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Towards Sustainable Tourism: Utilizing Fuzzy AHP-TOPSIS Approach for Green Hotel Selection

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Abstract

In recent years, the green hotel market in Belize has experienced notable growth due to the rising adoption of eco-friendly practices and increased environmental consciousness among customers. Despite being an emerging concept in Belize, green hotels play a pivotal role in fostering a green lifestyle and raising environmental awareness among the population. This study focuses on understanding factors influencing customers' intent to choose green hotels in Belize, presenting a consumer-oriented model for assessing hotels' green scores. Through an extensive literature review, 50 critical indicators were identified and grouped into nine key aspects as crucial attributes for selecting green hotels. The proposed model utilizes the Fuzzy AHP to determine criteria weights and the Fuzzy TOPSIS to calculate green scores and rankings. The Fuzzy Delphi method is incorporated for survey response analysis, distilling 50 indicators down to the most critical 40 factors grouped into nine key aspects for selecting green hotels. Results highlight "social responsibility and communication" as the most critical dimension. Comparative analyses with Fuzzy COPRAS and Fuzzy VIKOR validate the findings, contributing significantly to Belize's sustainability, ecotourism, and green hotel selection. The study offers valuable insights for businesses and marketers to formulate effective strategies, providing constructive solutions and directions for future sustainability and green tourism research.

Keywords: Green hotel, Fuzzy delphi, Fuzzy AHP, Fuzzy TOPSIS, Fuzzy theory, sustainability.

1 | Introduction

The hospitality industry has prioritized sustainability due to environmental and economic concerns, leading to the rise of "green hotels". These accommodations promote environmentally responsible practices and

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sustainable operations, contributing to sustainable tourism [1]. Green hotels differentiate themselves by implementing energy reduction, water conservation, waste management, and renewable energy sources [2]. They often participate in certification programs in urban areas, villages, or remote locations [3]. Despite the positive impact, the hotel industry still contributes to environmental harm, prompting more hotels to join the "green movement" [4]. However, the construction of green hotels is more expensive, influencing customer decision-making, yet the growing preference for sustainable experiences suggests an expanding market for green hotels [5].

Belize's tourism industry, vital for its economy, is addressing environmental concerns through sustainability practices while navigating the aftermath of the COVID-19 pandemic. Despite setbacks, the industry adapts to green practices, contactless payments, and digital marketing for recovery and customer satisfaction [6]. Belize's hotel industry is booming, with 30 new hotels and 10,359 rooms opening in 2022, driven by a surge in foreign tourists totaling 602,000 in the year's first half[1]. Online sales are expected to dominate, constituting 61% of total revenue by 2027. The growth boosts the national budget and creates job opportunities, highlighting the hospitality sector's pivotal role in Belize's economic development. The rise in tourism, reaching 18 million international visitors in 2019, has spurred interest in eco-friendly practices, led by the Sheraton Hotel's early adoption of green certifications, setting a standard for environmental conservation and community support among other hotels in Belize[2].

Green hotels are crucial in Belize's tourism industry, contributing directly to sustainable development goals. Their focus on community engagement, fair labor, and environmentally friendly practices promotes social, economic, and environmental well-being. However, Belize faces challenges in promoting environmentally responsible practices in its hotel sector, primarily due to the lack of comprehensive models for green hotel selection in small developing countries like Belize. The hospitality industry, particularly hotels, in Belize, struggles with environmental issues, leading to poor rankings in global sustainability assessments [7]. Despite a desire for sustainable travel, the lack of green hotels, influenced by cost, regulations, and awareness, remains a significant obstacle [8]. The absence of standardized criteria for approving green hotels complicates consumers' ability to identify eco-friendly options, hindering responsible travel choices [9]. Limited research on staying at green hotels in Belize raises concerns about the country's alignment with the global trend of green consumption, emphasizing the need for further research in this context [10]. By grounding in empirical data and rigorous analysis to provide actionable insights and guide hotel businesses in their pursuit of fostering sustainability, this research aims to achieve the following objectives:

I. To identify and analyze the key attributes influencing green hotel selection in Belize through a comprehensive literature review and expert consultation.

II. To assess and compare the sustainability performance of Belizean hotels, identifying the top green contributors to sustainable tourism.

III. To provide recommendations and guidelines for hotel managers, policymakers, and stakeholders to promote and enhance sustainable practices within the Belize tourism industry.

This research significantly advances sustainable tourism practices in Belize's hospitality industry. By identifying key attributes influencing green hotel selection, developing a robust model for evaluation through MCDM methods, and applying this model to assess sustainability performance, the study offers actionable insights for hotel managers, policymakers, and stakeholders. The comprehensive analysis addresses the challenges of promoting environmentally responsible practices in a small developing country like Belize, paving the way for enhanced sustainability in the tourism sector. Through empirical data and rigorous analysis, the research not only provides a framework for green hotel selection but also underscores the importance of aligning with global trends of green consumption for sustainable tourism development. This study highlights

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[1] https://tophotel.news/

[2] https://www.belizetourismboard.org/belize-tourism/statistics/

the critical role of green hotels in fostering environmental conservation, community engagement, and economic growth, positioning Belize as a leader in sustainable tourism practices.

The study's structure is described. The body of literature currently in existence is analyzed in Section 2. Section 3 explains the study process and the methodology used in detail. Section 4 presents the discussions and findings from the empirical analysis, and Section 5 concludes by summarizing the main conclusions, consequences, constraints, and prospective research areas.

2 | Literature Review

2.1 | Attributes of Green Hotel

Belize, known for its natural beauty, faces environmental challenges due to growing tourism, particularly in the hotel sector, which is criticized for its ecological footprint [11], [12]. Responding to concerns and regulations, hotels adopt green practices driven by eco-conscious travelers and environmental standards [13]. Green initiatives align with guest values, reduce costs, and enhance brand image, benefiting the environment and the industry [14], [15]. In Belize's ecotourism context, Green Hotels are crucial for sustainability, motivating a study exploring factors influencing tourists' preference for green hotels [16]. Responding to environmental awareness, Green hotelslay a significant role in hospitality by minimizing impact through waste management, energy efficiency, and pollution control [17]. Tangible and behind-the-scenes efforts build guest trust and extend to social responsibility, engaging with local communities and supporting cultural heritage [18]. Despite initial costs, green hotels emphasize long-term economic benefits, transforming luxury, comfort, and environmental responsibility for a more sustainable hospitality future [19].

Table 1 summarizes the literature review on the attributes used as the dimensions and sub-factors for the case study on sustainability performance evaluation of green hotels in Belize.

Table 1. Criteria and sub-criteria for sustainability evaluation.

No	Dimension	Code	Factors
1	Water and energy management [20–30]	SC11	Water conservation practices
2		SC12	Energy-efficient lighting systems
3		SC13	Energy management systems
4		SC14	Renewable energy integration
5		SC15	HVAC efficiency and optimization
6	Waste management and recycling [24–33]	SC21	Waste reduction strategies
7		SC22	Segregation and recycling programs
8		SC23	Composting and organic waste management
9		SC24	Hazardous waste disposal
10		SC25	Electronic waste recycling
11	Environmental innovation and technology [34]	SC31	Sustainable construction and materials
12		SC32	Carbon footprint tracking system
13		SC33	Application of digital services and devices
14		SC34	Integration of green technologies
15	Sustainable supply chain management [23], [25–30], [32], [33]	SC41	Supplier evaluation and selection
16		SC42	Local sourcing and fair-trade practices
17		SC43	Responsible procurement
18		SC44	Sustainable packaging and product choices
19		SC45	Waste reduction in the supply chain
20	Conservation and preservation of natural resources [23], [24], [32], [35], [36]	SC51	Protection of flora and fauna
21		SC52	Preservation of natural habitats and ecosystems
22		SC53	Sustainable landscaping and green spaces
23		SC54	Protection of coastal and marine environments
24		SC55	Conservation of water bodies (rivers, lakes, etc.)

Table 1. Continued.

No	Dimension	Code	Factors
25	Guest experience and education	SC61	Indoor air quality and ventilation
26	[24], [32], [35], [36]	SC62	Eco-friendly transportation options
27		SC63	Sustainable food and beverage options
28		SC64	Environmental education and guest engagement
29		SC65	Use of organic and biodegradable toiletries
30		SC66	Design for natural lighting and passive cooling
31		SC67	Reduction of single-use plastics
32	Certification and recognition	SC71	Green certifications
33	[24], [25], [29], [32], [35], [36]	SC72	Eco-labels
34		SC73	Certification criteria
35		SC74	Verification process
36		SC75	Marketing and branding benefits
37		SC76	Competitive advantage
38		SC77	Increased bookings and occupancy
39		SC78	Cost savings
40		SC79	Continuous improvement
41	Environmental performance	SC81	Monitoring and evaluation systems
42	measurement and reporting	SC82	Key Performance Indicators (KPIs)
43	[23], [24], [32], [35], [36]	SC83	Environmental impact assessments
44		SC84	Sustainability reporting
45		SC85	Transparency and accountability
46	Social responsibility and	SC91	Staff training and education on sustainability
47	communication	SC92	Engaging with local communities and indigenous groups
48	[24–30], [32], [33], [35–40]	SC93	Collaboration with government agencies and NGOs
49		SC94	Promotion of cultural heritage and traditions
50		SC95	Support for local environmental conservation projects
51		SC96	Ethical and fair labor practices
52		SC97	Accessibility and inclusivity for people with disabilities
53		SC98	Promotion of responsible tourism behavior among guests

2.2 | Literature Review on Theoretical Foundation

The study on eco-conscious travel and green hotel choices integrates theories like the theory of planned behavior and means-end chain theory to explore decision-making motivations [41]. It investigates attitudes, social influences, and behavioral control in selecting eco-friendly accommodations. Information processing theory, heuristics, and biases illuminate mental processes and decision distortions [42], [43]. Social influence theory and social exchange theory examine external influences and perceived benefits and costs [44], [45]. Sustainability frameworks, including the sustainable value framework and circular economy model, provide insights into the broader value proposition of green hotels [46]. Integrating these theories enhances understanding of sustainable tourism initiatives and calls for empirical research [47].

Green hotels face a complex decision-making problem in their pursuit of eco-friendly practices and sustainability, necessitating innovative approaches like MCDM methods. Since the 1970s, diverse MCDM approaches have been applied in various fields, allowing for assessing conflicting factors and identifying the most suitable option based on criteria [48]. These methods, including AHP, TOPSIS, and VIKOR, consider environmental, economic, social, and cultural factors impacting ecotourism sustainability. AHP has been applied in green hotel selection, assessing environmental management, energy efficiency, and waste management [49]. Additionally, the VIKOR method aids in handling complex decision-making problems by identifying compromise solutions that balance conflicting criteria, which is crucial for green hotel selection [50]. Fuzzy theory enhances the MCDM toolbox, addressing uncertainty through methods like Fuzzy Logic, which is applied in green hotels to handle imprecise data and prioritize elements like biophilic designs [51]. The Delphi technique contributes to achieving consensus in decision-making, while the COPRAS method provides a structured approach to rank green hotels based on sustainability criteria, considering contextual factors [52]. Together, these methods offer a comprehensive approach to address the challenges of green hotel selection, providing flexibility and tools for sustainable development [53].

Table 2 shows the literature surrounding green hotel selection and sustainability practices within the hospitality industry, which has grown significantly in recent years. A critical review of the provided papers reveals various methodologies to evaluate sustainability criteria, rank eco-friendly hotels, and assess green performance within hotel chains.

Several papers, such as those by Fu-Hsiang Chen et al. [54] and Sarfaraz Hashemkhani Zolfani et al. [46], adopt hybrid MCDM models. Chen utilize a balanced scorecard approach combined with DEMATEL and ANP, while Zolfani propose a model integrating SWARA and COPRAS techniques. These methodologies offer comprehensive frameworks for evaluating various aspects of sustainability and performance within hotel operations.

Yadegaridehkordi et al. [55] and Kamalkhani et al. [56] employ multi-criteria and machine learning techniques, including TOPSIS and Fuzzy PROMETHEE, to segment travelers' preferences and evaluate greenness in Iranian hotels, respectively. These studies underscore the importance of utilizing advanced decision-making methods to accommodate the complexity of sustainability assessments and guest preferences in hotel selection processes.

Research by Nasser et al. [57] and Saidet al. [58] focuses on sustainability indicators and critical criteria for eco-hotel performance in Yemen. They employ AHP, Fuzzy AHP, and FDM methods to identify essential measures and consensus among experts. Such studies highlight the need for context-specific evaluations and stakeholder engagement in sustainable hotel development.

Despite the advancements in methodologies and frameworks for green hotel selection and evaluation, there remains a notable research gap in the context of Belize. While studies have explored sustainability practices in various regions, more attention should be paid to the unique environmental, social, and economic factors influencing green hotel selection in Belize. Consequently, there is a need for a tailored approach that considers the specific challenges and opportunities within the Belizean hospitality industry.

In response to this gap, our research proposes an Integrated Fuzzy AHP- TOPSIS model for green hotel selection in Belize. By integrating Fuzzy logic into AHP and TOPSIS methodologies, we aim to accommodate uncertainty and subjective judgments inherent in sustainability assessments. Our approach will involve collecting data on sustainability indicators relevant to the Belizean context, engaging stakeholders to prioritize criteria, and applying the integrated model to rank eco-friendly hotels. Through this research, we seek to provide actionable insights for hotel managers, policymakers, and tourists interested in promoting sustainable tourism practices in Belize (*Table 2*).

Table 2. Summary of studies on Green Hotel evaluation and selection.

No.	Authors	Year	Location	Methods
1	Chen et al. [54]	2011	Taiwan	Balanced scorecard, hybrid DEMATEL, and ANP
2	Yadegaridehkordi et al. [55]	2021	Malaysia	Multi-criteria, machine learning (TOPSIS, CART)
3	Sari [59]	2018	Turkey	Fuzzy TOPSIS
4	Nasser et al. [57]	2021	Yemen	AHP, Fuzzy AHP, FDM
5	Hashemkhani et al. [46]	2018	Iran	SWARA, COPRAS
6	Wang and Nguyen [60]	2022	Vietnam	Best–worst method, fuzzy TOPSIS
7	Akel and Noyan [61]	2024	Turkey	Qualitative research, SWARA
8	Varolgüneş et al. [62]	2023	Turkey	AHP
9	Nasser et al. [58]	2021	Yemen	Fuzzy Delphi method
10	Kamalkhani et al. [56]	2022	Iran	Fuzzy PROMETHEE
11	Nuriyev et al. [63]	2023	Azerbaijan	Z-numbers, ORESTE, TOPSIS

3 | Methodology

3.1 | Research Framework

Steps for the FAHP-FTOPSIS model are illustrated in *Fig 1*. Phase 1 starts with identifying green hotels to be evaluated and establishing expert groups for consultation during the process. Then, the F-Delphi method is applied to delineate the criteria through an extensive literature review of green hotel attributes. Moreover, Phase 2 continues calculating the criteria, sub-criteria weights, and the consistency test using FAHP. Finally, in Phase 3, the FTOPSIS method calculates the green scores and ranking of the green hotels. It should be noted that the weight obtained from the FAHP method is applied throughout the FTOPSIS analysis. The following section will discuss each phase of the application process in more detail, including step-by-step procedures for each method.

3.2 | Fuzzy Delphi

The Delphi method, originally designed for forecasting purposes, depends on a group of experts for organized communication. Experts respond to questions in multiple rounds in the Delphi process, with a facilitator summarizing their input and reasoning after each round. Experts are required to amend their answers, as well as those of their peers, that leads the group towards consensus or stability in findings. The final round's average determines the overall results, often yielding more accurate outcomes than unstructured group discussions [64]. However, traditional Delphi techniques may need to adequately account for data imprecision and uncertainty [65]. To overcome this constraint, a modified strategy called the Fuzzy Delphi (F-Delphi) method integrates traditional Delphi procedures with Fuzzy sets to validate critical components and determine assessment criteria [66], [67]. Hence, this research employs the F-Delphi technique to ensure reliability and coherence, establishing expert consensus and identifying appropriate indicators utilized as criteria and sub-criteria for the FAHP methodology.

This study employs Triangular Fuzzy Numbers (TFNs) to capture better and represent expert knowledge. Linguistic values for each expert and attribute are derived using TFNs and linguistic terms, as shown in *Table 3*.

Step 1. For p experts (i = 1, 2, 3, … p) and q attributes (j = 1, 2, 3, …, q), TFN Fij = (lij ; mij ; uij), with lij as the lower limit, mij as the modal value, and uij as the upper limit (*Table 3*).

Table 3. Linguistic terms with TFNs value.

Code	Linguistic Terms	TFNs	Score of index
WK	Weak	(0, 0, 0.25)	0
MO	Moderate	(0, 0.25, 0.5)	1
FR	Fair	(0.25, 0.5, 0.75)	2
ST	Strong	(0.5, 0.75, 1)	3
EM	Extreme	(0.75, 1, 1)	4

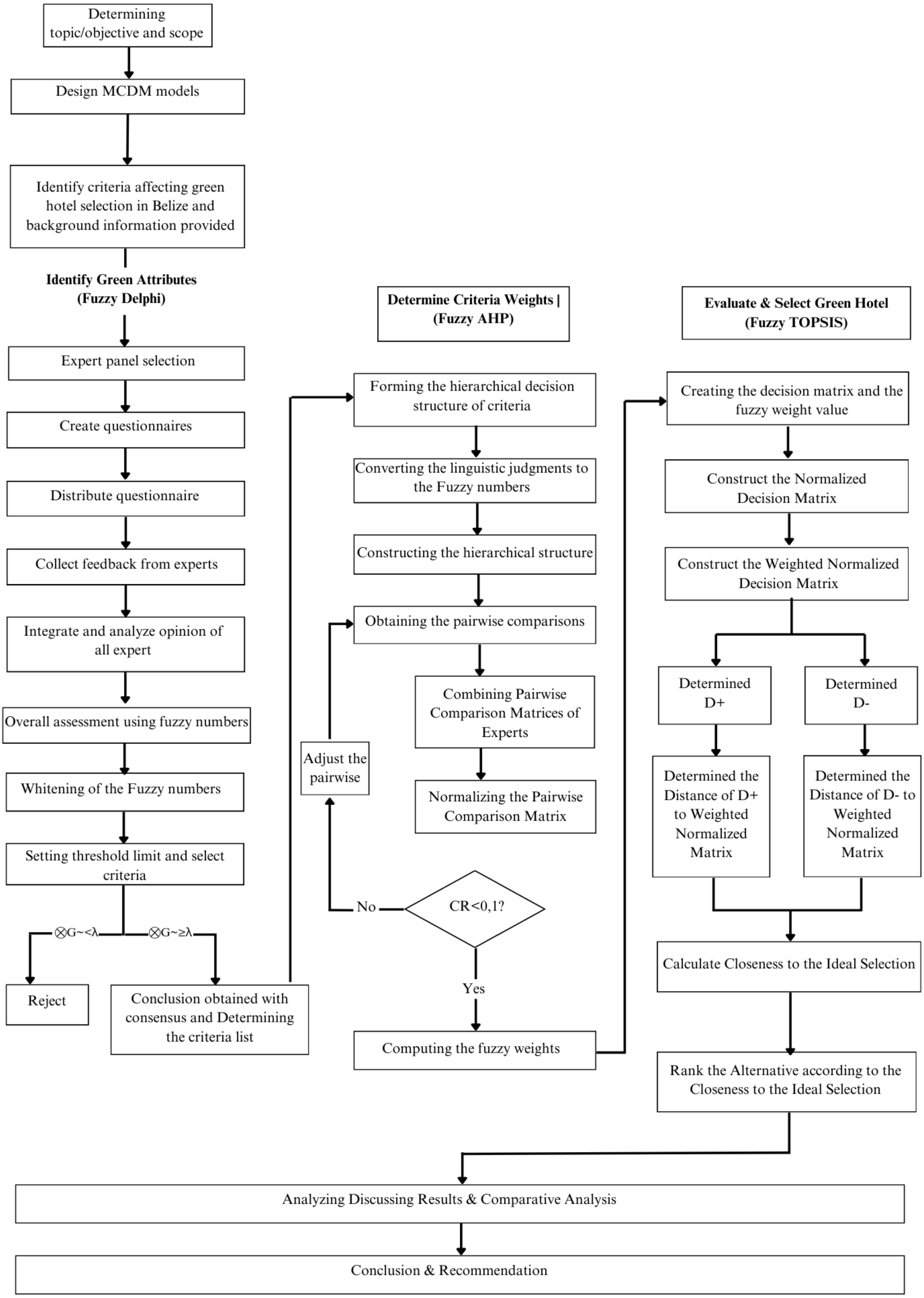

Fig 1. Research framework.

The weight of attribute Fj is then refers to Fj = (lj ; mj ; uj), where:

$$l_j = \min(l_{ij}); \quad m_j = \sqrt[n]{\prod_1^n m_{ij}}; \quad u_j = \max(u_{ij}). \tag{1}$$

Step 2. Two approaches are used for interpreting TFNs: convex combination and alpha cut values. The convex combination value calculates a weighted average considering membership levels across the TFN range, providing a representative value that reflects experts' opinions comprehensively [68]. On the other hand, the alpha cut value identifies a specific membership level and crisp value where the TFN holds that membership. The convex combination value, parameter λ ranges between 0 and 1. The resulting value, D_j (α_j, β_j) is obtained using *Eqs. (2)-(3)*:

$$\alpha_j = u_j - \lambda(u_j - m_j).$$
$$\beta_j = l_j - \lambda(m_j - l_j). \tag{2}$$
$$D_j = \int(\alpha_j, \beta_j) = \lambda[\alpha_j + (1 - \lambda)\beta_j]. \tag{3}$$

Step 3. The threshold for accepted attributes is determined by *Eq. (4)*. An attribute is deemed acceptable if $D_j > 6$, but rejected if $D_j < 6$.

$$\text{Therehold } (6) = \sum_{a=1}^{n} \frac{D_j}{n}. \tag{4}$$

3.3 | Fuzzy Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) involves breaking down problems into smaller parts and making judgments by comparing pairs of issues, known as "pairwise comparisons," to establish ratio scales. These scales are then synthesized to select the best alternative. AHP organizes perceptions, feelings, judgments, and memories into a framework that illustrates the forces influencing a decision, utilizing objective mathematics to process subjective preferences. The method arranges forces from general to specific aspects and enables result prediction, appealing to decision-makers at all levels. This study employs the FAHP method, which follows the steps outlined below [69].

Step 1. Criteria identified through F-Delphi will be used as the main dimension and sub-criteria for the FAHP.

Step 2. Construct a Fuzzy pairwise comparison matrix where experts assess the significance of one criterion relative to another in green practices. Expert opinions are collected using a linguistic scale established by Saaty [70] as illustrated in *Table 4*.

Table 4. Fuzzy linguistic scale for FAHP.

Linguistic Scale (xkij)	Saaty Scale	Fuzzy Membership Function (lij, mij, uij)	Fuzzy Reciprocals (1/uij, 1/mij, 1/lij)
No Important (NI)	1	(1, 1, 1)	(1, 1, 1)
Barely Important (BI)	2	(1, 2, 3)	(1/3, 1/2, 1/1)
Slightly Important (SI)	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Fairly Important (FI)	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Moderately Important (MI)	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Almost as Important (AI)	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very Important (VI)	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Strongly Important (STI)	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely Important (EXI)	9	(9, 9, 9)	(1/9, 1/9, 1/9)

In *Eq. (5)*, xkij denotes the linguistic scale determined by expert k concerning the preference of criterion i over criterion j.

$$\text{Dkij} = \begin{matrix} \widetilde{X}_{11} & \widetilde{X}_{12} & \cdots & \widetilde{X}_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ \widetilde{X}_{m1} & \widetilde{X}_{m2} & \cdots & \widetilde{X}_{mn} \end{matrix}, \quad (5)$$

Step 3. A Fuzzy matrix is then developed.

$$\text{Fkij} = \begin{matrix} x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix}, \quad (6)$$

$$\text{xij} = (\text{lij, mij, uij}), \text{xji} = (1/\text{uij}, 1/\text{mij}, 1/\text{lij}),$$

where i ≠ j.

Step 4. Aggregating Fuzzy matrices are aggregated using geometric mean method, as shown in *Eq. (7).*

$$\text{Bij} = \sqrt[k]{\prod_{k=1}^{K} F_{kij}}, \forall \text{Fkij} \in (\text{lkij, mkij, ukij}). \quad (7)$$

Step 5. The aggregated matrix is then defuzzified using best non-Fuzzy performance BNP method [71], as shown in *Eq. (8).*

$$\text{BNPij} = \frac{(u_{ij} - l_{ij}) + (m_{ij} - l_{ij})}{3} + \text{lij}. \quad (8)$$

Step 6. Normalization of the BNP score.

$$\text{Nij} = \frac{\text{BNP}_{ij}}{\sqrt{\sum_{i=1}^{n} \text{BNP}_{ij}^{2}}}, \quad (9)$$

Step 7. The weight score of each criteria is calculated.

$$\text{Wi} = \frac{\sum_{i=1}^{n} N_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} N_{ij}}. \quad (10)$$

Step 8. The consistency ratio is computed using *Eqs. (11)-(13)* to assess expert consistency during pairwise comparison.

$$CR = \frac{\text{CI}}{\text{RI}}. \quad (11)$$

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \quad (12)$$

with $\lambda\text{max} = \frac{\sum_{j=1}^{n} B_{ij} W_j}{W_i}$.

The consistency ratio (RI) value relies on the number of criteria n [72]. The consistency ratio should be below 0.1 to validate the pairwise comparison matrix. If it exceeds this threshold, experts should reassess their evaluations, as inconsistency would violate the transitivity principle.

3.4 | Fuzzy TOPSIS

Chen's Fuzzy TOPSIS approach encompasses the traditional TOPSIS technique to handle Fuzzy group decision-making scenarios by incorporating TFNs and defining crisp Euclidean distance between Fuzzy numbers. This approach encourages decision-makers to employ linguistic considerations to rank options relative to criteria. *Table 5* provides a linguistic rating scale for alternatives, aiding decision-makers in assigning ratings to options concerning each criterion. These ratings can be computed using the following formula, assuming a decision group comprises k members.

Table 5. Fuzzy linguistic rating scale for F-TOPSIS.

Linguistic Rating Scale	Fuzzy Score
Extremely Poor (EP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Fairly Poor (FP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Fairly Good (FG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

Step 1. Criteria's weights from F-AHP is applied. Fuzzy ratings of alternatives concern each criterion. The Fuzzy matrix can be described by *Eqs. (13)- (15)*.

$$\tilde{X}_{ij} = \frac{1}{k}\left[\tilde{X}_{ij}^{1} + \tilde{X}_{ij}^{2} + \cdots + \tilde{X}_{ij}^{k}\right]. \tag{13}$$

$$D = \begin{matrix} \tilde{X}_{11} & \tilde{X}_{12} & \cdots & \tilde{X}_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{X}_{m1} & \tilde{X}_{m2} & \cdots & \tilde{X}_{mn} \end{matrix}. \tag{14}$$

$$W = [w_1, w_2, \dots, w_n], \qquad j = 1,2,\dots,n, \tag{15}$$

where $\tilde{X}_{ij}^{k}$ is evaluation of alternative i respect to criterion j.

Step 2. The linear scale transformation simplifies the conversion of multiple criteria scales into a single scale. The normalized Fuzzy decision matrix, denoted by $\tilde{R}$, uses *Eq. (16)*.

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m\times n}. \tag{16}$$

Step 3. To obtain the weighted normalized Fuzzy decision matrix, we define sets B and C as the sets of benefit and cost criteria, respectively, using *Eqs. (17)-(20)*:

$$\tilde{r} = \left(\frac{\tilde{\mu}_{ij}}{C_j^*}, \frac{\nu_{ij}}{C_j^*}, \frac{\pi_{ij}}{C_j^*}\right), j \in B. \tag{17}$$

$$\tilde{r} = \left(\frac{\mu_j^-}{C_j}, \frac{\nu_j^-}{C_j}, \frac{\pi_j^-}{C_j}\right), j \in C. \tag{18}$$

$$C_j^* = \max_{i_{C_{ij}}}, j \in B. \tag{19}$$

$$a_j^- = \min_{i_{a_{ij}}}, j \in C. \tag{20}$$

According to the normalization above, the normalized triangular Fuzzy number ranges maintain the property that they fall within [0; 1]. The weighted normalized Fuzzy decision matrix is shown below, taking into account the various weights assigned to each criterion using *Eqs. (21)* and *(22)*.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m\times n}, i = 1,2,\dots,m;\ j = 1,2,\dots,n, \tag{21}$$

where

$$\tilde{v}_{ij} = \tilde{r}_{ij}(.)d(C_j). \tag{22}$$

Step 4. Calculating the Fuzzy Positive-Ideal Solution (FPIS, A*) and the Fuzzy Negative-Ideal Solution (FNIS, A-). The F (FPIS, A*) and the (FNIS, A-) are calculated using *Eqs. (23)-(25)*:

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*). \tag{23}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-), \tag{24}$$

where,

$$\tilde{v}_j^* = (1,1,1) \text{ and } \tilde{v}_j^- = (0,0,0), j = 1,2,\dots,n. \tag{25}$$

Step 5. The distance of each alternative from A* and A- can be computed using *Eqs. (26)* and *(27)* as

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1, 2, \ldots, m. \quad (26)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, \ldots, m. \quad (27)$$

Let $\tilde{\varrho} = (\varrho_1, \varrho_2, \varrho_3)$ and $\tilde{\xi} = (\xi_1, \xi_2, \xi_3)$ are two IFNs. The following formula calculates the distance between two Fuzzy numbers using *Eq. (28)*:

$$d(\tilde{\varrho}, \tilde{\xi}) = \sqrt{\frac{1}{3}[(\varrho_1 - \xi_1)^2 + (\varrho_2 - \xi_2)^2 + (\varrho_3 - \xi_3)^2]}. \quad (28)$$

Step 6. The alternatives ranking is based on the closeness coefficient using *Eq. (29)*.

$$C_{C_i} = \frac{\tilde{d}_j^-}{\tilde{d}_j^* + \tilde{d}_j^-}, i = 1, 2, \ldots, m. \quad (29)$$

4 | Discussions

4.1 | Expert Panel

Expert selection constitutes a pivotal phase in implementing the Delphi technique to guarantee data accuracy and research results. As Niederberger et al. [73] highlighted, establishing a well-rounded panel necessitates the thoughtful inclusion of experts from various backgrounds. A sample size larger than 10 experts is considered adequate for obtaining appropriated results [74]. To ensure research accuracy and validity, 30 experts from various green hotel and sustainability sectors were invited. These included professionals from the deliberative process, including government officials, hotel organization representatives, small and medium-sized enterprises, ecologists, tourism experts, and sustainable development practi-tioners. A range of perspectives and expertise secures green hotel initiatives' multifaceted complexity. Summary of re-spondents' demography is shown in *Table 6*.

Table 6. Demographic summary of 30 respondents.

Information	Item	Frequency	Percentage
AGE	Over 50 years old	7	23,33%
	30 - 50 years old	14	46,67%
	Under 30	9	30,00%
GENDER	Male	12	40,00%
	Female	12	40,00%
	Other	6	20,00%
EDUCATION	Bachelor's	15	50,00%
	Master	7	23,33%
	Phd	8	26,67%
EXPERIENCE	5-10 years	16	53,33%
	10-20 years	8	26,67%
	Over 20 years	6	20,00%

4.2 | F-Delphi Method's Results

The first key objective of the study is to identify the key indicator causing food waste in the food service industry. The process was conducted in two phases. In phase 1, the authors reviewed 98 publications related to food waste (the authors used key words food waste, food loss, food waste management, sustainable food consumption, food waste prevention, food service to find the articles). 70 articles in the field from 2013 to 2023 were chosen. 38 factors were identified as the key drivers causing food waste in the food service industry. These 38 drivers concern all the stakeholders of a food service operation, including suppliers, managers, employees and customers, offering a comprehensive view of the issue.

With a crisp value lower than the threshold limit, ten rejected criteria in *Table 7* are shown to have little influence on green hotel selection in Belize. These criteria do not have too much impact but only partially affect the evaluation and decision-making selection process. Some examples of disqualified factors include environmental education and guest engagement. Environmental education and guest engagement are not criteria that directly influence customers' hesitation in the selection process, but they play a role in reshaping the thinking and action trends of customers and employees, enhancing customer experience, and helping it associate with environmental protection implications.

Table 7. Result of the F-Delphi method.

	Aggregate	u	v	Db	Validate
SC11	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC12	(0,0.347,1)	0.673	-0.173	0.293	Reject
SC13	(0.5,0.697,1)	0.849	0.326	0.506	Accept
SC14	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC15	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC21	(0.75,0.75,1)	0.875	0.656	0.602	Accept
SC22	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC23	(0,0.372,1)	0.686	-0.186	0.296	Reject
SC24	(0.5,0.713,1)	0.857	0.322	0.509	Accept
SC25	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC31	(0.75,0.75,1)	0.875	0.656	0.602	Accept
SC32	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC33	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC34	(0.75,0.75,1)	0.875	0.656	0.602	Accept
SC41	(0.75,0.75,1)	0.875	0.656	0.602	Accept
SC42	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC43	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC44	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC45	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC51	(0,0.339,1)	0.669	-0.169	0.292	Reject
SC52	(0.5,0.697,1)	0.849	0.326	0.506	Accept
SC53	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC54	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC55	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC61	(0.75,0.75,1)	0.875	0.656	0.602	Accept
SC62	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC63	(0.75,0.75,1)	0.875	0.656	0.602	Accept
SC64	(0,0.38,1)	0.690	-0.190	0.298	Reject
SC65	(0.75,0.73,1)	0.865	0.659	0.597	Accept
SC66	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC67	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC71	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC72	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC73	(0,0.363,1)	0.682	-0.182	0.295	Reject
SC74	(0,0.354,0.75)	0.552	-0.177	0.232	Reject
SC75	(0.5,0.73,1)	0.865	0.318	0.512	Accept
SC76	(0,0.408,1)	0.704	-0.204	0.301	Reject

Table 7. Continued.

	Aggregate	u	v	Db	Validate
SC77	(0.5,0.73,1)	0.865	0.318	0.512	Accept
SC81	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC82	(0,0.331,1)	0.666	-0.166	0.291	Reject
SC83	(0.75,0.73,1)	0.865	0.659	0.597	Accept
SC84	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC85	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC91	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC92	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC93	(0.5,0.75,1)	0.875	0.313	0.516	Accept
SC94	(0,0.372,1)	0.686	-0.186	0.296	Reject
SC95	(0,0.37,0.75)	0.560	-0.185	0.234	Reject
SC96	(0.5,0.713,1)	0.857	0.322	0.509	Accept
SC97	(0.5,0.75,1)	0.875	0.313	0.516	Accept
Threshold				0.482	

Source: calculated by authors.

First, 30 decision-makers considered nine critical criteria affecting green hotel selection in Belize. Each expert was asked to rate the importance of each pair of comparison criteria. For example, according to the level of importance filled in the pairwise comparison matrix according to aspect C1 in relation to C2, two experts think that C1 is equivalently important to C2 (EI= 2), six scientist analysts agree that C1 is of medium importance relative to C2 (MI left = 6), two analysts say that C1 is Very Important (VI) than C2 (VI left = 2). Only one expert rated C1 as STI compared to C2 (STI left = 1). One expert rated C1 as infinitely EXI than C2 (EXI left= 1). One expert thinks that C2 is on average medium more important than C1 (MI right = 1). Two experts believe that C2 is EXI than C1 (EXI right = 2). For main criteria, pairwise comparisons were gathered through a survey, and the outcomes are depicted in *Table 8*.

Table 8. Initial comparison matrices.

Criteria	Left Criteria Is More Important						Right Criteria Is More Important					Criteria	Number of Experts
	AI	MI	SMI	FI	SI	EI	SI	FI	SMI	MI	AI		
C1			2	3	4	5	4	6	5	1		C2	30
C1			1	3	2	6	6	5	5	2		C3	30
C1		2	5	5	6	4	3	3	2			C4	30
C1			1	4	3	7	5	4	3	3		C5	30
C1			1	4	6	6	6	5	2			C6	30
C1				3	4	4	6	5	5	3		C7	30
C1				3	3	7	6	4	4	3		C8	30
C1				1	2	5	5	6	7	3	1	C9	30
C2				4	5	6	5	6	3	1		C3	30
C2			2	5	4	5	3	5	4	2		C4	30
C2			2	4	5	6	5	4	3	1		C5	30
C2			3	5	6	4	4	5	3			C6	30
C2			1	2	3	6	4	6	6	2		C7	30
C2			3	5	4	3	4	5	6			C8	30
C2			2	2	2	4	6	6	5	3		C9	30
C3				2	2	8	5	10	3			C4	30
C3				2	4	6	8	8	2			C5	30

Table 8. Continued.

Criteria	Left Criteria Is More Important						Right Criteria Is More Important					Criteria	Number of Experts
	AI	MI	SMI	FI	SI	EI	SI	FI	SMI	MI	AI		
C3				2	3	6	8	9	2			C6	30
C3			1	2	5	15	4	3				C7	30
C3			1	1	2	6	14	6				C8	30
C3				1	3	7	8	10	1			C9	30
C4				2	3	6	10	7	1	1		C5	30
C4			1	3	5	15	4	1	1			C6	30
C4				2	3	5	12	5	2	1		C7	30
C4				2	4	13	7	3	1			C8	30
C4		1	5	5	12	4	2	1				C9	30
C5		1	2	4	5	6	5	3	3	1		C6	30
C5		2	4	5	8	8	2	1				C7	30
C5	2	1	1	4	8	11	2	1				C8	30
C5		1	1	1	4	7	8	7	1			C9	30
C6				3	4	8	7	6	2			C7	30
C6				1	2	3	7	8	7	2		C8	30
C6				1	2	4	6	8	6	2	1	C9	30
C7				2	3	10	8	6	1			C8	30
C7				1	4	11	7	6	1			C9	30
C8				2	6	7	7	6	2			C9	30

The criteria weight is calculated using *Eq. (10)*, which illustrates the importance of one criterion over another in attaining green practices within the hotel industry, as depicted in Table 9. The consistency ratio, calculated with *Eqs. (11)* and *(12)*, assesses the experts' consistency during pairwise comparisons.

Table 9. Weights and consistency ratio of dimension criteria.

Criteria	Fuzzy Geometric Mean			Fuzzy Weights			BNP	Normalization	Weights
C1	0,5783	0,7563	1,0137	0,0476	0,0825	0,1472	0,092	0,0832	0,083
C2	0,6472	0,8580	1,1486	0,0533	0,0936	0,1667	0,105	0,0941	0,094
C3	0,6469	0,8447	1,1465	0,0532	0,0921	0,1664	0,104	0,0936	0,094
C4	0,7561	0,9985	1,3290	0,0622	0,1089	0,1929	0,121	0,1093	0,109
C5	0,9283	1,2524	1,6364	0,0764	0,1366	0,2375	0,150	0,1353	0,137
C6	0,6452	0,8509	1,1440	0,0531	0,0928	0,1661	0,104	0,0937	0,094
C7	0,8070	1,0616	1,3934	0,0664	0,1158	0,2023	0,128	0,1154	0,115
C8	0,8803	1,1863	1,5507	0,0724	0,1294	0,2251	0,142	0,1282	0,128
C9	0,9997	1,3613	1,7895	0,0823	0,1485	0,2598	0,163	0,1473	0,147
	5,8980	7,8216	10,3796				0,949	0,8543	Sum
	Consistency Ratio (CRm)								0,0364
	Consistency Ratio (CRg)								0,0986

In the F-AHP method, the global weight of a sub-criterion is calculated by multiplying its criteria weight by its dimension weight. This process helps determine the overall importance of each sub-criterion within the hierarchy. It combines the relative importance assigned to each criterion at the higher level with the relative importance assigned to each dimension at the lower level to obtain a comprehensive understanding of the decision-making structure, as shown in *Table 10*.

Table 10. Weighting and ranking results of F-AHP.

Main Dimensions	Dimension Weights	Sub-Factors	Criteria Weights	Global weight	Ranking
C1: Water and energy management	0,083	SC11: Water conservation practices	0,197	0,0165	35
		SC13: Energy management systems	0,268	0,0222	22
		SC14: Renewable energy integration	0,233	0,0194	25
		SC15: HVAC efficiency and optimization	0,301	0,0249	17
C2: Waste management and recycling	0,094	SC21: Waste reduction strategies	0,270	0,0253	14
		SC22: Segregation and recycling programs	0,197	0,0184	30
		SC24:Hazardous waste disposal	0,348	0,0326	8
		SC25: Electronic waste recycling	0,184	0,0172	32
C3: Environmental innovation and technology	0,094	SC31: Sustainable construction and materials	0,270	0,0252	15
		SC32: Carbon footprint tracking system	0,207	0,0193	27
		SC33: Application of digital services and devices	0,203	0,0189	28
		SC34: Integration of green technologies	0,320	0,0299	11
C4: Sustainable supply chain management	0,109	SC41: Supplier evaluation and selection	0,220	0,0244	18
		SC42: Local sourcing and fair trade practices	0,141	0,0157	37
		SC43: Responsible procurement	0,246	0,0272	13
		SC44: Sustainable packaging and product choices	0,195	0,0218	23
		SC45: Waste reduction in the supply chain	0,198	0,0217	24
C5: Conservation and preservation of natural resources	0,137	SC52: Preservation of natural habitats and ecosystems	0,385	0,0512	1
		SC53: Sustainable landscaping and green spaces	0,254	0,0340	6
		SC54: Protection of coastal and marine environments	0,188	0,0250	16
		SC55: Conservation of water bodies (rivers, lakes, etc.)	0,172	0,0229	21
C6: Guest experience and education	0,094	SC61: Indoor air quality and ventilation	0,243	0,0236	20
		SC62: Eco-friendly transportation options	0,161	0,0156	38
		SC63: Sustainable food and beverage options	0,168	0,0163	36
		SC65: Use of organic and biodegradable toiletries	0,126	0,0123	40
		SC66: Design for natural lighting and passive cooling	0,127	0,0123	39
		SC67: Reduction of single-use plastics	0,175	0,0169	33
C7: Certification and recognition	0,115	SC71: Green certifications	0,296	0,0334	7
		SC72: Eco-labels	0,160	0,0181	31
		SC75: Competitive advantage	0,147	0,0167	34
		SC77: Continuous improvement	0,397	0,0448	3
C8: Environmental performance measurement and reporting	0,128	SC81: Monitoring and evaluation systems	0,299	0,0375	4
		SC83: Environmental impact assessments	0,154	0,0194	26
		SC84: Sustainability reporting	0,150	0,0189	29
		SC85: Transparency and accountability	0,397	0,0497	2

Table 10. Continued.

Main Dimensions	Dimension Weights	Sub-Factors	Criteria Weights	Global weight	Ranking
C9: Social responsibility and communication	0,146	SC91: Staff training and education on sustainability	0,236	0,0355	5
		SC92: Engaging with local communities and indigenous groups	0,197	0,0297	12
		SC93: Collaboration with government agencies and NGOs	0,202	0,0305	10
		SC96: Ethical and fair labor practices	0,207	0,0313	9
		SC97:Promotion of responsible tourism behavior among guests	0,158	0,0238	19

This study provides criteria for nine groups. According to *Table 10*, the following results are obtained: Social responsibility and communication (C9) achieved the highest rank with a final weight of 0,146, followed by the weight Conservation and preservation of natural resources (C5) with a weight of 0,135, ranked third in Environmental performance measurement and reporting (C8) with a weight of 0,128, then Certification and recognition (C7) with a final weight of 0,115, ranked fifth is Sustainable supply chain management (C4) with a weight of 0,109. Waste management and recycling (C2) rank 6th with 0,0942 of weight. Rank 7th and eighth is Guest experience and education (C6) (0,0937) and Environmental innovation and technology (C3) (0,0936), respectively. Water and energy management (C1) ranked last with weights of 0,083.

Table 10 also illustrates the global weights and global ranking. The "preservation of natural habitats and ecosystems" (SC52) has a global weight of 0.0512 and is ranked as the criterion with the most influence on green hotel selection in Belize. Meanwhile, the Use of organic and biodegradable toiletries criterion (SC65) ranked last with a global weight of 0,0123. The "transparency and accountability" (SC85) ranked 2nd with a global weight of 0,0497. Ranked 3rd Continuous improvement (SC77) with a global weight of 0,0448. Monitoring and evaluation systems criteria (SC81) and the Staff training and education on sustainability weight (SC91) ranked 4th and 5th, respectively, with global weights of 0,0375 and 0,0355. The Sustainable landscaping and green spaces weight criteria (SC53) has a global weight of 0.034 and is the 6th most important, followed by Green certifications (SC71), ranked 7th with a global weight of 0.033, and Hazardous waste disposal (SC24) ranked 8th with a weight of 0.0326. Ranked 9th and 10th are traceability and food safety (SC96) and communication channel (SC93) with weights of 0.0313 and 0.0305, respectively.

4.3 | F-TOPSIS Method's Results

Following the determination of criteria weights through the F-AHP method, hotel alternatives were evaluated based on the importance of attributes. In this process, 30 experts utilized the scale provided in *Table 5* to assess hotel alternatives. Fuzzy decision matrices were constructed for each expert, incorporating Fuzzy number equivalents of pertinent verbal variables. *Table 11* displays ten hotels' closeness coefficients and rankings determined through the F-TOPSIS method. The alternative with the highest relative importance, identified as HOTEL 3 with a value of 0.756, emerged as the top choice. According to the outcomes, hotels are ranked from the most suitable to the least suitable as follows: 3, 10, 7, 9, 5, 6, 2, 1, 8, and 4.

Table 11. Hotels' closeness coefficient score and ranking.

Alternatives	Closeness Coefficient	Ranking
Hotel 1	0.476	8
Hotel 2	0.552	7
Hotel 3	0.756	1
Hotel 4	0.412	10
Hotel 5	0.583	5
Hotel 6	0.568	6
Hotel 7	0.666	3
Hotel 8	0.427	9
Hotel 9	0.623	4
Hotel 10	0.685	2

4.4 | Discussion

This study proposes an integrated approach that combines F-Delphi, FAHP and FTOPSIS to assess and rank green hotels in Belize. The evaluation criteria for green attributes are determined by Fuzzy Delphi method. Then, the FAHP method is employed to ascertain the weights of these criteria and sub-criteria, while the FTOPSIS method calculates green scores and ranks the green hotels accordingly.

From the FAHP analysis outcomes, the primary criteria for evaluating green attributes are ranked as follows: C9/C5/C8/C7/C4/C2/C6/C3/C1. Social responsibility and communication (C9) are the highest priority among all evaluation dimensions. Research confirms a positive influence of environmental concerns, social motivations, and awareness of the consequences of green hotel choices. C9 addresses these concerns by encompassing ethical labor practices, community engagement, and responsible tourism. C9 also fosters a sense of obligation by focusing on social responsibility and ethical practices, appealing to customers' awareness of consequences, value orientations, and a desire to contribute positively [75]. Furthermore, as green practices are still nascent, customers seek more information and reassurance [76]. C9's focus on transparency addresses this need, building trust and confidence. In essence, C9's success lies in its alignment with customer values, addressing the communication gap, and catering to the need for information in the early stages of green practice implementation. By effectively communicating their social responsibility efforts through C9, hotels can attract customers who prioritize these factors in their green hotel choices.

The conservation and preservation of natural resources (C5) criterion, encompassing aspects such as SC52 (preservation of natural habitats and ecosystems), SC53 (sustainable landscaping and green spaces), SC54 (protection of coastal and marine environments), and SC55 (conservation of water bodies - rivers, lakes, etc.), holds the second position in customers' considerations when selecting green hotels. This ranking is attributable to its alignment with the escalating environmental concerns, social motivations, and heightened awareness of consequences among consumers. As substantiated by previous research, environmental concerns and social motivations are pivotal in shaping individuals' positive attitudes toward green hotels. Moreover, consumers feel obligated to choose eco-friendly accommodations, influenced by their awareness of consequences and specific value orientations.

In this context, the emphasis on the conservation and preservation of natural resources reflects customers' preferences for hotels actively contributing to environmental preservation efforts [77]. Notably, the study findings underscore the substantial impact of a hotel's green image and environmentally friendly activities on its corporate image. This suggests that endeavors to conserve natural resources align with consumer preferences and elevate a hotel's reputation and competitive standing. Therefore, the prominence of C5 in customers' evaluation criteria underscores the increasing importance of environmental stewardship and sustainability initiatives in influencing consumer behavior and shaping hotel selection decisions.

The correlation between these individual factors and the overarching conservation and preservation of natural resources category indicates that customers prioritize hotels actively engaged in environmental conservation [26], [75], [77], [78]. The positive influence of a green image and sustainable activities on corporate image further underscores the significance of these environmental initiatives. Hotels demonstrating a commitment to preserving natural habitats, sustainable landscaping, and protecting coastal and marine environments will likely attract environmentally conscious consumers [78], [80], solidifying the link between environmental responsibility and consumer preferences.

The environmental performance measurement and reporting (C8) criterion evaluates a hotel's sustainability practices by examining SC81 (monitoring and evaluation systems), SC83 (environmental impact assessments), SC84 (sustainability reporting), and SC85 (commitment to transparency). The environmental performance measurement and reporting (C8) criterion ranks third in customers' criteria for choosing green hotels due to its pivotal role in fostering green trust and influencing future intentions towards green accommodations. Research findings suggest that tourists' evaluations of staying at a green hotel significantly influence their intentions to seek similar environmentally friendly accommodations. Notably, the green trust's positive correlation with intentions to visit green hotels emphasizes the importance of customers' perceptions of environmental performance and reporting [81]. By implementing robust monitoring and evaluation systems, conducting environmental impact assessments, engaging in sustainability reporting, and ensuring transparency and accountability, hotels can enhance green trust among customers [82]. This trust is crucial in shaping consumer behavior and reducing social hesitation, aligning with the extended TPB constructs. Therefore, including environmental performance measurement and reporting in customers' evaluation criteria reflects the increasing significance of transparency, accountability, and environmental performance in driving consumer preferences and intentions toward green hotels.

Certification and recognition (C7) encompass various components crucial for validating and showcasing a hotel's commitment to sustainability. This criterion includes SC71 (green certifications) and SC72 (eco-labels), serving as external validations of the hotel's adherence to environmental standards and practices. Additionally, certification and recognition encompass elements like leveraging sustainability initiatives for competitive advantage (SC75) in the market, demonstrating how green practices can differentiate the hotel and attract environmentally conscious customers. Moreover, it involves a focus on continuous improvement (SC77), whereby hotels strive to enhance their sustainability efforts over time, reflecting a dedication to ongoing environmental stewardship. Together, these components underscore the importance of certification and recognition as integral aspects of a hotel's green initiatives, signaling credibility, competitiveness, and a commitment to continuous environmental improvement. Certification and recognition (C7) ranks fourth in customers' criteria for selecting green hotels despite its importance in validating environmental efforts and signaling commitment to sustainability. While certifications and eco-labels validate a hotel's green practices, research suggests customer trust is more influential in shaping intentions toward green accommodations [77]. Studies have shown that trust in a hotel's environmental efforts positively influences customers' intentions to choose green accommodations in the future [81], [83]. This aligns with the extended TPB, indicating that customer trust can mitigate social hesitation and enhance behavioral control [18], [84]. Therefore, while certifications and recognitions are valuable, they may not be as decisive in customer decision-making compared to factors such as trust in the hotel's environmental commitment.

Sustainable supply chain management (C4) encompasses critical aspects of a hotel's environmental responsibility, including supplier evaluation and selection (SC41), local sourcing and fair trade practices (SC42), responsible procurement (SC43), sustainable packaging and product choices (SC44), and waste reduction in the supply chain (SC45). While these elements are essential for promoting sustainability throughout the supply chain, they may rank fifth in customers' criteria for selecting green hotels due to various factors. Research by Chen et al. [81] suggests that customers prioritize trust and environmental commitment over supply chain management practices when choosing green accommodations. While sustainable supply chain practices contribute to a hotel's overall sustainability efforts, customers may emphasize more visible aspects, such as green certifications and eco-labels, or the hotel's direct environmental impact. Therefore, while sustainable supply chain management is integral to a hotel's sustainability strategy, it may not be the primary consideration for environmentally conscious customers when selecting accommodations.

Waste management and recycling (C2) ranks sixth in customers' criteria for selecting green hotels despite its importance in contributing to environmental sustainability. This criterion encompasses waste reduction strategies (SC21), segregation and recycling programs (SC22), hazardous waste disposal (SC24), and electronic waste recycling (SC25), all of which contribute in minimizing environmental impact. However, the lower ranking may be attributed to several factors. While waste management practices are crucial for sustainability, they may not be as immediately visible or tangible to customers as other aspects, such as social responsibility or environmental performance. Furthermore, waste management initiatives may be considered standard practices rather than distinguishing features of a green hotel, potentially diminishing their perceived significance in customers' decision-making process. Additional studies support these findings, emphasizing the significance of environmental commitment in shaping consumers' choices of green hotels. However, this lower ranking does not necessarily imply that managers overlook this criterion, as it is linked to other top-ranked criteria such as social responsibility and communication (C9) and conservation and preservation of natural resources (C5) rank first and second, respectively. Effective waste management and recycling programs are integral to a hotel's social responsibility efforts and contribute directly to conserving natural resources. Therefore, while waste management may not be the primary focus for customers, hotel managers understand its significance in fulfilling broader sustainability goals and may prioritize it accordingly in their operational strategies.

The significance of green knowledge among customers cannot be overstated, as it directly influences their decision to choose environmentally friendly accommodations. However, despite the growing importance of environmentally friendly practices, eco-friendly hotels often have a premium price tag. In such cases, customers' perceived value of the green hotel service must surpass the additional cost. Therefore, customers' level of green knowledge becomes a crucial determinant in their willingness to visit green hotels [85].

The findings from the study by Garg et al. [86] further support that customers' eco-friendly attitudes are positively associated with their intention to select green hotels. The perceived significance of environmental friendliness and the level of responsibility exhibited by businesses significantly impact customers' intentions to visit green hotels and even share positive word-of-mouth experiences [86]. Hence, green hotel operators should actively engage in environmental education efforts, such as environmental campaigns or informal education tools like brochures and seminars, to highlight the positive impact of their green practices. By reducing individuals' perceptions of the inconvenience associated with eco-friendly behaviors and enhancing their perceived importance of environmental responsibility, these efforts can encourage more customers to prioritize environmentally friendly accommodations [87].

While customers may initially perceive eco-friendly practices as inconvenient, studies have shown that their attitudes, social pressures, and perceived ease of engagement eventually lead to an enhanced intention to pay comparable prices for green hotels despite a slightly reduced level of performance [80]. Customers' evaluations of eco-friendly behaviors strongly impact their preference for green hotels over conventional ones. Thus, green hotel operators must communicate the enjoyable outcomes and positive consequences of eco-friendly practices to customers. Moreover, green hotels should ensure their product quality remains comparable to conventional hotels, justifying the fair price customers pay for the value of the green hotel experience [88].

In summary, while guest experience and education (C6) are crucial in promoting environmental awareness and enhancing guests' experiences, they may rank seventh in customers' criteria for choosing green hotels due to factors such as the perceived value of green services and customers' eco-friendly attitudes. However, with practical environmental education efforts and a focus on delivering high-quality green products and services, green hotel operators can potentially influence customers' perceptions and encourage more sustainable choices.

Environmental innovation and technology (C3) encompasses crucial elements such as SC31 (sustainable construction and materials), SC32 (carbon footprint tracking system), SC33 (application of digital services and Devices), and SC34 (integration of green technologies), which are fundamental for advancing sustainability in hotel operations. However, despite their importance, this criterion may rank eighth in customers' criteria for selecting green hotels. This lower ranking could be attributed to several factors. Firstly, while innovative technologies play a crucial role in reducing environmental impact, customers may not always be fully aware of or understand the implications of these technologies. Moreover, the direct impact of environmental innovation and technology on guests' experiences may not be as immediately apparent as other criteria, leading customers to prioritize factors that more directly influence their stay experience. Factors beyond technological advancements influence customers' attitudes and perceptions towards sustainability, such as perceived environmental responsibility and ease of engagement in eco-friendly behaviors [87]. Therefore, while Environmental Innovation and Technology are essential for long-term sustainability goals, they may not be the primary consideration for customers when selecting green hotels.

Despite its critical role in environmental sustainability, water and energy management (C1) is ranked ninth in customers' criteria for choosing green hotels. This lower ranking may be attributed to the immediate visibility and perceived impact of other criteria on customers' experiences. Notably, the primary energy consumers in the hotel industry are heating, ventilation, and air conditioning systems, which are integral energy management components. Research emphasizes the importance of reducing and decarbonizing energy consumption in heating and cooling for the industry's energy transition. However, the analysis reveals that energy efficiency investments are often lower than necessary. This might explain the lower prioritization of water and energy management in customers' criteria, as investments in other more visible aspects, such as social responsibility and conservation efforts, may be perceived as having a more direct impact on their experience and aligning with their values.

Additionally, customer priorities are heavily influenced by their awareness of environmental concerns and social motivations, as evidenced by the higher rankings of social responsibility and communication (C9) and conservation and preservation of natural resources (C5). The study indicates that customers prioritize hotels actively contributing to environmental preservation efforts, aligning with their growing environmental concerns and awareness of consequences. The immediate visibility and tangible impact of conservation efforts, as compared to the somewhat abstract nature of energy management, may contribute to the lower ranking of water and energy management in customers' decision-making.

In conclusion, while water and energy management is vital for the overall sustainability of green hotels, its ninth position in customers' criteria may be influenced by factors such as the perceived visibility and immediate impact of other criteria on their experiences. Hotel managers should consider strategies to effectively communicate the positive environmental impact of their energy management practices to increase customer awareness and appreciation for these efforts, potentially influencing their decision-making in the future [89].

The process of selecting green hotels can be complex, given the many evaluation criteria involved. However, employing an integrated framework like the F-AHP combined with F-TOPSIS can streamline this selection process. By utilizing these methods, hotel decision-makers can rank the various green attributes and identify the most suitable green hotels for customers. In the context of Belize, where sustainable tourism is gaining prominence, the F-TOPSIS method identified three hotels as the most environmentally friendly choices: Black rock lodge, black orchid resort, and colinda cabanas.

Black rock lodge stands out for its commitment to environmental stewardship, offering guests a unique rainforest experience with opportunities for adventure while maintaining a focus on sustainability. The lodge's dedication to protecting the local wildlife and minimizing its environmental impact is evident in every aspect of the guest experience. Similarly, black orchid resort on the belize river provides a tranquil setting for wellness travelers while emphasizing environmental radiance and sustainability. With its proximity to the international airport and convenient access to mainland attractions, the resort offers guests a comfortable and environmentally conscious base for exploring Belize. Colinda cabanas, rated as the top hotel on caye caulker, offers guests breathtaking views of the barrier reef and a range of amenities while prioritizing sustainability. Although some accommodations may lack air conditioning or televisions to reduce energy consumption, the hotel provides guests complimentary bicycles, kayaks, and snorkel gear to encourage eco-friendly activities.

These hotels' efforts to achieve sustainable development align with the growing demand for environmentally responsible tourism. By employing an integrated evaluation framework, hotel decision-makers can ensure that their selection process considers not only the traditional criteria but also the sustainability practices that increasingly influence customer preferences and shape the future of the hospitality industry in destinations like Belize.

4.5 | Comparative Analysis

The choice to compare F-COPRAS and F-VIKOR with F-TOPSIS is to assess the consistency and effectiveness of the proposed methods. Firstly, F-COPRAS is suitable for scenarios where the criteria and alternatives involve degrees of uncertainty and ambiguity. F-VIKOR excels when decision-makers seek compromise solutions that consider both the best and worst-case scenarios, providing a comprehensive perspective on multi-criteria evaluations. In essence, F-COPRAS and F-VIKOR were chosen for this comparative analysis alongside F-TOPSIS because of their capacity to handle uncertainty, complexity, and conflicting objectives, making them valuable tools for assessing multi-criteria decision-making problems comprehensively and practically.

Table 12 and *Fig. 2* present the comparative analysis of the three ranking methods. The F-TOPSIS method ranks alternative Hotel 3 as the top choice, while the lowest-ranked alternative is Hotel 4. Similarly, the F-COPRAS method also ranks Hotel 3 as the best alternative, giving it a value of 100, while Hotel 4 receives the lowest score of 84.96. The F-VIKOR method aligns with the previous two methods, placing Hotel 3 in the first position, with a score of 0.5985, and Hotel 4 at the bottom, with a score of 0.8237. These consistent rankings across all three methods highlight the strong performance of alternative Hotel 3 and the comparatively weaker performance of Hotel 4.

Table 12. Comparative analysis.

	F-TOPSIS		F-COPRAS		F-VIKOR	
Hotel No.	**Closeness Ratio**	**Ranking**	**Closeness Ratio**	**Ranking**	**Closeness Ratio**	**Ranking**
H1	0.476	8	85.97	8	0.808	8
H2	0.552	7	89.59	7	0.7671	7
H3	0.756	1	100	1	0.5985	1
H4	0.412	10	84.96	10	0.8237	9
H5	0.583	5	90.6	6	0.7382	5
H6	0.568	6	90.87	5	0.7157	4
H7	0.666	3	95.23	3	0.6878	3
H8	0.427	9	85.1	9	0.8327	10
H9	0.623	4	91.35	4	0.7407	6
H10	0.685	2	96.3	2	0.6736	2

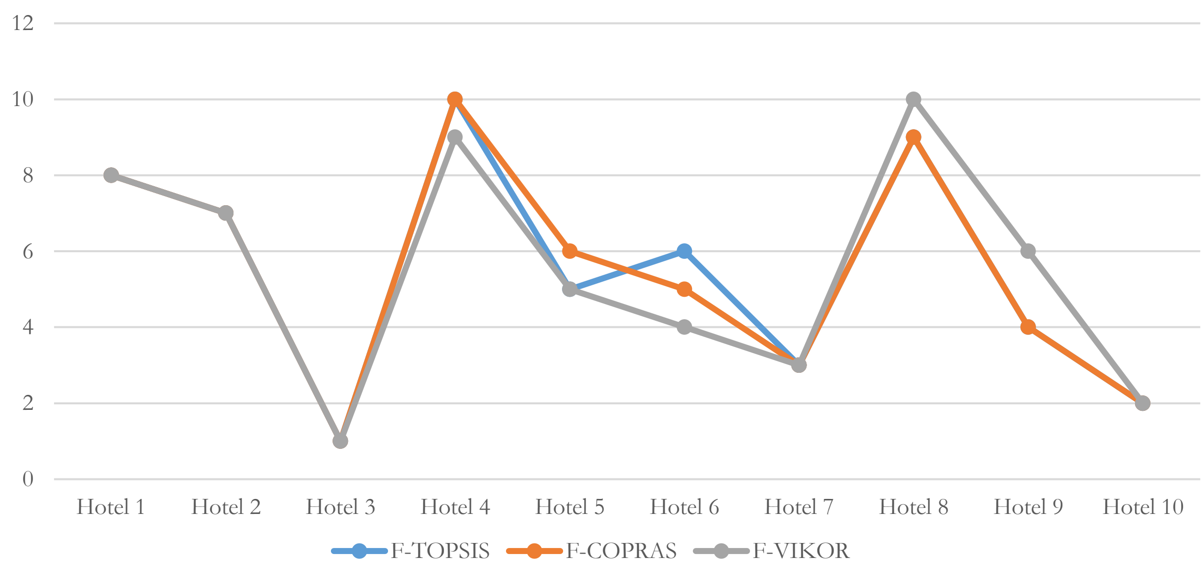

Fig 2. Comparative analysis based on rank.

In this study, we employed three rank correlation coefficients (Pearson, Spearman, Kendall) to examine the relationships among various MCDM techniques used to evaluate green hotels in Belize. According to our research results, the top three green hotels, as determined by F-TOPSIS, F-COPRAS, and F-VIKOR techniques, are Hotel 3, Hotel 10, and Hotel 7. This demonstrates that our proposed method consistently produces very similar results when employing various types of Fuzzy models.

Table 13. The results of the rank correlation.

Coefficient	F-TOPSIS & F-COPRAS	F-TOPSIS & F-VIKOR	F-COPRAS & F-VIKOR
Pearson	0.988**	0.939**	0.952**
Spear-man	0.988**	0.939**	0.952**
Kendall	0.956**	0.822**	0.867**

**. Correlation is significant at the 0.01 level (2-tailed)

As shown in *Table 13*, the Pearson correlation coefficients indicate strong positive associations between F-TOPSIS and F-COPRAS (0.988) and F-VIKOR (0.939). Similarly, F-COPRAS and F-VIKOR show a significant correlation of 0.952. Kendall's Tau-b coefficients also confirm the substantial agreement between F-TOPSIS and F-COPRAS (0.956) and F-TOPSIS and F-VIKOR (0.822). Additionally, F-COPRAS and F-VIKOR exhibit a high correlation of 0.867. Spearman's Rho: The Spearman's Rho coefficients further support the strong relationships between F-TOPSIS and F-COPRAS (0.988), F-TOPSIS and F-VIKOR (0.939), and F-COPRAS and F-VIKOR (0.952). These high correlations suggest the three methods produce consistent rankings, emphasizing their robustness in evaluating the alternatives.

5 | Conclusions

The integrated F-AHP and F-TOPSIS approach provides a robust framework for evaluating and selecting green hotels in Belize, addressing the complexity of sustainability assessments using Fuzzy logic and participatory methods. The findings emphasize key attributes influencing green hotel selection, such as social responsibility, conservation efforts, environmental performance, and certification, enabling decision-makers to identify environmentally responsible accommodations aligned with sustainable tourism principles. The model's practical implications extend to promoting transparency, accountability, and continuous improvement in green hotel practices, contributing to conservation, cultural heritage preservation, and community well-being for Belize's more sustainable tourism industry. Overall, the proposed model offers valuable insights for decision-makers to advance environmental sustainability and responsible tourism practices in Belize's quest for long-term sustainability goals.

5.1 | Theoretical Implications

The study contributes to the MCDM literature, showcasing the effectiveness of the FAHP-FTOPSIS methods in evaluating green hotels. The research emphasizes the importance of incorporating stakeholders' perspectives through the Fuzzy Delphi method, highlighting the need for participatory approaches in sustainability assessments. The study advocates for holistic evaluation frameworks, combining subjective expert judgments and objective criteria weights, emphasizing the multidimensional nature of sustainability. Additionally, it reveals evolving consumer preferences in the tourism industry, with Social Responsibility and Communication ranking high. Overall, the study extends beyond green hotel selection, providing insights into decision-making models in sustainable tourism and contributing to responsible tourism and environmental management discourse.

5.2 | Managerial Implications

This study offers actionable strategies for hotel managers in Belize to enhance sustainability practices and attract eco-conscious guests. The highest-ranking criteria, such as social responsibility and communication (C9), present a prime opportunity for differentiation by focusing on staff training, community engagement, and transparent communication of sustainability efforts. This strengthens the hotel's competitive advantage and builds trust and loyalty among guests. Additionally, criteria like conservation and preservation (C5) provide avenues for showcasing environmental stewardship through sustainable landscaping, habitat protection, and water conservation. Addressing lower-ranking factors like sustainable supply chain management (C4) and waste management (C2) is crucial for reducing environmental impact and improving operational efficiency. Despite water and energy management (C1) having a ninth-ranking position, minimizing ecological footprints through investments in energy-efficient technologies and water conservation measures is imperative. A comprehensive approach to high and low-ranking criteria enables hotels to develop sustainability strategies that appeal to eco-conscious guests and position themselves as leaders in the green tourism market.

5.3 | Limitations and Future Work

The study acknowledges limitations and proposes areas for future research. Using the Fuzzy Delphi method with a selected group of experts introduces potential sampling bias, and the small sample size limits the generalizability of findings to a broader stakeholder population. Future research should employ more rigorous sampling techniques to enhance representation and involve a more significant, diverse group of experts. The reliance on subjective expert judgments also raises concerns about biases influencing outcomes, suggesting that alternative methods, such as data-driven approaches or stakeholder consultations, could improve objectivity. The study's focus on Belize may restrict generalizability, prompting the suggestion for replication studies in varied cultural and environmental settings to explore variations in green hotel selection criteria. While the study identifies criteria, it lacks an in-depth exploration of their operationalization in practice, prompting the recommendation for future research to develop practical tools or frameworks for evaluating and benchmarking green hotels. Overall, the study contributes to understanding green hotel criteria in Belize but acknowledges limitations and proposes avenues for future research to enhance the applicability of findings in informing sustainable tourism practices.

Data availability

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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