in the reliability dimension reflects the development of sustainability competencies in higher education curricula. The indicator C34 focuses on the sustainability awareness of students to improve the responsiveness component. The indicators C43 and C44 in the assurance dimension reveal the sustainable development of staff and policies in higher education. In the empathy dimension, the indicator C53 is concerned with particular students to enhance student-centered sustainability.

Table 1. Evaluation indicators of student-perceived service quality in higher education for sustainable development.

Code	Indicator	Description	References
C11	Cleanliness of campus and staff	The campus is kept clean, and staff (academic, other) are neat and professional looking.	[23,31,32,49,61]
C12	Campus Internet and Wi-Fi access	Easy access to campus Internet and Wi-Fi.	[23,31]
C13	Attractive view of physical facilities	Physical facilities (buildings, classrooms, labs) are visually attractive and convenient.	[9,31–33,61]
C14	Adequate equipment and resources	Necessary modern equipment (technologies, materials) is widely used for teaching, and sufficient information resources (books, journals, Internet, etc.) are available to meet the needs of the courses.	[9,23,32,49,61]
C15	Recreational and support facilities	Plenty of recreational and support facilities (medical facilities, canteens, transportation services, etc.) are good enough to serve students' needs.	[9,23,33]
C16	*Environment-friendly infrastructures*	*Environmentally friendly infrastructures and products are widely used for energy conservation and pollution and waste reduction.*	[1,13]
C17	*Sustainability oriented practices*	*Students are encouraged to participate in sustainability initiatives and to consider internships and jobs in enterprises with the pledge of social and environmental responsibility.*	[6,13]
C21	Accuracy of records	Education records remain accurate, coherent, and accessible.	[26,32,61]
C22	Well-kept schedules	There are fixed class schedules and punctual service hours, which are maximally adjusted to students.	[23,31,49]
C23	High-quality teaching	The course's subject matter is adequate to meet the needs of the labor market, and the teaching methods are modern.	[9,26,31,32,49]
C24	*Sustainable curricula*	*Through interdisciplinary teaching and active learning methods, courses on sustainability issues are offered to develop students' critical, holistic, and systems thinking.*	[1,6,13]
C31	Timely and efficient service	Staff (academic, other) are prompt and efficient in issuing services notices (courses, administrative activities, etc.) and resolving students' problems.	[1,23,31–33,49,61]
C32	Availability of staff for assistance	Staff (academic, other) are readily available and capable of providing guidance and support.	[9,23,31–33,49]
C33	Friendly and supportive attitude	Staff (academic, other) have a courteous, friendly, and supportive attitude towards students and protect the best interests of students.	[9,33,61]
C34	*Environmental sensitivity*	*Seminars and workshops on sustainability issues are organized to develop the environmental sensitivity of students.*	[1]
C41	Sincere commitments	Some sincere commitments are fully provided to make students feel safe with campus, faculty, and support services.	[23,31,49,61]
C42	Staff competence	Staff (academic, other) are knowledgeable and familiar with rules, regulations, and procedures.	[23,31,32,61]
C43	*Staff development and rewards*	*Staff (academic, other) have some professional development opportunities to contribute to sustainability, which will be used as a criterion for staff promotion or new employment.*	[13]
C44	*Rules and regulations*	*Rules and regulations are sound and consistent with sustainability requirements.*	[6,31]
C51	Individualized consideration	Rules and regulations are centered on the best interests of the students, the facilities and equipment are arranged for the convenience of the students, and the staff (academic, other) are attentive to the students' individual needs.	[9,23,31,32]
C52	Fair and unbiased treatment	Staff services and learning assessments are fair and unbiased to students.	[23,49]
C53	*Access for disabled students*	*There are adequate services for disabled students.*	[1,13]

According to the conceptual model in Table 1, the questionnaire with fuzzy-linguistic evaluation scales can be developed to survey and collect the student perceptions of service quality. The students are asked to assess their judgements using the linguistic terms for each indicator in five dimensions. Then, the initial evaluation can be determined based on the probability distribution of student-perceived service quality. Next, the overall evaluation results of the alternative HEIs and dimensions can be calculated based on an appropriate MCDM method, a hybrid fuzzy TODIM-ERA in the study.

3.2. A Hybrid Fuzzy TODIM-ERA Method

Evaluating student-perceived service quality in higher education for sustainable development can be considered an MCDM problem. To manage the complex decision problem with uncertainty and bounded rationality, a hybrid MCDM method is developed by combining intuitionistic fuzzy set (IFS) theory, the TODIM method, and the ERA (evidential reasoning algorithm). First, the evaluation matrix for the alternative HEIs on 22 indicators can be generated using a seven-level linguistic preference scale, in which uncertainty of linguistic preference can be represented based on IFS theory. Next, the uncertain evaluation information can be aggregated based on the ERA method to obtain the linguistic preferences for the alternative HEIs, which are further transformed into the format of IFSs. Finally, the ranking and prioritization of all alternative HEIs can be determined using the TODIM method based on the assumption of bounded rationality. The procedure of the proposed hybrid fuzzy TODIM-ERA method is shown in Figure 2. Then, the proposed MCDM procedure is detailed below.

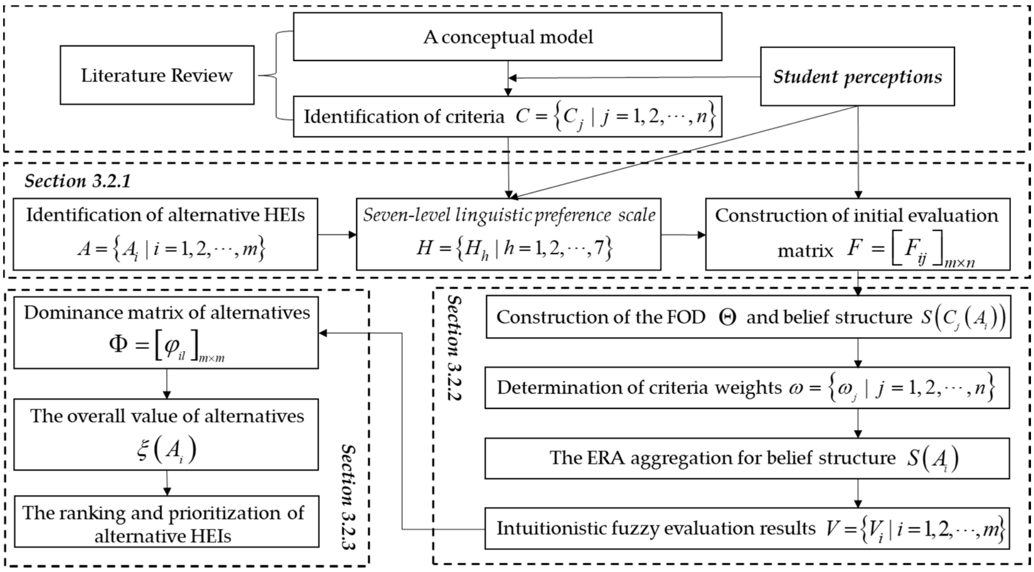

Figure 2. The procedure of the proposed hybrid fuzzy TODIM-ERA method.

3.2.1. Construction of Evaluation Matrix Based on IFS

For the MCDM problem in the study, we assume that there are m alternatives denoted by $A=\{A_i|i=1,2,\cdots,m\}$, and n criteria denoted by $C=\{C_j|j=1,2,\cdots,n\}$. Then the weight vector of criteria can be denoted by $\omega=\{\omega_j|j=1,2,\cdots,n\}$, satisfying $0\le\omega_j\le 1$ and $\sum_{j=1}^{n}\omega_j=1$. Based on the proposed conceptual model, students can express the perceptions on each indicator C_j for the alternative HEIs A_i using a seven-level linguistic preference scale, as represented by $H=\{H_h|h=1,2,\cdots,7\}$. In this study, the linguistic term H_h can be very low (VL), lower (LR), low (L), medium (M), high (H), higher (HR), and very high (VH), as shown in Table 2. Thus, we can obtain the initial evaluation matrix $F=[F_{ij}]_{m\times n}$, where F_{ij} is the linguistic preference for alternative A_i concerning indicator C_j. The element $F_{ij}\in F$ consists of the linguistic terms and their probabilities, which can be denoted by $F_{ij}=\left\{\left\langle H_h,\beta_{h,ij}\right\rangle\middle|H_h\in H\right\}$, $i=1,2,\cdots,m$, and $j=1,2,\cdots,n$. For example, $F_{11} = \{\langle L, 0.2\rangle, \langle M, 0.2\rangle, \langle H, 0.6\rangle\}$ indicates that the linguistic terms L, M, and H for alternative A_1 on indicator C_1 have preference probability distributions of 20%, 20%, and 60%, respectively.

Table 2. Equivalent intuitionistic fuzzy numbers for linguistic terms.

Linguistic Terms	Intuitionistic Fuzzy Numbers
Very Low (*VL*)	(0.00, 1.00)
Lower (*LR*)	(0.05, 0.95)
Low (*L*)	(0.25, 0.70)
Medium (*M*)	(0.40, 0.50)
High (*H*)	(0.70, 0.25)
Higher (*HR*)	(0.95, 0.05)
Very High (*VH*)	(1.00, 0.00)

Because linguistic preferences frequently lack confidence degrees, there is inevitably subjective uncertainty when evaluating student-perceived service quality. As mentioned earlier, the most widely-used fuzzy set theory involves only a membership function. In contrast, the intuitionistic fuzzy set characterized by three states of support, opposition, and neutrality can better describe uncertain information. This study lists the relations between IFS and the seven-level linguistic preference scale, as shown in Table 2 [39]. The concept of IFS was initially promulgated by Atanassov [57]. In this study, the definitions of IFS are shown as follows.

Definition 1 [57]. *Let X be a finite universal set, $a = \{\langle x, \mu_a(x), v_a(x)\rangle | x \in X\}$, which is defined as an IFS, where $\mu_a(x), v_a(x) \in [0,1]$ and $0 \le \mu_a(x) + v_a(x) \le 1$ for all $x \in X$. $\mu_a(x)$ is the membership degree of the element x to a, $v_a(x)$ is the corresponding non-membership, and $\pi_a(x) = 1 - \mu_a(x) - v_a(x)$ is the hesitancy degree. Thus, $a = (\mu_a, v_a)$ is called the intuitionistic fuzzy number (IFN).*

Definition 2 [57]. *Let $a_1 = (\mu_1, v_1)$ and $a_2 = (\mu_2, v_2)$ be two IFNs, and then their algebraic operations can be defined as:*

(1) $a_1 \oplus a_2 = (\mu_1 + \mu_2 - \mu_1\mu_2, v_1 v_2)$;
(2) $a_1 \otimes a_2 = (\mu_1\mu_2, v_1 + v_2 - v_1 v_2)$;
(3) $\gamma a_1 = \left(1 - (1-\mu_1)^\gamma, {v_1}^\gamma\right), \gamma > 0$;
(4) ${a_2}^\gamma = \left({\mu_2}^\gamma, 1 - (1 - v_2)^\gamma\right), \gamma > 0$.

Definition 3 [38]. *Assuming that there are n IFNs $a_j = (\mu_j, v_j)$, $j = 1, 2, \cdots, n$, then the intuitionistic fuzzy weighted averaging (IFWA) operator is defined as:*

$$IFWA_\omega(a_1, a_2, \cdots, a_n) = \omega_1 a_1 \oplus \omega_2 a_2 \oplus \cdots \oplus \omega_n a_n,$$

where ω_j is the weight of a_j, $j = 1, 2, \cdots, n$.

Definition 4 [38]. *For an IFN $a = (\mu_a, v_a)$, its $\boldsymbol{\mathcal{H}}$ score function is defined as $\mathbf{S}(a) = \mu_a - v_a$, and its accuracy function is defined as $\boldsymbol{\mathcal{H}}(a) = \mu_a + v_a$. Let $a_1 = (\mu_1, v_1)$ and $a_2 = (\mu_2, v_2)$ be two IFNs. Then:*

(1) $a_1 > a_2$, *if* $\mathbf{S}(a_1) > \mathbf{S}(a_2)$ *or* $\mathbf{S}(a_1) = \mathbf{S}(a_2) \wedge \boldsymbol{\mathcal{H}}(a_1) > \boldsymbol{\mathcal{H}}(a_2)$;
(2) $a_1 < a_2$, *if* $\mathbf{S}(a_1) < \mathbf{S}(a_2)$ *or* $\mathbf{S}(a_1) = \mathbf{S}(a_2) \wedge \boldsymbol{\mathcal{H}}(a_1) < \boldsymbol{\mathcal{H}}(a_2)$;
(3) $a_1 = a_2$, *if* $\mathbf{S}(a_1) = \mathbf{S}(a_2) \wedge \boldsymbol{\mathcal{H}}(a_1) = \boldsymbol{\mathcal{H}}(a_2)$.

Definition 5 [62]. *For two IFNs $a_1 = (\mu_1, v_1)$ and $a_2 = (\mu_2, v_2)$, the Euclidean distance is defined as:*

$$DiSt(a_1, a_2) = \sqrt{\frac{1}{2}\left[(\mu_1 - \mu_2)^2 + (v_1 - v_2)^2 + (\pi_1 - \pi_2)^2\right]}.$$

3.2.2. Aggregation of Evaluation Information Based on ERA

Evidence theory was proposed by Dempster [63] and improved by Shafer [64] and is also known as the D-S evidence theory. As a generalization of Bayes probability theory, it is an efficient tool for uncertainty reasoning. Then, Yang and Xu extended the D-S evidence theory to advocate an evidential reasoning algorithm (ERA) for MCDM [65] and has been applied widely in various fields, such as performance evaluation [38] and design decisions [39]. The related concepts are described as follows.

Definition 6 [65]. *Let $\Theta = \{\theta_1, \cdots, \theta_N\}$ be the frame of discernment (FOD), and then its power set is defined as:*

$$2^\Theta = \{\varnothing, \{\theta_1\}, \cdots, \{\theta_1, \theta_2\}, \cdots \{\theta_1, \cdots, \theta_{N-1}\}, \Theta\},$$

where $\varnothing$ is an empty set.

Definition 7 [65]. *For the FOD Θ, a basic probability assignment (BPA) $m(\cdot)$, also called a mass function, is a mapping $m : 2^\Theta \to [0,1]$ that satisfies:*

$$\sum\nolimits_{A \subseteq \Theta} m(A) = 1,\ m(\varnothing) = 0.$$

Definition 8 [63]. *For two independent BPAs m_1 and m_2 on the FOD Θ, the Dempster combination rule for any element $A \subseteq \Theta$ is defined as follows:*

$$m_\oplus(A) = m_1(B) \oplus m_2(C) = \begin{cases} \frac{\sum_{B,C \subseteq \Theta, B \cap C = A} m_1(B) m_2(C)}{1-K} & A \neq \varnothing \\ 0 & A = \varnothing \end{cases},$$

where the normalization coefficient $K = \sum_{B,C \subseteq \Theta, B \cap C = \varnothing} m_1(B) m_2(C)$, indicating the degree of conflict between two BPAs.

Definition 9 [66]. *Let m be a BPA on the FOD Θ, and the belief entropy is defined as:*

$$E_d(m) = -\sum\nolimits_{A \subseteq \Theta} m(A) \log_2 \frac{m(A)}{2^{|A|} - 1},$$

where $|A|$ is the cardinality of the subset $A \subseteq \Theta$.

In this study, we aggregate the uncertain evaluation information of all criteria to calculate the evaluation results of alternatives. Thus, the ERA can fuse the evaluation matrix F and weight vector ω for the alternative A_i on the criteria C_j. The aggregation steps are detailed as follows.

First, the frame of discernment (FOD) can be constructed based on a seven-level linguistic preference scale [39], $\Theta = H = \{VL, LR, L, M, H, HR, VH\}$. Then, the linguistic preference in the evaluation matrix can be considered to be the body of evidence (BOE) on the FOD Θ. Then the element $F_{ij} \in F$ of alternative A_i on criteria C_j can be expressed as a belief structure shown as follows.

$$S(C_j(A_i)) = \left\{\left\langle H_h, \beta_{h,ij} \right\rangle \middle| H_h \in \Theta \right\},\ i = 1, 2, \cdots, m,\ j = 1, 2, \cdots, n, \tag{1}$$

where $\beta_{h,ij}$ in the evidence theory denotes the belief degree of proposition H_h on criteria C_j for alternative A_i, satisfying $0 \leq \beta_{h,ij} \leq 1$, and $\sum_{h=1}^{7} \beta_{h,ij} \leq 1$. Then, we let $\beta_{H,ij} = 1 - \sum_{h=1}^{7} \beta_{h,ij}$ be the belief degree unassigned to any propositions.

Second, a weighting method based on belief entropy is proposed to obtain more objective weights rather than being directly provided by decision makers. Therefore, $\omega = \{\omega_j | j = 1, 2, \cdots, n\}$ can be determined by measuring the information volume of BOEs based on belief entropy. The weight will be larger when the value of belief entropy is greater, indicating that the BOE contains more information volume [66]. In this study, the belief entropy $E_d\left(S\left(C_j(A_i)\right)\right)$ can be calculated for BOE $S\left(C_j(A_i)\right)$ on the FOD Θ based on Definition 9. Then, the information volume for alternative A_i on criteria C_j can be defined as:

$$IV_{ij} = e^{E_d(S(C_j(A_i)))},\ i = 1,2,\cdots,m,\ j = 1,2,\cdots,n. \tag{2}$$

Therefore, the criteria weights can be measured as

$$\omega_j = \frac{\sum_{i=1}^{m} IV_{ij}}{\sum_{j=1}^{n}\sum_{i=1}^{m} IV_{ij}}. \tag{3}$$

Third, the ERA is leveraged to combine the evaluation information of the criteria for each alternative according to the Dempster combination rule (see Definition 8). Let $m_{h,ij}$ be a basic probability mass assigned to the proposition H_h on the jth BOE. Then, the remaining probability mass, which is denoted as $m_{H,ij}$, can represent the unassigned mass to any propositions in the FOD Θ on the jth BOE. They can be calculated as follows:

$$m_{h,ij} = \omega_j \beta_{h,ij},\ h = 1,2,\cdots,7,\ i = 1,2,\cdots,m,\ j = 1,2,\cdots,n, \tag{4}$$

$$m_{H,ij} = 1 - \omega_j \sum_{h=1}^{7} \beta_{h,ij},\ i = 1,2,\cdots,m,\ j = 1,2,\cdots,n. \tag{5}$$

We can obtain that $\overline{m}_{H,ij} = 1 - \omega_j$ and $\widetilde{m}_{H,ij} = \omega_j \beta_{H,ij}$. Let $m_{h,iJ_{(j+1)}}$ be the probability mass to proposition H_h on the first j bodies of evidence (BOEs), defined as follows:

$$m_{h,iJ_{(j+1)}} = K_{J_{(j+1)}}\left[m_{h,iJ_{(j)}} m_{h,i(j+1)} + m_{H,iJ_{(j)}} m_{h,i(j+1)} + m_{h,iJ_{(j)}} m_{H,i(j+1)}\right]. \tag{6}$$

Then, the remaining probability mass $m_{H,iJ_{(j+1)}}$ represents the unassigned mass to neither proposition on the first j BOEs, which can be calculated as follows:

$$m_{H,iJ_{(j+1)}} = \widetilde{m}_{H,iJ_{(j+1)}} + \overline{m}_{H,iJ_{(j+1)}}, \tag{7}$$

$$\widetilde{m}_{H,iJ_{(j+1)}} = K_{J_{(j+1)}}\left[\widetilde{m}_{H,iJ_{(j)}} \widetilde{m}_{H,i(j+1)} + \overline{m}_{H,iJ_{(j)}} \widetilde{m}_{H,i(j+1)} + \widetilde{m}_{H,iJ_{(j)}} \overline{m}_{H,i(j+1)}\right], \tag{8}$$

$$\overline{m}_{H,iJ_{(j+1)}} = K_{J_{(j+1)}} \overline{m}_{H,iJ_{(j)}} \overline{m}_{H,i(j+1)}, \tag{9}$$

where $K_{J_{(j+1)}} = \left[1 - \sum_{h=1}^{7}\sum_{h=1,k\neq h}^{7} m_{h,iJ_{(j)}} m_{k,i(j+1)}\right]^{-1}$ is the normalization coefficient.

Finally, the evaluation results of each alternative can be calculated by aggregating the belief degrees on all criteria C_j, $j = 1,2,\cdots,n$, shown in the following:

$$S(A_i) = \left\{\left\langle H_h, \beta_{h,i}\right\rangle \middle| H_h \in \Theta\right\},\ i = 1,2,\cdots,m, \tag{10}$$

where $\beta_{h,i}$ is the combined belief degree of proposition H_h for alternative A_i that can be defined as follows:

$$C_j\beta_{h,i} = m_{h,iJ_{(n)}} / \left(1 - \overline{m}_{H,iJ_{(n)}}\right),\ h = 1,2,\cdots,7,\ i = 1,2,\cdots,m. \tag{11}$$

According to Table 2, the proposition H_h can be transformed into the corresponding IFNs, denoted by $IFN(H_h) = (\mu_h, v_h)$. For example, $IFN(H_1) = IFN(VL) = (0,1)$ represents that the IFN related to the proposition H_1 (i.e., the linguistic terms VL) is $(0,1)$. Then, the evaluation results $S(A_i)$ of the alternative A_i can be expressed in the format of IFN, denoted by $V_i = \left(\mu_i^v, v_i^v\right)$. The belief degree $\beta_{h,i}$ of the proposition H_h can be considered to be the weight of the corresponding $IFN(H_h)$. Based on the IFWA operator, the intuitionistic fuzzy evaluation results V_i of the alternatives A_i can be calculated as:

$$IFWA_{S(A_i)}(H_1, H_2, \cdots, H_7) = \left(1 - \prod_{h=1}^{7}\left(1 - \mu_h^{IFN(H_h)}\right)^{\beta_{h,i}}, \prod_{h=1}^{7}\left(v_h^{IFN(H_h)}\right)^{\beta_{h,i}}\right). \tag{12}$$

Thus, we can obtain the intuitionistic fuzzy evaluation vector of the alternatives, denoted by $V = \{V_i | i = 1, 2, \cdots, m\}$, where $V_i = \left(\mu_i^v, v_i^v\right) = IFWA_{S(A_i)}(H_1, H_2, \cdots, H_7)$.

3.2.3. Prioritization of Evaluation Alternatives Based on TODIM

TODIM is derived from prospect theory and can effectively manage the bounded rationality behaviors of decision makers in MCDM problems [37,58,67]. Its basic principle is to determine the dominance degrees between alternatives and obtain the overall evaluation values by combining the dominance matrix of the alternatives. Thus, the alternatives can be sorted and ranked based on their overall values [62]. In this study, intuitionistic fuzzy set theory is introduced into the classic TODIM method to address the vague perceptions of decision makers. The details are described as follows.

First, the dominance degree of the alternative over the other alternatives is based on the intuitionistic fuzzy evaluation vector of alternatives, as shown below. In this study, the dominance matrix of alternatives denoted by $\Phi = [\varphi_{il}]_{m \times m}$ can be calculated as,

$$\varphi_{il} = \begin{cases} \sqrt{DiSt(V_i, V_l)} & V_i \geq V_l \\ -\frac{1}{\theta}\sqrt{DiSt(V_i, V_l)} & V_i < V_l \end{cases}, \; V_i, V_l \in V, \tag{13}$$

where the element φ_{il} is the dominance degree of alternative A_i relative to alternative A_l. $V_i \geq V_l$ and $V_i < V_l$ can be determined using Definition 4 in the IFS theory. The former implies a gain or no loss, while the latter describes a loss. $DiSt(V_i, V_l)$ indicates the gain or loss values of alternative A_i over alternative A_l, which can be calculated based on the Euclidean distance between IFNs (see Definition 5). The parameter θ is the attitude of loss aversion, as shown in Figure 3.

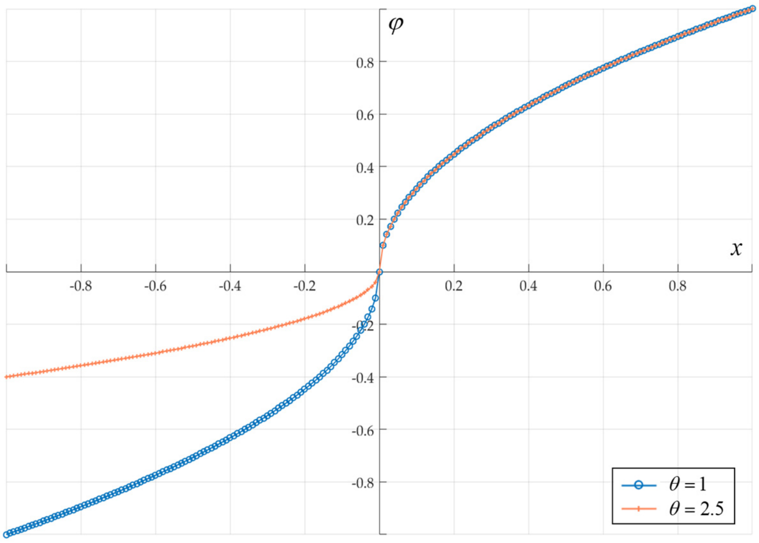

Figure 3. Dominance value function curves.

When $\theta = 1$, the curve in the loss quadrant is steeper. Conversely, the losses are attenuated when $\theta = 2.5$, the curve is to the x-axis. Thus, the decision makers become increasingly sensitive to changes in the losses as parameter θ declines. Also, decision makers are typically more sensitive to changes in losses than to changes in gains [62,68]. In the practical evaluation of educational service quality, HEIs' administrators will pay more attention to students' negative perceptions than positive perceptions, which is consistent with the concept of the loss attenuator in TODIM.

Second, the overall value concerning the alternative A_i can be calculated by

$$\xi(A_i) = \frac{\sum_{l=1}^{m} \varphi(A_i, A_l) - \min_i\left(\sum_{l=1}^{m} \varphi(A_i, A_l)\right)}{\max_i\left(\sum_{l=1}^{m} \varphi(A_i, A_l)\right) - \min_i\left(\sum_{l=1}^{m} \varphi(A_i, A_l)\right)}, \; i = 1, 2, \cdots, m. \tag{14}$$

Finally, the ranking and prioritization of alternatives can be obtained according to the overall dominance $\xi(A_i)$, $i = 1, 2, \cdots, m$. The larger the value of $\xi(A_i)$ is, the better the sorting of alternative A_i.

4. Case Study

In this section, the proposed method is applied to solve a practical evaluation problem of student-perceived service quality in five Chinese HEIs within the context of sustainable development. Relevant background and problem description are first introduced. Then, the evaluation process based on the proposed hybrid fuzzy TODIM-ERA method is demonstrated to prioritize the performance of five HEIs in terms of student-perceived service quality for sustainability.

4.1. Case Background and Description

In China, the concept of evaluating service quality in higher education is deeply embedded in education policies. In 2019, the State Council of China published China's Education Modernization 2035, highlighting the urgent need to enhance the quality of talent cultivation and innovative skills in higher education [16]. Later the same year, the Outline of Building China's Strength in Transportation was released, stating that one of the primary strategies is to cultivate high-quality talent in the field of maritime transportation [44]. In line with the 2030 Agenda, China has been striving to explore the integration of sustainable development and higher education. Therefore, evaluation of student-perceived service quality within the context of sustainable development is the essential task for HEIs to measure the realization and performance of high-quality talent cultivation in the field of maritime transportation. Comprehensive evaluation enables Chinese HEIs to continuously improve their educational facilities and policies to increase their service quality and contribute to the achievement of the SDGs. In this study, five Chinese HEIs in the field of maritime transportation provide the basis for the case study. These HEIs are renamed in this study to A1, A2, A3, A4, and A5 to maintain anonymity. Therefore, students from the five HEIs can provide individual perceptions on service quality within sustainable development.

4.2. Evaluation Process Based on the Proposed Method

Due to the subjective uncertainty characteristics of student-perceived service quality, it is challenging to make a unified and accurate evaluation for the five HEIs. Thus, the seven-level linguistic preference scale can be used to construct the initial evaluation matrix of 22 indicators in five dimensions for the five HEIs, as shown in Table 3.

We can comprehensively evaluate each alternative HEI by aggregating the initial evaluation information based on the ERA. Thus, the belief structure of ERA is first formed for each alternative on each indicator. Considering space limitations, we take the evaluation information of HEI A1 on indicator C11 as an example. According to Equation (1), its belief structure can be denoted by $S(\text{C11}(\text{A1})) = \{\langle H, 0.5\rangle, \langle HR, 0.5\rangle\}$, indicating that the belief degree of High (H) for HEI A1 with respect to indicator C11 is 0.5, and the corresponding belief degree of Higher (HR) is 0.5.

In this study, belief entropy can be used to measure the information volumes and further determine the weight vector of the indicators for each dimension. For example, the information volume of seven indicators in the tangibility dimension (i.e., D1) for five alternatives can be calculated using Equation (2) and can thus be denoted by:

$$IV(\text{D1}) = \begin{bmatrix} 2.718 & 3.653 & 4.581 & 3.180 & 4.811 & 1.598 & 3.900 \\ 4.581 & 4.417 & 3.939 & 3.180 & 3.653 & 3.180 & 4.811 \\ 4.811 & 3.939 & 3.900 & 36530 & 4.811 & 3.900 & 4.417 \\ 4.417 & 4.581 & 3.900 & 4.417 & 4.417 & 4.417 & 3.653 \\ 4.581 & 4.417 & 4.417 & 4.417 & 4.811 & 3.653 & 4.581 \end{bmatrix}.$$

Table 3. The initial evaluation information of indicators for five HEIs.

Indicators	Higher Education Institutions (HEIs)				
	A1	**A2**	**A3**	**A4**	**A5**
C11	<H, 0.5>, <HR, 0.5>	<M, 0.4>, <H, 0.4>, <VH, 0.2>	<M, 0.4>, <H, 0.3>, <HR, 0.3>	<L, 0.2>, <M, 0.5>, <H, 0.3>	<LR, 0.2>, <L, 0.4>, <M, 0.4>
C12	<H, 0.6>, <HR, 0.3>, <VH, 0.1>	<H, 0.2>, <HR, 0.5>, <VH, 0.3>	<M, 0.2>, <H, 0.6>, <VH, 0.2>	<LR, 0.2>, <M, 0.4>, <H, 0.4>	<L, 0.2>, <M, 0.5>, <HR, 0.3>
C13	<M, 0.4>, <H, 0.4>, <HR, 0.2>	<M, 0.2>, <HR, 0.6>, <VH, 0.2>	<L, 0.5>, <H, 0.4>, <HR, 0.1>	<M, 0.4>, <HR, 0.5>, <VH, 0.1>	<L, 0.2>, <H, 0.5>, <HR, 0.3>
C14	<H, 0.2>, <HR, 0.7>, <VH, 0.1>	<H, 0.1>, <HR, 0.7>, <VH, 0.2>	<M, 0.3>, <HR, 0.6>, <VH, 0.1>	<LR, 0.2>, <M, 0.5>, <HR, 0.3>	<M, 0.2>, <H, 0.5>, <VH, 0.3>
C15	<LR, 0.3>, <M, 0.4>, <HR, 0.3>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<LR, 0.3>, <M, 0.4>, <H, 0.3>,	<L, 0.2>, <H, 0.5>, <HR, 0.3>	<LR, 0.3>, <M, 0.3>, <HR, 0.4>
C16	<HR, 0.9>, <VH, 0.1>	<H, 0.1>, <HR, 0.7>, <VH, 0.2>	<M, 0.4>, <HR, 0.5>, <VH, 0.1>	<M, 0.2>, <H, 0.3>, <HR, 0.5>	<M, 0.3>, <HR, 0.6>, <VH, 0.1>
C17	<L, 0.4>, <H, 0.5>, <HR, 0.1>	<L, 0.3>, <H, 0.4>, <VH, 0.3>	<LR, 0.2>, <M, 0.5>, <H, 0.3>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<L, 0.4>, <H, 0.4>, <HR, 0.2>
C21	<M, 0.2>, <H, 0.4>, <VH, 0.4>	<L, 0.2>, <H, 0.6>, <HR, 0.2>	<L, 0.2>, <M, 0.4>, <HR, 0.4>	<L, 0.3>, <H, 0.5>, <VH, 0.2>	<L, 0.2>, <M, 0.6>, <HR, 0.2>
C22	<L, 0.1>, <M, 0.5>, <HR, 0.4>	<M, 0.1>, <H, 0.6>, <VH, 0.3>	<L, 0.2>, <M, 0.3>, <HR, 0.5>	<L, 0.1>, <M, 0.4>, <HR, 0.5>	<L, 0.2>, <M, 0.3>, <H, 0.5>
C23	<M, 0.2>, <HR, 0.6>, <VH, 0.2>	<L, 0.4>, <H, 0.5>, <HR, 0.1>	<LR, 0.3>, <M, 0.5>, <HR, 0.2>	<L, 0.2>, <M, 0.4>, <H, 0.4>	<LR, 0.4>, <M, 0.5>, <H, 0.1>
C24	<L, 0.3>, <H, 0.4>, <VH, 0.3>	<L, 0.2>, <H, 0.7>, <HR, 0.1>	<LR, 0.2>, <M, 0.7>, <H, 0.1>	<LR, 0.2>, <M, 0.4>, <H, 0.4>	<L, 0.5>, <M, 0.4>, <HR, 0.1>
C31	<H, 0.1>, <HR, 0.5>, <VH, 0.4>	<M, 0.3>, <HR, 0.6>, <VH, 0.1>	<M, 0.5>, <HR, 0.4>, <VH, 0.1>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.3>, <M, 0.3>, <H, 0.4>
C32	<M, 0.1>, <H, 0.7>, <VH, 0.2>	<M, 0.5>, <H, 0.5>	<L, 0.2>, <M, 0.3>, <H, 0.5>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<L, 0.1>, <M, 0.7>, <HR, 0.2>
C33	<LR, 0.1>, <L, 0.3>, <H, 0.6>	<L, 0.2>, <M, 0.5>, <HR, 0.3>	<L, 0.3>, <H, 0.6>, <HR, 0.1>	<M, 0.1>, <H, 0.5>, <HR, 0.4>	<LR, 0.2>, <L, 0.6>, <H, 0.2>
C34	<M, 0.3>, <H, 0.5>, <HR, 0.2>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<L, 0.2>, <M, 0.6>, <HR, 0.2>	<M, 0.3>, <H, 0.5>, <VH, 0.2>	<L, 0.4>, <H, 0.5>, <HR, 0.1>
C41	<L, 0.2>, <M, 0.2>, <HR, 0.6>	<M, 0.3>, <HR, 0.4>, <VH, 0.3>	<LR, 0.2>, <L, 0.2>, <H, 0.6>	<M, 0.2>, <H, 0.5>, <VH, 0.3>	<L, 0.5>, <M, 0.3>, <H, 0.2>
C42	<M, 0.1>, <H, 0.2>, <HR, 0.7>	<L, 0.2>, <H, 0.5>, <HR, 0.3>	<LR, 0.2>, <L, 0.4>, <H, 0.4>	<M, 0.4>, <HR, 0.5>, <VH, 0.1>	<LR, 0.4>, <M, 0.4>, <HR, 0.2>
C43	<M, 0.3>, <H, 0.5>, <HR, 0.2>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.1>, <L, 0.4>, <M, 0.5>	<L, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.3>, <L, 0.5>, <M, 0.2>
C44	<LR, 0.3>, <M, 0.6>, <H, 0.1>	<L, 0.3>, <M, 0.4>, <HR, 0.3>	<LR, 0.2>, <M, 0.6>, <HR, 0.2>	<M, 0.3>, <H, 0.6>, <HR, 0.1>	<LR, 0.2>, <L, 0.4>, <M, 0.4>
C51	<L, 0.2>, <M, 0.6>, <H, 0.2>	<L, 0.3>, <M, 0.4>, <H, 0.3>	<LR, 0.4>, <M, 0.4>, <HR, 0.2>	<L, 0.2>, <M, 0.4>, <H, 0.4>	<L, 0.3>, <M, 0.5>, <H, 0.2>
C52	<LR, 0.2>, <M, 0.5>, <H, 0.3>	<L, 0.1>, <M, 0.3>, <H, 0.6>	<L, 0.2>, <M, 0.6>, <HR, 0.2>	<M, 0.3>, <H, 0.5>, <HR, 0.2>	<LR, 0.3>, <M, 0.5>, <H, 0.2>
C53	<L, 0.2>, <H, 0.6>, <HR, 0.2>	<M, 0.1>, <H, 0.5>, <HR, 0.4>	<M, 0.2>, <H, 0.6>, <VH, 0.2>	<M, 0.1>, <H, 0.5>, <VH, 0.4>	<M, 0.3>, <H, 0.4>, <HR, 0.3>

Based on $IV(\text{D1})$ and Equation (3), the weight vector of the seven indicators in the tangibility dimension can be determined to be:

$\omega(\text{D1}) = \{0.148, 0.148, 0.146, 0.132, 0.158, 0.118, 0.150\}$, for indicators C11 to C17.

Similarly, we can determine the indicator weights for other dimensions. Also, the weights of the five dimensions can also be calculated based on the belief entropy and their belief structure after aggregating the corresponding indicators, shown as follows:

$\omega(\text{D2}) = \{0.255, 0.264, 0.247, 0.234\}$, for indicators C21 to C24 in dimension D2;

$\omega(\text{D3}) = \{0.264, 0.218, 0.249, 0.269\}$, for indicators C31 to C34 in dimension D3;

$\omega(\text{D4}) = \{0.255, 0.245, 0.256, 0.244\}$, for indicators C41 to C44 in dimension D4;

$\omega(\text{D5}) = \{0.351, 0.327, 0.322\}$, for indicators C51 to C53 in dimension D5;

$\omega = \{0.191, 0.191, 0.199, 0.254, 0.165\}$, for dimensions D1 to D5.

Based on the core algorithm of ERA in Equations (4)–(11), the evaluation values and weights of the related indicators can be aggregated to generate the combined belief structures of each dimension for the five HEIs, as shown in Table 4. In the same way, the final belief structure of each alternative on the FOD Θ can be calculated based on the combined evaluation values in Table 4 and the dimension weights ω, as follows:

$$S(\text{A1}) = \{\langle H_4, 0.022\rangle, \langle H_5, 0.271\rangle, \langle H_6, 0.707\rangle\} = \{\langle M, 0.022\rangle, \langle H, 0.271\rangle, \langle HR, 0.707\rangle\};$$
$$S(\text{A2}) = \{\langle H_4, 0.002\rangle, \langle H_5, 0.709\rangle, \langle H_6, 0.289\rangle\} = \{\langle M, 0.002\rangle, \langle H, 0.709\rangle, \langle HR, 0.289\rangle\};$$
$$S(\text{A3}) = \{\langle H_4, 0.998\rangle, \langle H_5, 0.002\rangle\} = \{\langle M, 0.998\rangle, \langle H, 0.002\rangle\};$$
$$S(\text{A4}) = \{\langle H_4, 0.001\rangle, \langle H_5, 0.999\rangle\} = \{\langle M, 0.001\rangle, \langle H, 0.999\rangle\};$$
$$S(\text{A5}) = \{\langle H_3, 0.018\rangle, \langle H_4, 0.980\rangle, \langle H_5, 0.002\rangle\} = \{\langle L, 0.018\rangle, \langle M, 0.980\rangle, \langle H, 0.002\rangle\}.$$

Table 4. The combined evaluation information of dimensions for five HEIs.

Dimensions	Higher Education Institutions (HEIs)	
	A1	A2
D1	*<H, 0.16>, <HR, 0.84>*	*<L, 0.008>, <M, 0.265>, <H, 0.133>, <HR, 0.375>, <VH, 0.219>*
D2	*<H, 0.129>, <HR, 0.856>, <VH, 0.015>*	*<L, 0.012>, <H, 0.987>, <HR, 0.001>*
D3	*<M, 0.653>, <H, 0.322>, <HR, 0.025>*	*<LR, 0.004>, <L, 0.002>, <M, 0.876>, <HR, 0.118>*
D4	*<M, 0.316>, <H, 0.597>, <HR, 0.087>*	*<L, 0.028>, <M, 0.41>, <H, 0.546>, <HR, 0.016>*
D5	*<L, 0.043>, <M, 0.373>, <H, 0.095>, <HR, 0.489>*	*<LR, 0.002>, <L, 0.053>, <M, 0.933>, <H, 0.011>, <HR, 0.001>*

Dimensions	Higher Education Institutions (HEIs)	
	A3	A4
D1	*<L, 0.001>, <M, 0.002>, <H, 0.962>, <HR, 0.025>, <VH, 0.01>*	*<LR, 0.002>, <M, 0.27>, <H, 0.055>, <HR, 0.673>*
D2	*<L, 0.014>, <M, 0.476>, <H, 0.175>, <HR, 0.335>*	*<L, 0.107>, <M, 0.064>, <H, 0.27>, <HR, 0.557>, <VH, 0.002>*
D3	*<L, 0.038>, <M, 0.717>, <H, 0.195>, <HR, 0.05>*	*<LR, 0.064>, <L, 0.274>, <M, 0.39>, <H, 0.272>*
D4	*<L, 0.006>, <M, 0.002>, <H, 0.98>, <HR, 0.012>*	*<L, 0.001>, <M, 0.081>, <H, 0.864>, <HR, 0.051>, <VH, 0.003>*
D5	*<LR, 0.017>, <L, 0.372>, <M, 0.177>, <H, 0.432>, <HR, 0.002>*	*<LR, 0.086>, <L, 0.537>, <M, 0.377>*

Dimensions	Higher Education Institutions (HEIs)
	A5
D1	*<LR, 0.003>, <L, 0.023>, <M, 0.511>, <H, 0.46>, <HR, 0.003>*
D2	*<L, 0.021>, <M, 0.161>, <H, 0.801>, <HR, 0.017>*
D3	*<LR, 0.036>, <L, 0.004>, <M, 0.832>, <H, 0.093>, <HR, 0.032>, <VH, 0.003>*
D4	*<L, 0.003>, <M, 0.161>, <H, 0.817>, <HR, 0.002>, <VH, 0.017>*
D5	*<LR, 0.009>, <L, 0.011>, <M, 0.794>, <H, 0.177>, <HR, 0.009>*

Due to the uncertainty of linguistic preferences during the practical evaluation, the linguistic terms should be converted into the corresponding IFNs based on Table 2. Then, the intuitionistic fuzzy evaluation results of the five HEIs can be obtained using the IFWA operator in Equation (12):

$V_1 = (0.914, 0.081)$, for HEI A1; $V_2 = (0.821, 0.157)$, for HEI A2; $V_3 = (0.401, 0.499)$, for HEI A3; $V_4 = (0.700, 0.250)$, for HEI A4; $V_5 = (0.398, 0.503)$, for HEI A5.

Finally, due to the bounded rationality of subjective assessment, five HEIs can be prioritized based on the TODIM method. Let $\theta = 2.5$, and thus, the dominance matrix between five HEIs can be determined based on Equation (13):

$$\Phi = \begin{bmatrix} 0 & 0.293 & 0.688 & 0.442 & 0.690 \\ -0.117 & 0 & 0.622 & 0.331 & 0.624 \\ -0.275 & -0.249 & 0 & -0.211 & 0.055 \\ -0.177 & -0.133 & 0.527 & 0 & 0.529 \\ -0.276 & -0.250 & -0.022 & -0.212 & 0 \end{bmatrix}.$$

According to Equation (14), the overall dominance of each HEI can be described by:

$$\xi(\text{A1}) = 1;\ \xi(\text{A2}) = 0.773;\ \xi(\text{A3}) = 0.028;\ \xi(\text{A4}) = 0.524;\ \text{and}\ \xi(\text{A5}) = 0.$$

Therefore, we can determine that $\xi(\text{A1}) > \xi(\text{A2}) > \xi(\text{A4}) > \xi(\text{A3}) > \xi(\text{A5})$. The ranking of the five Chinese HEIs can be determined as A1 $\succ$ A2 $\succ$ A4 $\succ$ A3 $\succ$ A5, where the symbol '$\succ$' means 'superior to'.

5. Results and Discussion

To evaluate student-perceived service quality in five Chinese HEIs within the context of sustainable development, the obtained result (i.e., A1 $\succ$ A2 $\succ$ A4 $\succ$ A3 $\succ$ A5) reveals that A1 achieves the best performance by comprehensively considering all five dimensions. Using the hybrid fuzzy TODIM-ERA method, the overall dominance degrees of all the HEIs for each of the five dimensions can be calculated to obtain the corresponding prioritization results and analyze the pros and cons of each HEI.

As shown in Figure 4, HEI A1 is the best rated in dimensions D2, D3, and D4, and ranks second and third in dimensions D1 and D5, respectively. Thus, it is not surprising that A1 is the optimal HEI for all-around performance. However, the overall dominance degree of A1 on the empathy dimension (D5) is only 0.255, which is markedly lower than those of the top two HEIs (A4 and A2). These results suggest that HEI A1 must develop student-centered educational policies and pay attention to educational equity in teaching and administrative implementation. HEI A2 performs best in dimension D1 and ranks second in the other four dimensions. Specifically, all the degrees of overall dominance for D2, D3, and D5 are near 0.5. Thus, the service quality of A2 must be improved in terms of the reliability, responsiveness, and empathy dimensions. In general, HEI A3 ranks lower in all five dimensions. In particular, the overall dominance degree of A3 on D1 is 0, indicating that A3 has the lowest evaluation in the tangibility dimension. In practice, HEI A3 has just moved to a new campus on the city's outskirts. Therefore, HEI A3 should continue to construct and upgrade its campus, facilities, and equipment to meet the needs of students in learning and living. HEI A4 achieves the first performance level in dimension D5, highlighting the success of its personalized talent training model. However, there is still room for A4 to improve in dimensions D1 to D4, in which A4 only ranks third and fourth, respectively. Therefore, HEI A4 must fully consider the relevant indicators in the dimensions of tangibility, reliability, responsiveness, and assurance in future educational practice. Regarding HEI A5, its best performance is in dimension D1, in which the overall dominance degree is 0.532. However, the degrees of A5 for the other dimensions D2 to D5 are the worst among the five HEIs. Therefore, there is an urgent need for HEI A5 to pay attention to students' insights and formulate comprehensive and long-term strategies to improve its service quality with sustainability.

As discussed by Lau et al. [43], maritime transportation education is considered to stem from practical orientation. Professional education needs to bridge scientific knowledge and practical requirements. For maritime transportation students, it should be essential to acquire the fundamental theories and pick up practical skills to fulfil the expectations of the labor market and sustainable development [21]. The school-enterprise cooperative training model has been emerging and popular in China in recent years. Therefore, the HEIs are encouraged to establish collaboration relations with industrial enterprises, such as port operators and shipping companies [51]. To align with the educational trends in maritime transportation, the HEIs must enhance the teaching facilities and environments in the tangibility dimension [42]. In terms of the reliability dimension, the multi-disciplinary curriculums and programs need to focus on the involvement of industry professionals to prepare students for the workforce [51]. Maritime transportation courses need to incorporate innovative pedagogical approaches in the responsiveness dimension, such as guest lectures, game-based learning, and problem-solving education [21,40], to encourage a shift in thinking and attitudes toward environmentally friendly behavior. In the assurance dimension, the HEIs should ensure that teachers and other staff possess sufficient relevant expertise in maritime transportation to guide their students in their career planning [42]. Additionally, student-centered educational philosophy should be emphasized in the empathy dimension to strengthen the students' satisfaction, engagement, and performance [33].

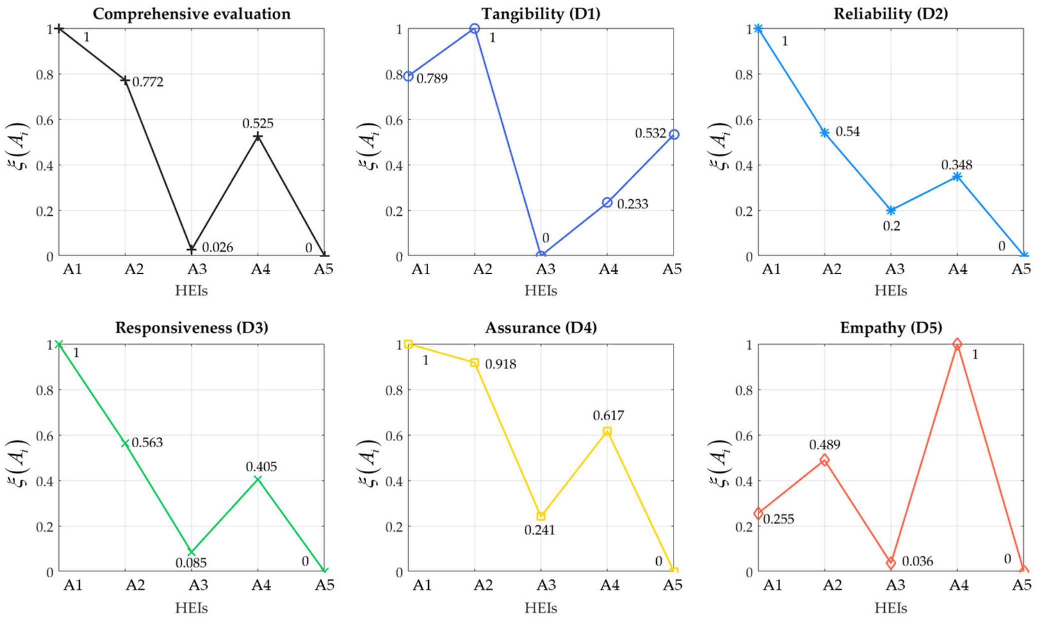

Figure 4. The ranking of alternative HEIs for each dimension.

To investigate the influence of the parameter θ, sensitivity analyses are conducted in this section. Assuming that the parameter θ ranges from 0.25 to 10, then the overall dominance of each HEI can be determined based on different θ, as shown in Figure 5. The parameter θ represents the attitude to loss aversion: a better alternative can provide more gain when θ is larger and can provide less loss when θ is smaller [37]. As shown in Figure 5, the variation of the parameter θ has only a marginal effect on the overall dominance degrees of the alternative HEIs, particularly for the best and worst alternatives. These results imply that the results of this study can be used reliably and effectively to guide the HEIs to evaluate their service quality. Regarding the other HEIs (A2–A4), their overall dominance degrees decrease smoothly as θ increases. A2′s better performance also gives it a lower rate of change (approximately 8%), while A3's worse performance gives it a markedly higher rate of change (approximately 16%), which indicates that loss aversion has different influences on various HEIs.

The evaluation results can prioritize all alternative HEIs and potentially affect higher education policymakers. From a practical perspective, the evaluation of HEIs in this study can clarify the implementation effect of educational policies and thus ensure the continuous improvement of higher education service quality within sustainability. First, the evaluation results can describe the strengths and weaknesses of each HEI from various aspects. Thus, empirical evidence can be provided to policymakers to make reasonable decisions concerning campus construction, teaching reform, administrative management, etc. Second, each HEI's performance level for different dimensions can assist managers in determining which aspects of the HEI require the most attention and how to allocate the limited resources most appropriately. Third, the evaluation method based on uncertainty and bounded rationality can help decision makers manage the complex environment while considering five dimensions and 22 indicators. Also, the proposed evaluation process has been shown to be reliable and robust. Finally, the ranking of the alternative HEIs should encourage HEIs to set their own benchmarks by considering their competitors' performances. Thus, HEIs can more effectively develop strategic planning and achieve their development goals based on the evaluation results produced by this study's proposed method.

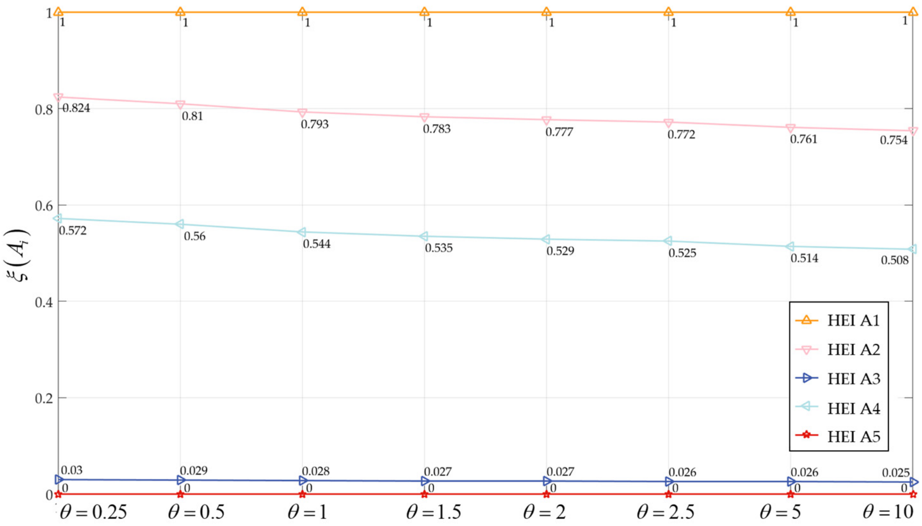

Figure 5. The overall dominance degrees of alternative HEIs with different θ.

6. Conclusions

In this study, a novel evaluation framework of higher education service quality for sustainable development is established and employed in five Chinese higher education institutes (HEIs). Using the fuzzy SERVQUAL scale and ESD goals, a conceptual model is designed by systematizing 22 indicators in five dimensions: tangibles, reliability, responsiveness, assurance, and empathy. Then, to address such a multicriteria decision-making (MCDM) problem catering to uncertainty and bounded rationality, a hybrid fuzzy TODIM-ERA method is proposed to obtain the comprehensive evaluation results of all alternative HEIs. Based on empirical research and sensitivity analysis, the proposed evaluation framework is shown to be effective and robust. In this study, the innovative contributions can be primarily summarized into the following three key points:

(1) Compared with the classic SERVQUAL scale, the conceptual model of the evaluation indicator system has added seven indicators related to sustainable development, namely "Environmentally friendly infrastructures (C16)", "Sustainability oriented practices (C17)", "Sustainable curricula (C24)", "Environmental sensitivity (C34)", "Staff development and rewards (C43)", "Rules and regulations (C44)", and "Access to disabled students (C53)". Therefore, this study provides a theoretical basis for HEIs to improve service quality and formulate sustainable development goals.

(2) To address uncertainty in evaluating higher education service quality, intuitionistic fuzzy theory and the ERA are used to represent and aggregate the uncertain information, respectively. This method can provide a more reasonable and accurate representation and fusion of uncertain information in contrast to the fuzzy set and its aggregation operators in the existing literature.

(3) The ranking order of all the alternative HEIs is determined based on the TODIM method and the intuitionistic fuzzy Euclidean distance. This method can consider the various attitudes of loss aversion by adjusting the value of the parameter θ and then has the advantage of overcoming the drawbacks of assuming complete rationality.

In future research, the perceptions of more stakeholders, such as administrators, teachers, and the government, must be considered when assessing the quality of higher education for sustainable development, which will markedly increase the complexity and difficulty of the evaluation process.

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