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Application of Selected MCDM Methods for Developing a Multi-Functional Framework for Eco-Hotel Planning in Yemen

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Abstract— This study aims to develop a multi-criteria decision-making (MCDM) based framework for evaluation, ranking and structured comparison of the sustainability practices in the Yemeni hotels. To achieve this goal, the performance criteria of green hotels ranking and classification problems with the Yemeni context are discussed, some possible applications of MCDM technics are illustrated, three most common approaches (AHP, Fuzzy AHP, and FDM) were selected, and implemented for ranking and classification of the eco-hotels performance criteria, a case study on the impact of their application on a ranking and classification decisions was conducted, three possible multi-functional frameworks were obtained. The required consistency and criteria acceptability tests for each implemented method were examined. The sensitivity analysis, total number of the position's shifts of the ranked criteria, the overall level of change in them, and the Pearson coefficient are used to compare the results obtained by all methods, and to select the best and less sensitive evaluation framework. The result shows that different variants of MCDM methods leads to the same classification's and different ranking's result. A Very high level of numerical correlation coefficients, low degree of sensitivity and very small change level in the positions of the ranked criteria were observed between results defined by the Fuzzy AHP method and those which were obtained by the AHP and FDM methods. Accordingly, a new more accurate, and more relevant to the Yemeni reality fuzzy based and multi-functional framework was developed. Study suggests the application of this framework for further sustainable planning practices in Yemen.

Keywords— MCDM, Comparative analysis, Eco-hotels, Sustainability, Prioritization, Green hotels, AHP, F-AHP, FDM

I. INTRODUCTION

Today, tourism considered one of the speediest rising economic divisions in the world. This progress has turned the tourism industry into a significant player of socioeconomic enlargement and income sources for several developing nations. According to [1], in 2018, this sector directly contributed 4.4% of global GDP, 6.9 % of employment, and 21.5 % of services-related exports to OECD countries. The outpaced growing impacts of this sector as an economic [2] and social forces [3] and a sustainable development tool are indisputable. It contributes to achieving economic prosperity [2], poverty alleviation [4], environmental justice, and ecological equity [5]. It also serves as social equity and cohesion, ecological and cultural protection instruments [6]. Sustainability is considered one of the modern goals and trends of many development sectors [7], [8], [9], [10], especially the tourism sector [11]. It characterizes a significant matter that must to be processed to improve the outputs and performance of this vital sector. From another negative side, tourism development in general, and hotels in particular contributes to many problems and adverse effects that disturb the ecological balance and the environmental framework [12], resulting from the waste of vast amounts of necessary water and electricity resources for countries, improper sanitation practices, and the acquisition of products and technologies that are not environmentally friendly.

For this reason, a large group of worldwide hotels has begun to integrate the sustainable practices into their businesses [13], [14]. They have worked to develop strategies and implement sustainable policies to reduce these negative impacts and in a way that promotes healthy living societies.

Recently, Many studies have been conducted to study the sustainable need and significance of the integrating its practices into the hotel's sector business, including [15], [16],[17]. These studies and other similar literature emphasis that the sustainable practices are considered one of the most important factors contributing to reduce the harmful effects of this sector on the environment, maximizing social and economic benefits, and achieving sustainability goals. The sustainable planning process is considered the first stage for achieving that. Despite the field of application, this process as a general decision making problem, involves a number of activities. For example, investigation and analyzing the real application level of the sustainable practices in institutions, vital business or service sectors [18], [19], [20], [21], taking into account the sustainable priorities and various special conditions, and criteria affected the activity in a certain sector or institution is one of commonly and more widely addressed activities for improving the economic, social and environmental sustainable development status of countries. Analyzing the gap in the implementation of these practices in a certain sector, ranking and prioritization of institutions in it according that status is also addressed to determine the general strong and weak sustainable points, improvement directions and their priorities, and drawing the resource planning and allocation strategies [22],[23]. Also, the structured comparison of the sustainable maturity level of application in a selected number of institutions, in a certain sector, is also considered one of the more important issues that helps government to allocate their resources in a justice, equity, and effective way [23]. It has also helped external organizations to allocate their aids as a corporate social responsibility by the same way, and according to their various objectives [23]. However, all these activities are sharing one fundamental task, and cannot be carried out without its consideration. This is the process of prioritization, ranking and selection of the sustainable criteria that will used for further evaluation, prioritization, ranking, structured comparison, analyzing and other sustainable planning decisions. This process is solved taking into account various considerations, which are different from one decision environment to another [23]. The outcome of such a pressing is a multifunctional frame work, including a hierarchical structure of the weighted, m ost relevant and effected sustainability criteria, and sub crit eria on this decision problem (and its sub problems).

The Multi criteria decision making (MCDM) technics such as Analytic Hierarchy Process (AHP), Fuzzy AHP (FAHP), and Fuzzy Delphi Method (FDM) are some of the most common and widely used methods for solving such task, and for construction the expected framework [24].

n research [12], which has been recently published by a group of researchers participating in the current study, the importance of this framework for the Yemeni hotel sector was reviewed in more detail. Its practical, constructive steps using the Fuzzy Delphi Method (FDM) are also provided. That study also describes the decision making conditions in the Yemeni context, which stresses the importance of addressing this problem. However, The current study differs in that it sheds light on the application of two additional (AHP and FAHP) techniques for building the expected framework, and compares results of all three methods with each other, aiming to reach a more accurate and efficient framework than the previous one. It also reviews a range of other applications of this framework. So, this study aims at studying the possibility of developing a new multi-functional framework for supporting the sustainable planning in Yemeni hotels, relying on the application and comparison of outcomes of the AHP, FAHP and FDM Methods.

The rest of the paper is organized as follows, Section I cont ains the introduction, Section II contains the related work o f the decision making environment, the need and the applic ation of the multiexpert MCDM tools for solving the probl em, standards for green hotels planning, research gap, prob lem statement, and objectives of the study, Section. 3 described our methodology. The results and discussion are shown in Section 4, followed by the proposed framework and its applications in Section 5. followed by a limiting of study and conclusion in Section 6 and Section 7, respectively.

II. RELATED WORK

A. International standards for green hotels' planning

In sustainable tourism, reliance on international standards in planning processes have become more widespread, and prevalent [6], the area of green hotels was also no exception to this. According to [12], the reliance on these standards and the guidelines that they provide in green hotel planning processes is increasing globally, as they greatly help in preserving natural resources, reducing the negative effects of the hotel industry on the environment, managing and rationalizing financial resources, and providing an environmentally friendly environment, and healthy for guest. Among the most important of these standards are the Global Sustainable Tourism Council standards (GSTC), The Green Globe Standard (TGGS), Green step Sustainable Tourism Standard (GSTS), Asian Ecotourism Standard For Accommodations (AESA), Green Tourism Active (GTA), ISO26000, and ISO14000. These standards provide measurable factors, which must be chosen in different cases. As this study depends on the comparison of the results of the application of the AHP and FAHP MCDM methods with the results of the FDM [12], the implemented international standard in this study will be the same standard used in that study (GSTC), More information on the GSTC standard, and the justifications behind his choice are available in [12].

B. Group decision making for selecting and weighting sustainability factors

The prioritization of sustainability factors appropriate for application in a hotel sector are used to analyze the interaction between the natures of the intended industry, the environmental conditions surrounding it, and the sustainable community priorities for the classification and selection of factors according to their suitability, efficiency, and ability to meet benefits, in a way that serves the community. Practically, this selection process should be made considering several aspects [25] such as natural system limitations, compatibility with local sustainability priorities, size and nature of industry activity, availability of natural resources, surrounding socio-economic conditions and constraints [26],[27]. The prioritization process as a decision-making process is always associated with many conflicting objectives, governed by many economic and societal development conditions, and sometimes institutional or individual interests. however, if the institutions conduct their planning, decision-making operations in isolation from other institutions, external related bodies and stakeholders or without considering those objectives may lead to wrong decisions [28],[29],[30],[31]; to avoid this situation, the decision-makers are encouraged to revise the decision-making methods and tools they practice, as well as their ways of thinking in a fashion that ensures the achievement of public interests at the cost of personal interests and in a tactic that contributes to meeting the needs of society and overcoming the changing challenges facing it, by selecting a group of participants in the decision-making process [31] so that they undertake the conditions for effective planning, represented by the availability of a diversity discourse varieties, knowledge and values among the participants, which confirms the theory of communicative planning, theory of participation and other modern theories in the field of planning. This tactic is effective in achieving an objective, knowledgeable and accurate decisions [31].

C. Group MCDM methods

The problem of determining sustainable factors that are more important and appropriate to the reality and the environment of the Yemeni hotel sector, as a decision problem, requires involving a group of experts to evaluate a set of factors in a group decision making process. Relying on the group decision-making in the ranking, prioritization and evaluation processes for planning purposes is useful [32],[33]. But, it is a complex and difficult process. It integrates a large amounts of complex information, characterized by the difficulty in continuous dealing with that information, and accommodating experts' opinions; it is also surrounded by uncertain situations [24], which affect the results of the decision. To reduce those cases and to deal with these difficulties, the group MCDM methods are used [28]. These methods are used to avoid the pitfalls resulting from the illiteracy of the limited target groups within one institution on the reality required to be analyzed. In addition to being able to integrate heterogeneous data of the views and ideas of a wider group of experts and specialists [28].

1) The Analytic Hierarchy Process (AHP) method

The Analytic Hierarchy Process (AHP) method was developed at the beginning of the eighties of the last century by the global scientist (Saaty) [34]. It is considered one of well-known multi-criteria decision making (MCDM) methods that stress the crucial role of choosing the basic criteria and the judgment about their relevant importance [24]. The prioritization process is carried out through a pairwise comparison of each option with all the others. The main advantages of this method are reducing a multi-dimensional problem into a one-dimensional problem, highlighting the key attributes, strengths and weaknesses of every ranked item, and integrating the final choices from a group to agree on a single outcome. Analyzing the earlier AHP based studies showed that the justification for choosing this approach is the wish to express experts' preferences by precise numeral values.

In sustainable tourism, the practical applications of AHP support techniques have become more widespread, and the area of green hotels was also no exception to this. For example, internationally, in [35] the AHP method has been integrated with the ISO framework to improve the green practices in supply chains; in [36] the perilous sustainability factors in the voyage tourism sector were analyzed using AHP, The study[37] developed an evaluation index (SCTEI) for tourism using a Delphi and AHP methods. strategies for developing medical tourism in the social security organization of iran were defined and prioritized by [38] using A SWOT-AHP approach; and based on the AHP method, the study [39] determined the aspects that influences the choice of hostels by tourists.

2) The Fuzzy Analytic Hierarchy Process (AHP) method

according to [24], the traditional Satty's AHP method does not deal with the uncertainty involved in assessing the importance of the criteria. Progressive MCDM theories, including Random set, Fuzzy set, and qualitative reasoning theories deliver more sophisticated procedures to deal with this inaccuracy of information and fuzziness problem; according to [28], the most common methods to dealing with this problem are the fuzzy set-based one. For this reason, a fuzzy version of AHP was also selected as a second method for this study. This approach performs AHP under uncertainty and ambiguity, has received increasing acceptance, and has been approved and implemented to solve decision-making problems in many fields [40], [41]. Studies [42], [43], and [44] are some examples of the application of this method in the green hotel planning domain. In [42], hotel websites were analyzed through the use of fuzzy AHP and fuzzy TOPSIS, A fuzzy AHP approach to construct international hotel spa atmosphere evaluation model was suggested by [43], While, [44] provides a research on the evaluation of hotel operation risk in mountain scenic resorts based on AHP and fuzzy comprehensive evaluation.

D. Problem statement and objectives of study

The locally recent study provided by some of this research team [12] shows that the applications of MCDM technologies in the field of sustainability in general and in developing and evaluating green hotel standards are rare on a local scale. In that work, the performance criteria for hotels and accommodations based on the GSTC standards were prioritized and classified according to their sustainability importance in Yemen, using the Fuzzy Delphi method (FDM), and a FDM based multi-criteria hierarchical framework for evaluating the sustainability practices of hotels in Yemen was recommended.

In any case, analysis of internationally and locally observational studies observed that most of them used some of the more sophisticated methods like AHP, Fuzzy Delphi or Fuzzy AHP without a comparative analysis to examine whether the application of these methods will create significant variance compare to each other. On the other side, studies that have addressed a comparative analysis of these three methods to each other in eco-hotel applications do not exist; on the third hand, the available reviews, compare only the two types of AHP method based or Fuzzy AHP with Fuzzy TOPSIS on the absolute comparison approach [45],[46],[47], while this study focuses on the relative based comparison of criteria.

Through the analysis of the presented studies, it is clear that comparative studies are of great importance in sustainable applications for countries. This importance increases when the clarity, accuracy and appropriateness of the influencing factors, and the reliability of the rules and experienced people used in choosing and determining the importance of factors are among the main factors required to deal with the decision problem. So, the offered study utilizes a pilot study on a specific case to prioritize the eco-hotels performance criteria in Yemen by application the AHP and Fuzzy AHP. It also aimed to compare the outcome of these methods with each other and with the results of the FDM, which have been recorded in our recently published work [12].

In addition to the factor ordering variations, this study compares the classification categories of the important factors and the final sustainable multi-criteria hierarchical frameworks for evaluating the sustainability practices of hotels in Yemen recommended by all three methods. Finally, based on the results of those comparisons, it suggests an optimal framework for future evaluation, structural comparison, and analyzing purposes of sustainability practices in Yemeni hotels.

III. METHODOLOGY

This section illustrates the detailed methodological stages used to solve the research problem:

1) *Define the research problem and objectives (sec. 1)*
2) *Literature review and research gap identification (sec.2)*
3) *Preparing and collecting comparison data for the studied case (sec. 3):*

In this step, two sub-steps were conducted, a case study data collection and the case data's reformatting to suit the requirements of current comparison techniques:

a) Case study data collection

As it was presented above, this work is a part of a project; in its first part, the performance criteria for Hotels and Accommodations based on the GSTC standards were prioritized and classified according to their sustainability importance in Yemen, using the Fuzzy Delphi method [12], The preference values of experts on these criteria were gotten relying on a survey questionnaire. Thirteen questionnaires were shared among a category of experts; they were specialists in hotel management who are strangely familiar with tourism sustainability, have participated in relevant and closely associated concerns and activities for more than ten years, and have paid prominent attention to the issues of study [12].To make a real comparison with the results of the previously used FDM, and to get accurate and not contradictory results, this research was conducted using the data of the previous study, with the necessary conversions made to match the requirements of the techniques used in this study. The data that have been considered as inputs to this study are [12]: (1) the sustainable criteria that were evaluated (see fig. 1). (2) The result of the experts 'preferences, which will be analyzed using the fuzzy and classical AHP methods (3) The ranking outcome criteria using the FDM (4) the result of criteria classification using the FDM method (5) the suggested FDM based model for further eco-hotel evaluation and planning processes in Yemen.

b) Reformatting the case data

However, through the FDM implementation, experts were requested to assess criteria in accordance with its sustainable orientation, taking into account the reality of Yemen, the numerical 5- point Likert scale was applied. But, the five-point importance scales are not suitable to use for this study, as the AHP and Fuzzy AHP used a nine-point scales. For this reason, the evaluation opinions using a five-point scoring scale were converted into the nine-point scoring scale of AHP. Table (1) represents the proposed conversation scheme between them.

On the other hand, the AHP and Fuzzy AHP implementation require making the experts' pairwise comparison matrixes of criteria. This study applied a relative preference approach instead of the absolute; so, the mutual evaluation approach was used for building these matrixes. For each expert (K), the pairwise comparison matrix elements were determined; the devaluation matrix is determined precisely based on the criterion importance's mutual comparison, respectively associated criteria. Let C_i^k expresses an assessment of the significance of i-th criteria, and C_j^k expresses an assessment of the significance of j-th criteria by expert k; then, the mutual assessment of the significance of these two criteria can be defined as [46]:

$$S_{ij}^k = \begin{cases} C_j^k - C_i^k + 1 \text{.......} if\ (C_i^k < C_j^k) \\ 1 \text{..........................} if\ (C_i^k = C_j^k) \\ 1/(C_i^k - C_j^k + 1) \text{.......} if\ (C_i^k < C_j^k) \end{cases} \quad \dots (1)$$

Table 1. Scoring Scales

Five point Likert scale	Fuzzy Delphi Scale	AHP - Nine point scale
		1. Absolutely important
5. Very strongly important	(0.6,0.8,1)	2. Very strongly important
4. strongly important	(0.4,0.6,0.8)	3. Strongly important
3. Important	(0.2,0.4,0.6)	4. Important
2. Weakly important	(0,0.2,0.4)	5. weakly important
1- Not important	(0,0,0.2)	6. Not important
		7. strongly unimportant
		8. Very strongly unimportant
		9. Absolutely unimportant

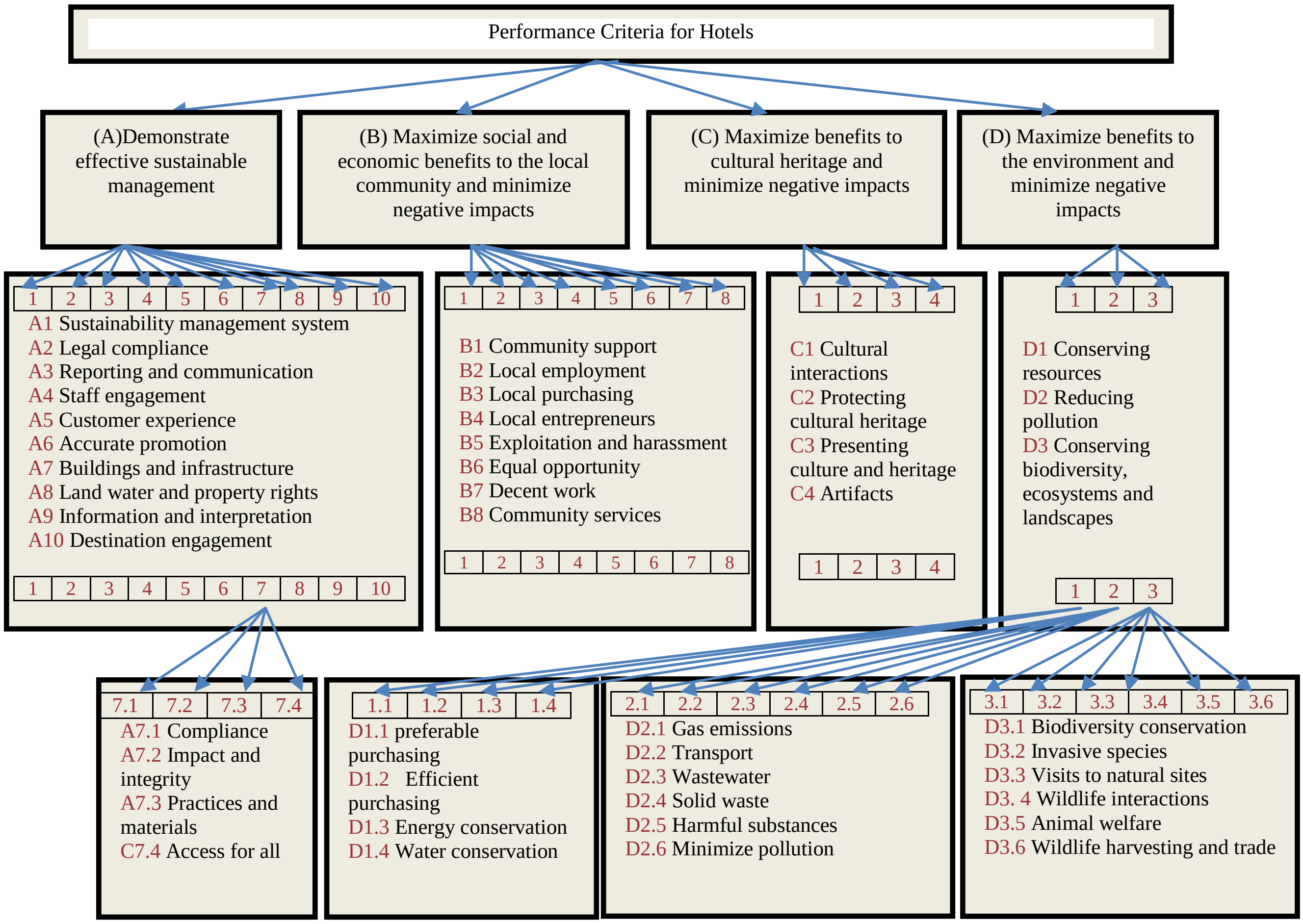

Figure 1. Eco-hotel performance criteria [12]

By adopting the proposed reformatting procedures, 13 comparison matrixes were created; table 2 represents an example of pairwise comparison matrixes.

4) Prioritization of the eco-hotels performance criteria in Yemen by application the AHP and Fuzzy AHP

Through the AHP analysis; firstly, the investigation process was conducted utilizing aggregated experts' preferences; the geometric means of all thirteen experts' reformatted ratings were computed for all 42 previously defined eco-hotel criteria. This type of aggregation is reparable, homogeneous, and supports consistency and consensus that must be provided and realized to score expert preferences [28]. Secondly, The Consistency Ratio (CR) was tested; this ratio was computed by the formula (CR = CI/RI (n)) to estimate the consistency of each comprised pairwise [49]. Where the CI and RI symbolize the index of consistency index performed by using CI= (λ_{max} –n) /(n-1) , and the index of random consistency of n's order matrix, respectively. While the λ_{max} is the decision matrix's principal eigenvalue. In our current study, the value 0.10 was adopted as a standard threshold value (CR). This means that the pairwise comparison matrix will have incorrect weight values, will not achieve acceptable consistency, and cannot be used if this rate value is greater than 0.1. In such cases, the evaluation process should be repeated.

Table 2. Pairwise Comparison Matrix of Expert 1

Expert	Criteria													
	A1	*A2*	*A3*	*A4*	*A5*	*A6*	*A7.1*	*A7.2*	*A7.3*		*D3.2*	*D3.3*	*D3.4*	*D3.5*	*D3.6*
A1	1	1	2	2	1	2	2	2	2	….	2	2	3	3	3
A2	1	1	2	2	1	2	2	2	2	….	2	2	3	3	3
A3	0.5	0.5	1	1	0.5	1	1	1	1	….	1	1	2	2	2
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
D3.5	0.33	0.33	0.5	0.5	0.33	0.5	0.5	0.5	0.5	….	0.5	0.5	1	1	1

In this study, the consistency ratio of (0.0000133 < 0.1) was obtained. In the third sub-step, the traditional AHP algorithm has been replaced by its fuzzy version. This technique is generally used to deal with uncertainties resulting from the circumstances and information of the evaluation environment and the vacillation involved in the opinions of decision-makers [31], it is also characterized by its ability to integrate these uncertainties. It uses a group of fuzzy numbers, each of which reflects a level of the nine previously described levels. Each number represents one of these levels through three different values (upper, medium, and lower) to reflect the optimist, average, and pessimistic attitudes of the expert, respectively. Chang's algorithm [49] is one of the standard algorithms, developed as a fuzzy algorithm for the Sati mentioned above algorithm. It was used in this study to derive the criteria weights. The outlines of this algorithm can be gained in many pieces of literature, such as [28]. Finally, the final values of the weights of all 42 criteria were determined completely using the two methods, as presented in fig. [2]. It also presents the equivalent values that were previously obtained using the FDM. It also represents the percentage influence of each criterion and the change in the criteria ranking positions.

The perilous input to the desired eco-hotel planning model is the order of the investigated green criteria given according to their weights. The results presented variances in the eventual relative importance weights acquired by each method. FDM method used a range of [0-1] values to describes the weights of criteria, while the AHP methods used a percentage scale (summation of weights equal 1), to estimate whether the obtained distinctions produced different effects of criteria on the ranking and classification outcomes of the MCDM model, the FDM weights were normalized, and the relative influence (percentage) of criteria were determined as:

$$RI=(w(c_i)/\sum_{i=1}^{m} w(c_i)) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

Where $W(C_i)$ is a weight given to an (i-th) criteria and m is the total number of criteria, the RI (Rank) of criteria based on the AHP, FAHP and FDM weighting algorithms presented in Fig.2.

5) Classification of criteria

It should be noted here that all criteria are important for green hotel planning, and must be considered in the upcoming planning stages, but the most critical factors and issues must be addressed first. A procedure has been adopted to classify the sustainable criteria into four significant groups. The first group refers to the critical importance criteria (Absolutely significant) that decision-makers in the relevant bodies and authorities must take into account in the early stage of sustainable planning and development, and to study them in more detail later by building indicators, developing a fuzzy maturity model for measurement and evaluation in many local institutions, and developing appropriate solutions and suggestions. Simultaneously, the second, third and fourth groups were assigned to a set of criteria for Absolutely Significant (VH), Very strongly Significant (H), Strongly Significant (MH), and Significant (LH) care. Table 3 shows the classification scores that were adopted by the experts in agreement to classify the criteria into four significant classes (SC) [12]. This table also represents the equivalent fuzzy Delphi scores. In the next sections, the last two methodological steps will be presented in detail.

After that, criteria based on the AHP, FAHP and FDM weighting algorithms were classified using previously determined classification criteria, Figures 3.1, 3.2, 3.3 and 3.4 illustrate the classification of criteria covered by the four sustainability domains (A, B, C, and D), these figures also represent the distribution of them (number of criteria (N (C)) and their rate) over the four significant classes (SC).

Table 3. The Significant Classes Of Criteria

Sign. class, Sign	Likert Score	FDM Score
Absolutely Significant (VH)	W >= (4.5)	W >= (0.7)
Very strongly Significant (H)	(4.3) <= W < (4.5)	(0.66) <= W < (0.7)
Strongly Significant (MH)	(4)< W < (4.3)	0.60 < W < (0. 66)
Significant (LH)	W < (4)	W < (0. 60)

	W			Rank			Sign.Class			% Influence			P-Chang		
C	AHP	FDM	FAHP	AHP	FDM	FAHP	AHP	FDM	FAHP	AHP	FDM	FAHP	AHP,FDM	AHP,FAHP	FDM,FAHP
A1	0.034	0.028	0.035	2	2	2	VH	VH	VH	3.370	2.817	3.512	0	0	0
A2	0.034	0.028	0.035	2	3	3	VH	VH	VH	3.370	2.817	3.507	1	1	0
A3	0.022	0.024	0.023	21	11	21	MH	MH	MH	2.247	2.366	2.274	10	0	10
A4	0.026	0.025	0.026	9	6	12	H	H	H	2.617	2.535	2.590	3	3	6
A5	0.026	0.025	0.029	10	7	10	H	H	H	2.617	2.535	2.900	3	0	3
A6	0.020	0.023	0.021	27	13	24	MH	MH	MH	2.040	2.254	2.115	14	3	11
A7.1	0.020	0.022	0.018	31	15	34	LH	LH	LH	1.951	2.197	1.801	16	3	19
A7.2	0.020	0.023	0.019	25	13	31	MH	MH	MH	2.041	2.254	1.926	12	6	18
A7.3	0.020	0.023	0.021	28	14	26	MH	MH	MH	2.038	2.254	2.105	14	2	12
A7.4	0.020	0.023	0.020	30	13	29	MH	MH	MH	2.028	2.254	1.968	17	1	16
A8	0.022	0.024	0.023	20	11	20	MH	MH	MH	2.248	2.366	2.287	9	0	9
A9	0.024	0.024	0.026	18	10	13	H	H	H	2.361	2.423	2.590	8	5	3
A10	0.022	0.024	0.021	23	11	23	MH	MH	MH	2.245	2.366	2.142	12	0	12
B1	0.020	0.023	0.019	29	14	32	MH	MH	MH	2.037	2.254	1.887	15	3	18
B2	0.032	0.028	0.035	3	4	4	VH	VH	VH	3.216	2.761	3.507	1	1	0
B3	0.021	0.023	0.021	24	12	25	MH	MH	MH	2.135	2.310	2.110	12	1	13
B4	0.020	0.023	0.020	26	14	28	MH	MH	MH	2.040	2.254	1.989	12	2	14
B5	0.026	0.025	0.026	12	7	15	H	H	H	2.613	2.535	2.582	5	3	8
B6	0.022	0.024	0.023	19	11	22	MH	MH	MH	2.248	2.366	2.274	8	3	11
B7	0.032	0.028	0.034	5	4	5	VH	VH	VH	3.209	2.761	3.360	1	0	1
B8	0.025	0.025	0.027	15	8	11	H	H	H	2.485	2.479	2.741	7	4	3
B9	0.024	0.024	0.026	17	9	16	H	H	H	2.361	2.423	2.577	8	1	7
C1	0.031	0.027	0.031	7	5	9	VH	VH	VH	3.051	2.704	3.050	2	2	4
C2	0.030	0.027	0.034	8	5	6	VH	VH	VH	3.049	2.704	3.354	3	2	1
C3	0.019	0.022	0.017	35	15	36	LH	LH	LH	1.936	2.197	1.715	20	1	21
C4	0.019	0.022	0.018	32	15	33	LH	LH	LH	1.938	2.197	1.845	17	1	18
D1.1	0.026	0.025	0.026	11	7	17	H	H	H	2.617	2.535	2.576	4	6	10
D1.2	0.032	0.028	0.032	4	4	8	VH	VH	VH	3.213	2.761	3.213	0	4	4
D1.3	0.037	0.029	0.038	1	1	1	VH	VH	VH	3.745	2.930	3.810	0	0	0
D1.4	0.037	0.029	0.038	1	1	1	VH	VH	VH	3.745	2.930	3.810	0	0	0
D2.1	0.019	0.022	0.020	33	15	30	LH	LH	LH	1.938	2.197	1.968	18	3	15
D2.2	0.019	0.022	0.017	34	15	35	LH	LH	LH	1.937	2.197	1.747	19	1	20
D2.3	0.032	0.028	0.034	6	4	7	VH	VH	VH	3.206	2.761	3.351	2	1	3
D2.4	0.025	0.025	0.024	13	8	18	H	H	H	2.487	2.479	2.427	5	5	10
D2.5	0.025	0.025	0.024	14	8	19	H	H	H	2.485	2.479	2.426	6	5	11
D2.6	0.024	0.024	0.026	16	10	14	H	H	H	2.364	2.423	2.587	6	2	4
D3.1	0.014	0.018	0.012	36	16	37	LH	LH	LH	1.404	1.803	1.233	20	1	21
D3.2	0.013	0.017	0.011	37	17	38	LH	LH	LH	1.343	1.746	1.135	20	1	21
D3.3	0.022	0.024	0.021	22	11	27	MH	MH	MH	2.246	2.366	2.082	11	5	16
D3.4	0.013	0.017	0.009	38	18	40	LH	LH	LH	1.276	1.690	0.915	20	2	22
D3.5	0.013	0.017	0.011	39	18	39	LH	LH	LH	1.276	1.690	1.105	21	0	21
D3.6	0.012	0.016	0.009	40	18	41	LH	LH	LH	1.208	1.634	0.897	22	1	23

Figure 2. The ranking, classification, influence and p-change results using the three MCDM models

Sig. Class (SC)	Criteria (C)	N (C) by SC	% (N(C), SC)	(N(C),D) %
VH	1,2	2	20%	15%
H	4,5,9	3	30%	23%
MH	3,6,7.2,7.3,7.4,8, 10	7	58%	54%
LH	7.1	1	10%	8%
Total	D(A)	13	31%	100%

Figure 3.1 Classification of criteria – Class A

Sig. Class (SC)	Criteria (C)	N (C) by SC	% (N(C), SC)	(N(C),D) %
VH	2,7	2	20%	22%
H	5,8,9	3	30%	33%
MH	1,3,4,6	4	33%	44%
LH	-	0	0%	0%
Total	D(B)	9	21%	100%

Figure 3.2 Classification of criteria – Class B

Sig. Class (SC)	Criteria (C)	N (C) by SC	% (N(C), SC)	(N(C),D) %
VH	1,2	2	20%	50%
H	-	0	0%	0%
MH	-	0	0%	0%
LH	3,4	2	20%	50%
Total	D(C)	4	10%	100%

Figure 3.3 Classification of criteria – Class C

Sig. Class (SC)	Criteria (C)	N (C) by SC	% (N(C), SC)	(N(C),D) %
VH	1.2,1.3,1.4,2.3	4	40%	25%
H	1.1,2.4,2.5,2.6	4	40%	25%
MH	3.3	1	8%	6%
LH	2.1,2.2,3.1,3.2,3, 4,3,5,3,6	7	70%	44%
Total	D(D)	16	38%	100%

Figure 3.4 Classification of criteria – Class D

6) Building the three proposed frameworks

Based on the results of criteria classification according to the three algorithms used, three multi-functional frameworks were built, each of these frameworks consists of criteria with the highest priority in the application, which were classified in the first category only and represent (24)% of the total criteria. Then their local and global weights of the criteria of each framework were independently recalculated as shown in figures 4, 5, and 6.

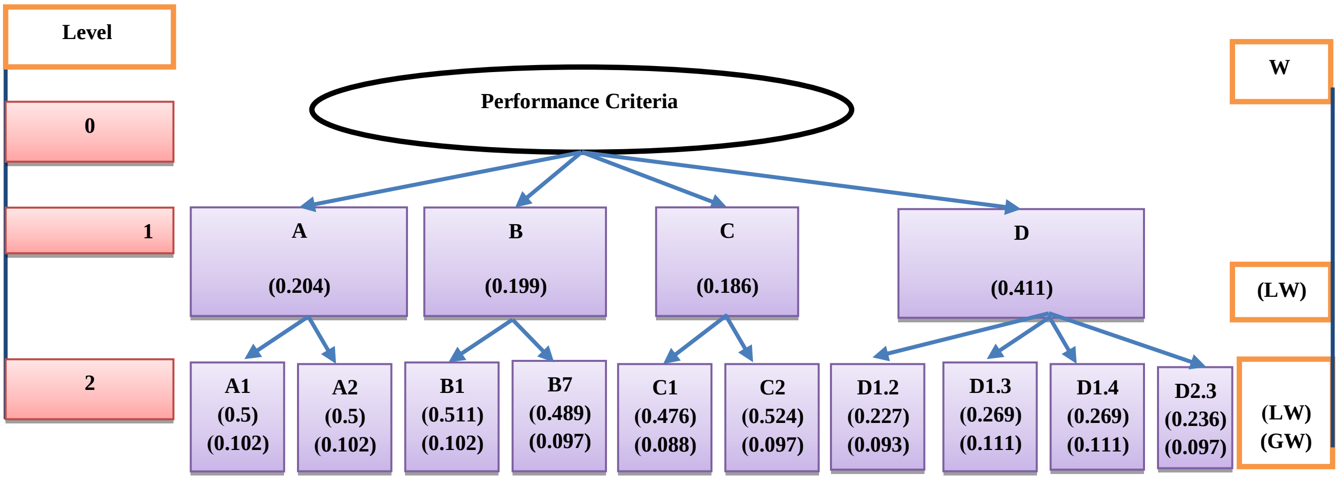

Figure 4. The proposed F-AHP Based framework for future eco-hotel evaluation in Yemen

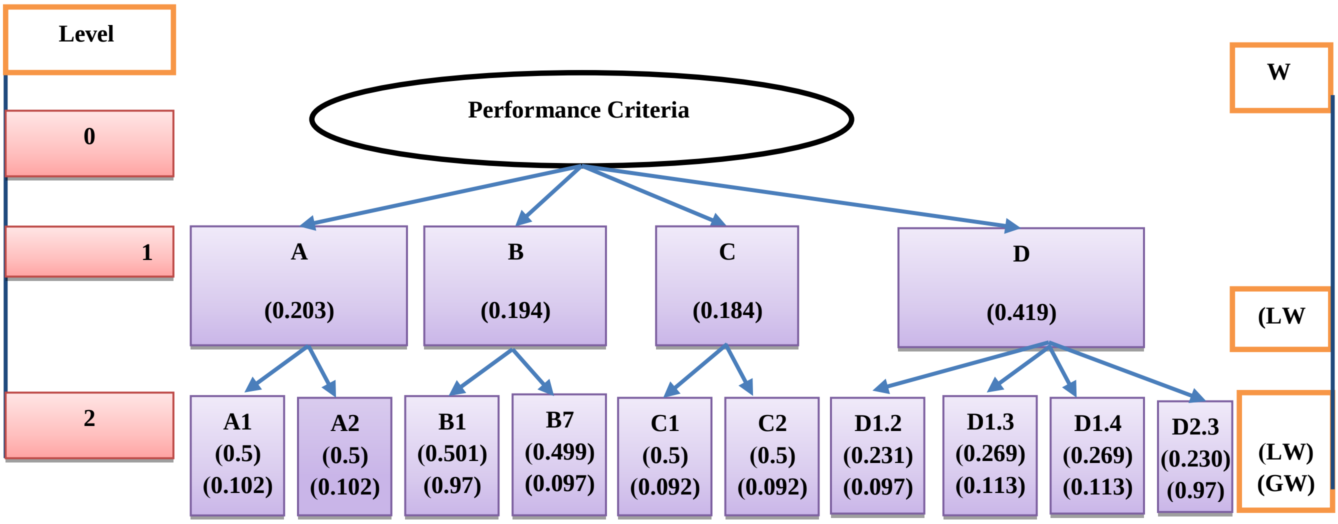

Figure 5. The AHP Based evaluation model

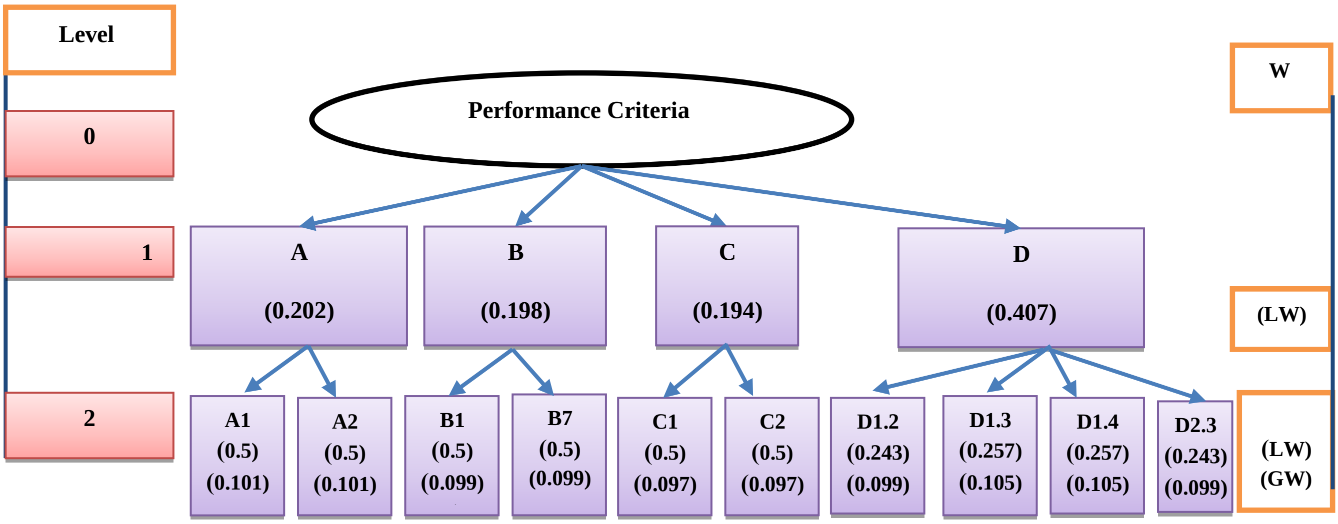

Figure 6. The FDM Based evaluation model

7) Comparative analysis of the result
In this step of study, the obtained outcomes presented in (Fig. 2, 3,4,5 and 6) were analyzed and discussed. As it shown in the next section. Based on that, the expected best framework was selected and proposed for future evaluation and planning processes in Yemen. The suitable recommendations were also provided as it shown in the last section of study.

IV. RESULTS AND DISCUSSION

A. Analyzing the classification results
By analyzing the classification result (figure. 2, figures 3.1, 3.2, 3.3 and 3.4), it was found that all three MCDM methods give the same classification result, and the different procedures did not affect the result of the classification of criteria into the four previously identified significant categories. This indicates the convergence of the outputs of these methods and suggests that the differences that exist at the general ranking level of criteria, and the differences in the ranking positions of each criterion (or the so-called level of change in the number of order places (s), as well as the differences in their final weights, are formal, small and do not affect the criteria classification result.

B. Analysing the ranking results
The general ranking results (fig. 4) showed that there are differences in the order of criteria between the three techniques. Perhaps the most noticeable results in this regard is that the ranking scopes are different; for example, all criteria (42 criteria) were arranged into (18) ranking levels only, using FDM technology. They reached forty levels when the AHP technique is applied; and with one rank increase (41), these criteria were arranged using the fuzzy AHP (Figures 2 and 4). This confirm that the two AHP techniques give better ranking results than the FDM, perhaps due to the dependence of AHP and FAHP techniques on pairwise comparison of experts' opinions more accurate results.

It also has been observed that despite the convergence of the ranking levels between the AHP and FAHP methods, differences between criteria weights resulting from the application of the AHP, were very small. This means that, although criteria got different AHP based ranks, their weights were very close to each other (for instance, the length of the range in which the AHP based weights of the (A6, A7.1, A7.2, A7.3, A7.4, B4, and B1) seven criteria are fall, is not more than 0.0009 (for simplicity these values have been rounded to 0.020 (see fig. 2)). Despite this, they were given seven different ranks.

Comparing with the fuzzy AHP based alternative, this range was wider. For the presented example, it doubled around 16 times. However, this result confirm that the fuzzy AHP way is better than its equivalent classical method (AHP) in that it gives non-convergent evaluation results, allowing for better arrangement of criteria, because of that the fuzzy algorithm modifies experts' opinions by using three-valued numbers as an alternative to the one valued numbers representing the AHP rating levels, and this considerably affects the final weight [28].

To compare the adapted pairs of methods, the average level of change in the rankings position (ranking place) of the criteria (P-change)) between each of the three technical pairs (AHP-FAHP, AHP-FDM, FDM-FAHP) was used. As illustrated in Figure. 7.

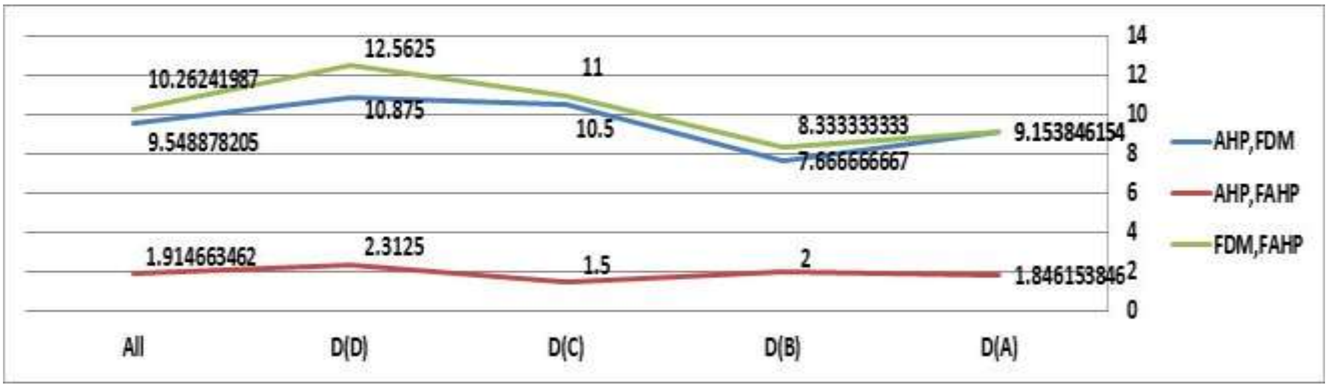

Figure 7. the average level of change in the rank's position of criteria

The most prominent results are that the lowest average change in the positions of the importance of the elements was between the AHP, and FAHP methods, reaching (0.2), while this value was bigger and very close between the other two pairs of methods (9.5, 10.3), respectively. Which, also stresses that the fuzzy AHP technique is considered the best compared to the classical AHP technique, and that both AHP techniques give better results compared to the FDM.

C. Agreement comparative analysis
This sub step is implemented to accurately explain the differences between the two best techniques comparing to each other. Firstly, the correlation coefficients between the ranking results of F_AHP – AHP pairs were obtained, a high correlation coefficients between them (0.987) was observed, Although these coefficients are high, it doesn't, however, explain precisely the agreement between these methods. For this reason, and to show that more readily, a

Bland-Atman analysis of their weights (Influence percentage) was implemented, it represents one of the best techniques used for this purpose [50, 51]. The following steps were used [49]: (1) calculate the average weights and differences in them, (2) determine the mean of differences (d), and (3) compute limits of agreement. With assumption that the differences are normally distributed, and prediction interval of 95% as suggested by [50], [51]; the limits of agreement were calculated as (d + 1.69 * Sd ; d - 1.69 * Sd), where (Sd) is the standard deviation of the differences.

The values of (-0.013 and 0.165) were obtained, the first represents the mean of difference; the second one describes the standard deviation of the differences for the investigated pair (F_AHP – AHP). It also was found that a 95 % of the differences in weights between the F_AHP and AHP are possible to fall within (0,265) upper , and (-0.29) lower limits of the confidence interval (0.556). By the same way, it also was found that a 95 % of the differences in weights between the F_AHP and FDM are possible to fall within (0,679) upper , and (-0.850) lower limits of the confidence interval (1.529), and a 95 % of the differences in weights between the AHP and FDM are possible to fall within (0,683) upper , and (-0.447) lower limits of the confidence interval (1.130).

In any case, the simplicity in the use of FDM is a good advantage over the two AHP methods, which rely on rather complex algorithms. On the other hand, they have better capabilities in giving more accurate ranking results. Taking this into account, the Bland-Atman analysis results indicate that the limits of agreement between (F_AHP and FDM) and (AHP _FDM) pairs of methods are small enough (< 1.53 %) to be confident that the proposed FAHP and AHP based frameworks can be used in place of FDM. It also indicate that the limits of agreement between (F_AHP and AHP) is small enough (<0.556) to be confident that the proposed FAHP based framework can be used in place of AHP.

V. THE LIMITATIONS OF THE STUDY

This study was carried out taking into account the following limitations: (1) the performance criteria for hotels and accommodations of numerous international standards provide many measurable factors, which must be chosen in different cases, in this study the criteria of the GSTC standard was chosen to build the proposed model. Also, (2) the practical applications of multi-criteria group decision support techniques have become more widespread. In this study, the AHP, FDM and F-AHP technics were comparably studied. In addition, (3) As it discussed early, this study seeks to compare the effect of the selected three methods on a ranking and classification decisions and to build a general model for hotel sustainability planning in Yemen and because that the factors of this model should be compatible with its conditions and environment, which are varied from one city to another, So, the evaluation and implementation procedures were scoped by the condition of the capital of Yemen (Sana'a).

VI. CONCLUSION

Choosing the appropriate sustainable factors for application in any development sector and determining their application priorities is one of the most critical steps in sustainable planning. It is also considered the first step in building general frameworks with multiple uses in the field of sustainable planning, such as measuring the level of application of sustainable practices in institutions, determining the application gap in them, arranging single sector institutions, defining their development's critical priority, and structured comparison of institutions according to the level of their application of sustainability practices, which in turn contribute significantly in achieving many sustainable economic, social and environmental goals. Choosing unimportant factors, neglecting other more important factors may lead to unreliable results. A contemporary planning principle emphasizes the application role of decision-making methodologies that count the experts' knowledge in dealing with such issues. In recent times, the implementation of quantitative approaches is increasing in sustainable eco-hotel planning domain. However, Different MCDM methods may give different arrangement results for the alternatives being studied in order to build general frameworks that are used for different planning purposes. This study tested the use of AHP, FDM, and FAHP MCDM techniques in determining the highest priority sustainable criteria and sub criteria for building a general multi-use framework in the field of green hotel planning in Yemen. It also studied the possibility of using each of them in determining the weights of these criteria, their classification and arrangement according to the priorities of sustainability and its environment in Yemen from the Yemeni experts' point of view, as well as the impact of each of them on the results of classification and arrangement of criteria. The most prominent findings of the study are that the application of the three aforementioned techniques does not affect the classification of criteria into the four categories of importance that were identified for this purpose, because the differences in the results of the indicators' weights and their ranking according to their importance using the three techniques were marginal, and the differences in the indicators' weights and their order of importance using the three techniques were marginal, and slightly variable within the internal range of the classification groups. At the level of ranking criteria, the Delphi technique arranged the sub-criteria into 18 levels, while they were arranged more clearly and more precisely using the other two techniques. The number of levels increased by 222 percent (40 levels) when the AHP method was applied, and by 227 percent (41 levels) when using its fuzzy version; this gives an advantage to these two technologies compared to the FDM. Also, it was found that, although each of them gives multiple rankings, the differences are very small and largely unclear between the weights of a group of successive sub-criteria that have different ranking levels, while with an increase of up to 16 times, those differences were clear in the results of its fuzzy version. Which gives an advantage to this technology compared to its traditional version. The results of the comparison of the average change in the standards of standards between this method and its traditional alternative was acceptable (1.9), but doubled by approximately seven times when it was compared with the FDM. In addition, the results of similarity analysis between those pairs were also confirmed on the convergence and similarity of the first pair of methods (AHP and FAHP) , and confirmed on the marginal differences of ranks, it was at least 3 times better compared to the results of similarity between the other pairs. Accordingly, this confirms the possibility of using any of the AHP techniques as an alternative to FDM. But, taking into account the preference of the fuzzy version in giving more disparity ranks and weights for alternatives, this study suggests the application of the proposed FAHP based framework for further sustainable planning purposes in the Yemeni hotel sector.

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