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"A Study of the Impact of Varying Construction Conditions between Countries on the Weighting of Sustainable Building Assessment Criteria within the BREEAM system, using Fuzzy Logic Techniques"

Researcher:

Ph.D. Mohammed Ali Alshamali

PhD in Civil Engineering, Department of Engineering Management and Construction, Damascus University, Syria

Abstract:

With the global trend towards developing the construction industry and achieving resource sustainability, several systems for evaluating sustainable buildings have emerged, most notably BREEAM UK, LEAD US, Green Global Canada, Green Pyramid Egypt, and many others. Numerous studies indicate the impossibility of establishing a unified and comprehensive system for measuring and evaluating sustainability for all countries, given the differences in building conditions, lifestyles, and economic, environmental, and social realities from one country to another (Ali Alshamali, Ibrahim, 2023). To support this hypothesis, this research presents an analytical study of the BREEAM system in the United Kingdom, including its main criteria for evaluating building sustainability and their sub-criteria, and determines the relative weights (relative importance) of these criteria within the BREEAM system that align with UK building conditions. The relative importance of these same criteria was then recalculated to suit Syrian building conditions using Fuzzy Hierarchy Analysis (FAHP), relying on sustainability experts in the Syrian construction sector. This recalculation aimed to highlight the importance of these criteria and encourage their adoption in the Syrian construction industry. A graph was then created to compare the resulting and original weights of the criteria. The results showed a difference in the relative weights of the criteria within the same assessment system between the UK and Syria, due to differences in construction conditions and lifestyles in the two countries. A set of recommendations was developed to increase the adoption of sustainable building technologies in the Syrian construction sector. This research can also serve as a basis for analyzing and studying sustainability assessment criteria that can be applied to many countries by recalculating the relative importance and weights according to the construction conditions and lifestyles in each country, relying on sustainability experts and stakeholders in this type of research within each country.

Keywords: Sustainability, Sustainable Building Rating Systems, BREEAM System, Sustainability Assessment Criteria.

1. Introduction:

Construction industry specialists around the world believe that traditional economic development formulas related to construction lead to a significant overuse of natural resources. They have begun to recognize the close link between economic development and the environment. Therefore, many methods, approaches, and concepts have emerged in advanced industrial countries, such as sustainable design, green architecture, green buildings, and sustainable buildings, with the aim of developing the construction industry and achieving resource sustainability and rationalizing water and energy consumption (Ali,2009).Many sustainable building rating systems have emerged in developed countries, the most important of which are the BREEAM environmental performance rating system in Britain, the LEED sustainable building rating system in America, the Green Globes green building rating system in Canada, the ESTIDAMA pearl rating system in the UAE, and the Green Pyramid Rating System in Egypt (Alshamali,2020).

These systems included a number of building sustainability assessment criteria, in addition to the areas of application of these criteria and their relative importance by assigning a percentage weight to each of them, according to the conditions of the construction industry in each country in which one of these systems was developed (Ali Alshamali, Ibrahim, 2023). In the context of this research, the BREEAM system was highlighted, including its important and useful criteria, and these criteria and their weights were studied, their relative importance was determined, and these criteria were reweighted to suit the construction conditions in Syria and the possibility of using these criteria to improve the current construction situation in Syria and try to reach sustainable buildings that achieve economic, social and environmental efficiency.

2. Research problem:

Given the difficulty of establishing a precise and standardized global system for measuring sustainability, due to the varying conditions and circumstances of the construction industry from one country to another, sustainability remains a challenging issue to measure and define. Its measurement is inherently relative, meaning it may involve uncertainty and imprecision. Furthermore, assessing building sustainability involves complex processes and encompasses numerous economic, environmental, and social indicators (Alshamali,2020). These and other factors have prevented the adoption of any global building sustainability assessment systems in the Syrian construction industry, regardless of their professionalism, advancement, or success in assessing building sustainability in the countries where they were developed.

3. Research objectives:

This research aims to determine the relative importance (weights) of the sustainable building assessment criteria included in the BREEAM system and their suitability to the construction conditions in the United Kingdom. Since the BREEAM system is specific to the UK construction sector, and given that the economic, environmental, social, and lifestyle conditions in the UK differ from those in other countries, these weights will be recalculated to align with the construction conditions in the country under study (Syria). This serves as a practical example that can be generalized to many neighboring countries or those with similar construction conditions. This recalculation will be achieved using fuzzy logic applications, specifically the FAHP (Fuzzy Hierarchical Analysis Process), which relies primarily on expert opinions in the field of sustainability within the country under study (Syria). Consequently, the challenges and obstacles that may hinder the application of these criteria in Syria can be analyzed, and proposals and recommendations can be developed to mitigate the negative aspects and enhance the positive aspects of implementing sustainability standards in the construction sector.

4. Research hypothesis:

Since the attributes and characteristics of sustainability are closely linked to the characteristics of each country (social, economic, environmental and even cultural) and are related to the different construction conditions and lifestyles between countries, the research assumes the possibility of applying the assessment criteria within the British BREEAM system within the Syrian construction industry.

5. Literature Review

In their research entitled "Developing a Green Building Assessment Tool for Developing Countries - A Case Study of Jordan", researcher Ali and his colleagues studied international green building assessment tools, such as LEED, CASBEE, BREEAM, GBTool, and others, to determine the criteria most suitable for the building conditions in Jordan. The selected criteria were discussed with about 60 different specific entities and were reweighted using the AHP multi-criteria decision-making method to suit the local context of the country of study (Jordan). The study concluded by proposing a computer-programmed sustainability assessment tool (SABA) that takes into account the environmental, economic, and social aspects in Jordan. (Ali,2009)

Alshamali and his colleague also used the FAHP method to recalculate the building sustainability assessment criteria included in the American system to suit construction conditions in Syria. They emphasized:

The difficulty of establishing a stable, effective, and globally applicable rating system due to differences in construction conditions, economic circumstances, and priorities among countries, as well as variations in climatic conditions from one region to another. Despite the researchers using the same basic criteria adopted in the United States, the results in Syria differed, reflecting the local context of the study area. (Ali Alshamali, Ibrahim, 2023)

With the aim of developing a new and customized classification system that meets the needs of the construction and environment sectors in Egypt, researcher Younan reviewed, in her master’s thesis entitled “Developing a Classification System for Green Buildings in Egypt,” the study concluded that there is a need for a comprehensive list of categories and their subcategories that affect green buildings. This list was prepared by conducting a comparative analytical study between several sustainable building classification systems, identifying the main and sub-evaluation criteria, and then designing a special questionnaire to reweight them in a way that takes into account the local context by relying on experts in the field of sustainability who are familiar with green buildings and the system (LEED) using the method (AHP), and their answers were consistent, as is evident from the AHP consistency index, and therefore the resulting weights are reliable (Younan,2011).

In his doctoral dissertation entitled (Developing an intelligent system for evaluating sustainable green buildings in Syria), researcher Alshamali prepared a comparative analytical study of several global evaluation systems for sustainable green buildings. He then studied the local context of the country of study and identified the evaluation criteria that are appropriate for the construction conditions in Syria. He then calculated their relative importance using the multi-criteria decision-making method based on fuzzy logic (FAHP). He developed an evaluation mechanism that includes the selected criteria and their relative weights. The mechanism was applied to some buildings in the Marota City project in the capital, Damascus. The mechanism achieved accurate results because the evaluation mechanism was based on experts in the field of sustainability and the environment and researchers interested in this type of research (Alshamali,2020).

Ferreira and colleagues conducted a comprehensive review of the most common building sustainability assessment methodologies and their suitability for retail buildings. LEED, BREEAM, and DGNB methodologies were selected for comparison in terms of certification ratings, categories, indicators, weights, and guidelines for their use in retail buildings. They emphasized that:

While the DGNB methodology is the most robust for assessing commercial building sustainability in this field, it is essential to pay closer attention to performance metrics, such as water and energy consumption, carbon footprint, materials, life-cycle cost, or economic value, to facilitate comparison between the different methodologies by identifying the strengths and weaknesses of each. (Ferreira et. al. 2023)

This study supports informed decision-making when selecting a commercial building assessment method and guides the development of regional commercial building assessment methodologies, taking into account the limitations of current tools (Ferreira et. al. 2023).

6. Research Methodology and Steps

This research is based on the descriptive analytical method, which includes a field study (distribution of a designed questionnaire), and Figure (1) illustrates the research steps.

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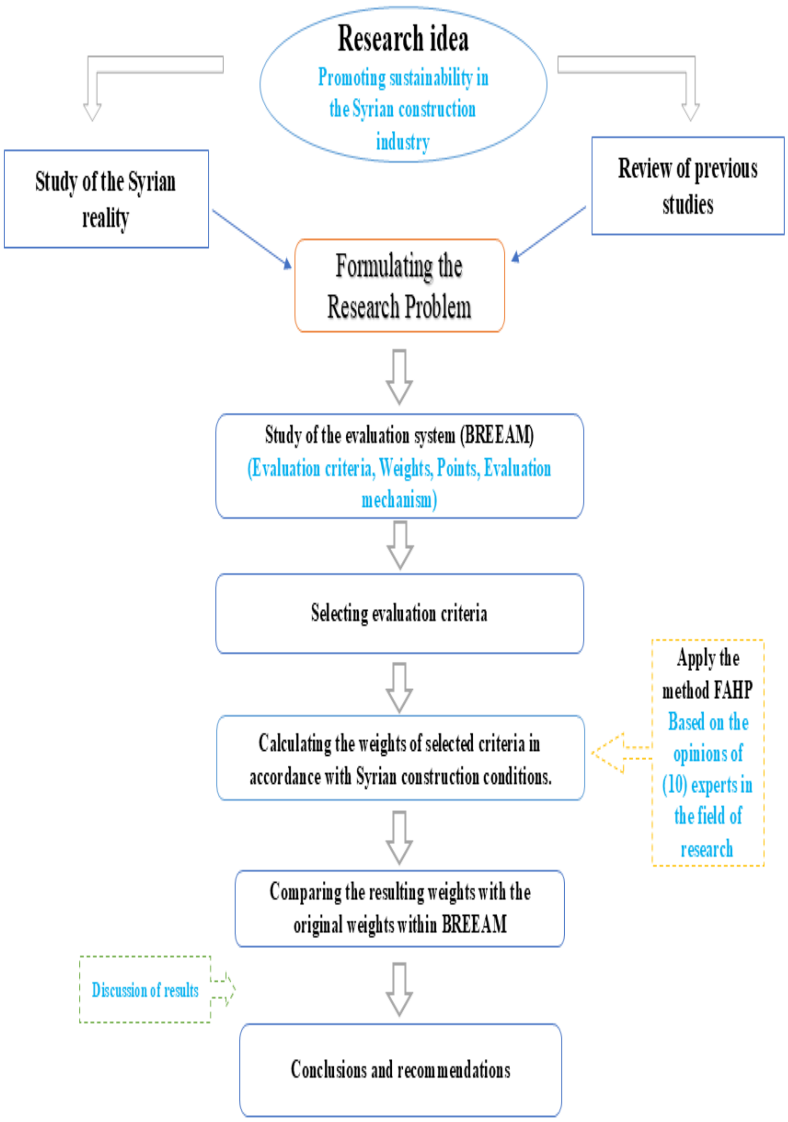


Fig. 1 Research steps

7. Building Research Establishment's Environmental Assessment Method – BREEAM

It is the world's first method for environmentally assessing and classifying buildings. It was launched in 1990 by the British Building Research Foundation (BRE). It covers a range of building types (offices, houses, industrial units, schools, prisons, courts) (BRE Global,2008). This system allows for the creation of exceptional rating systems to deal with building types not included in the basic structure of the rating system. The system gives points when certain elements (criteria) are achieved, and then the points are totaled. Based on the total score, the building is given a rating between (successful / good / very good / excellent)(BRE. Building Research Establishment, 2009).

7.1. The code for sustainable homes (CSH)

The code for sustainable homes (CSH) sets standards for the sustainability of buildings during their design, construction, and use. It is one of the most comprehensive and widely recognized global measures in this field, encompassing nine categories, six of which are mandatory and three flexible, in addition to innovation. The rating system awards six stars for best performance (BRE. Building Research Establishment, 2009)(Ferreira et. al. 2023). Among the most important elements of this rating system are (Figure 2):

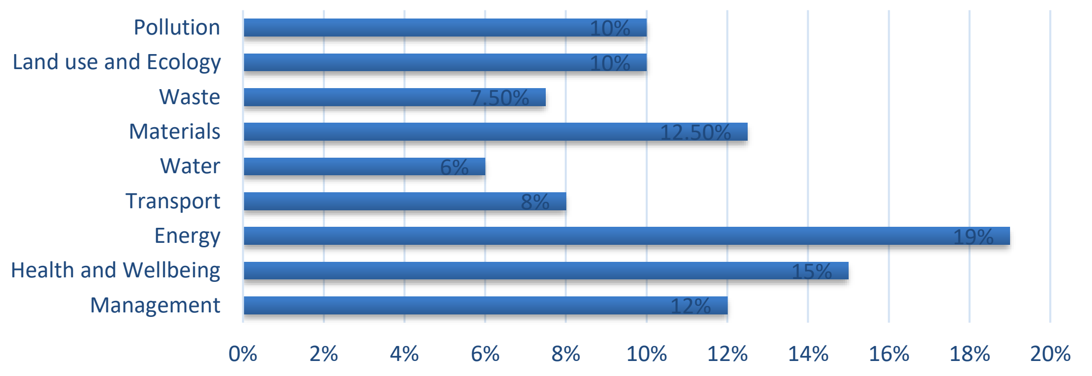
• **Management** (supervision and monitoring, recycling, pollution reduction, material consumption reduction)

• **Health and Safety** (adequate ventilation, humidity and its factors, lighting, thermal comfort)

• **Pollution** (leak monitoring systems, on-site sanitary treatments, on-site or off-site renewable energy sources, designs with minimal pollution impacts, avoidance of ozone-depleting materials or those that contribute to global warming)

• **Energy – Transportation – Water – Materials – Waste – Innovation – Ecology.**

Fig.2 Evaluation criteria according to BREEAM and their weights



7.2. Assessment Method According to BREEAM

The sustainability of the required building is assessed using this system by awarding the building specific points when certain criteria are met. The points earned for the building are then totaled, and from this total of points, an evaluation of the building is given, which is within the following categories (Successful - Good - Very Good - Excellent). The evaluation process is coded by stars (★), and Table (1) shows the relationship between the total points, the classification level, and the number of stars according to this system (BRE Global,2008)(BRE. Building Research Establishment, 2009)(Alshamali,2020).

Table (1) The relationship between total points, rating level and number of stars according to BREEAM

Number of stars	Level	Total points
★	Level 1 (Licensed)	**36**
★★	Level 2	**48**
★★★	Level 3	**57**
★★★★	Level 4	**68**
★★★★★	Level 5	**84**
★★★★★★	) Zero carbon home(Level 6	**90**

Table (2) shows that the total number of points that the BREEAM system can award is (104 points) and corresponds to a percentage of 100%. In other words, if the building whose sustainability is to be assessed achieves a total of 104 points, it can be classified as 100% sustainable according to the BREEAM system, taking into account the existence of mandatory items (Mandatory) that have been coded with the symbol (M).

Table (2) Assessment criteria according to BREEM in United Kingdom

Number	Evaluation criteria	Relative weights	Points	Mandatory elements
1	Management	12%	7	-
2	Health and Wellbeing	15%	12	**M**
3	Energy	19%	29	**M**
4	Transport	8%	2	**M**
5	Water	6%	10	**M**
6	Materials	12.5%	24	**M**
7	Waste	7.5%	7	**M**
8	Land use and Ecology	10%	9	-
9	Pollution	10%	4	-
	Total	**100%**	**104**	

8. Fuzzy Logic:

8.1. Definition

Professor Lotfi Zadeh[1] is considered the founder of fuzzy logic in 1965. Since then, fuzzy logic applications have seen a succession of successful applications, including data classification, control systems, and expert systems. Several factors have contributed to the growing popularity of fuzzy systems (ZADEH,2005), including:

• Ease of understanding: The mathematical concepts underlying fuzzy reasoning are easy to grasp.

• Flexibility: A given system can be assigned a range of additional functions without needing to rebuild the system entirely.

• Efficient handling of imprecise data: In the real world, everything appears imprecise even when examined carefully and meticulously. Fuzzy logic excels at handling imprecision and obtaining entirely new results using imprecise data.

• Fuzzy logic can model complex nonlinear functions: Fuzzy systems can be built to match any set of inputs and outputs, especially with the emergence of powerful, readily available technologies such as fuzzy logic integration systems with artificial networks.

8.2. A comparison between traditional logic and fuzzy logic

A classical set can be defined as follows: if element x belongs to set A, then the value of the membership function of element x to set A is equal to one; otherwise, it takes the value (zero). However, when defining a fuzzy set, element x belongs to set A to varying degrees between zero and one [0, 1] (ZADEH,2005). That is, there is a partial affiliation that can be expressed through the following affiliation function:

$$\mu_A(x) \in [0,1]$$

[1] Lotfi Zadeh (February 4, 1921, Baku, Azerbaijan – September 6, 2017) was an Azerbaijani-American mathematician. He is considered the founder of fuzzy logic. At the age of ten, Zadeh moved with his family to Iran, where he studied electrical engineering at the University of Tehran, graduating in 1942.

$$\forall\, x \in X \qquad \mu_A(x) = 0 \text{ if } x \notin A$$

$$\mu_A(x) = 1 \text{ if } x \in A$$

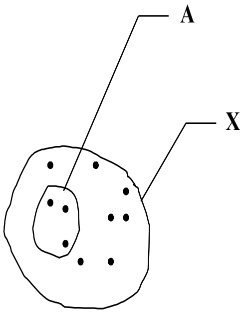


Fig.3 illustrates the traditional set

For example, we can define the group that represents tall people according to traditional and fuzzy logic as follows:

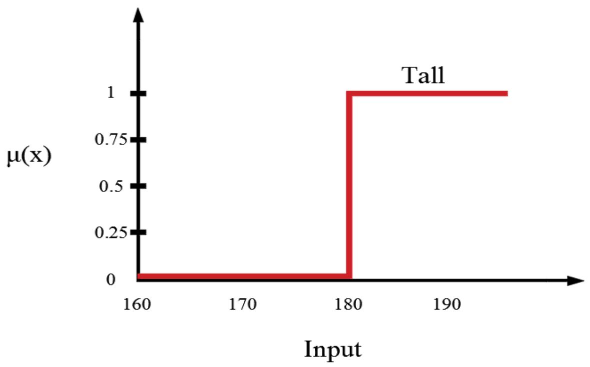


Fig.4 The traditional group representing tall people

Figure (4) illustrates, People can be considered tall if they are 180 cm or taller, while short people are those 180 cm or shorter.

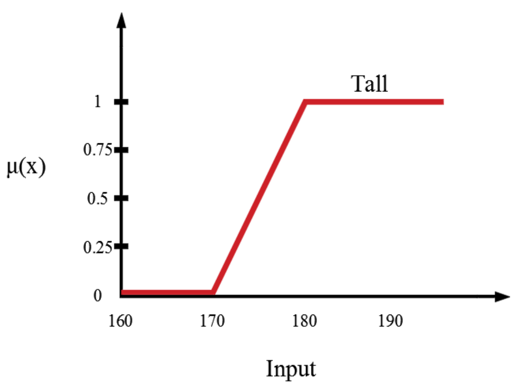
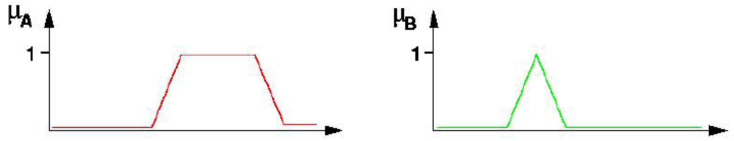


Fig.5 The fuzzy group representing tall people

Figure (5) shows that tall people can be considered to be people whose height is 180 cm and above, while short people are people whose height is 170 cm and below, while people whose height is between 170 cm and 180 cm are classified as people with degrees of height and degrees of shortness. For example, people whose height is 175 cm belong to the group of tall people to a degree of 50% and to the group of short people to a degree of 50%

We can express the basic mathematical operations of classical logic, such as intersection and union, using fuzzy logic. Suppose we have two fuzzy sets, A and B, and an element x that belongs to both sets in degrees. We want to define the intersection and union between them as shown in the following figure (6):



Fuzzy set A, B

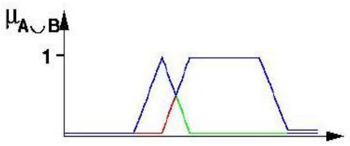


Illustration: Meeting of the two fuzzy sets A and B

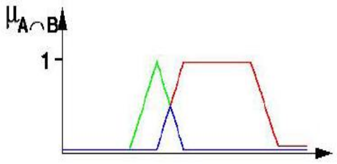


Illustration: Intersection of the two fuzzy sets A and B

Fig.6 Intersecting and converging operations on fuzzy sets

- Intersectional relationship: Element x must belong to both sets A and B. This relationship can be expressed as the MIN relation, meaning that for element x to belong to both sets A and B together, it must also belong to both sets A and B individually.
- The relationship of association: The element x must belong to either group A or B. This relationship can be expressed as the MAX relation. That is, for the degree of association of the element x with both groups A and B to be strong, the degree of association of the same element x with either group A or B must be strong.

$$\mu_{A\cap B}(x) = min\,[\,\mu_A(x), \mu_B(x)]$$

$$\mu_{A\cup B}(x) = max\,[\,\mu_A(x), \mu_B(x)]$$

9. Fuzzy Analytical Hierarchy Process (FAHP)

It is a modification of the AHP[2] method introduced by Saaty[3] (Saaty,2004), which is one of the most famous methods for multi-criteria decision-making. Despite the widespread use of this method, it is criticized for its inability to deal with uncertainty and ambiguity in the decisions of decision-makers. In order to overcome these problems, and since ambiguity and ambiguity are known characteristics in most decision-making problems, the Fuzzy Logic modification was added to the AHP method to become FAHP, which is able to tolerate ambiguity (Ibrahim,2014)(Awad,2014)(Change,1996).

9.1. FAHP Method Steps

It includes a set of steps (the steps will be explained first and then applied to the study criteria), which are:

[2] The AHP (Analytical Hierarchy Process) is a multi-criteria decision-making method that aims to rank alternatives based on qualitative and quantitative criteria by dividing the problem into a hierarchical structure. The method involves creating matrices for pairwise comparisons, calculating the weight of each criterion and alternative, and verifying the consistency of the results using the consistency ratio (CR).

[3] Thomas Saati was born in Mosul, Iraq in 1926. He is a mathematical scientist and professor at the University of Pittsburgh in the United States, where he teaches at the Joseph Katz Graduate School of Business. He is the inventor, designer, and principal researcher of the Analytic Hierarchy Process(AHP).

Step 1: Defining the study criteria and transforming the decision problem into a hierarchical structure so that the general elements of the decision problem are shown, i.e., the complex problem is analyzed into a hierarchical structure with decision elements (criteria).

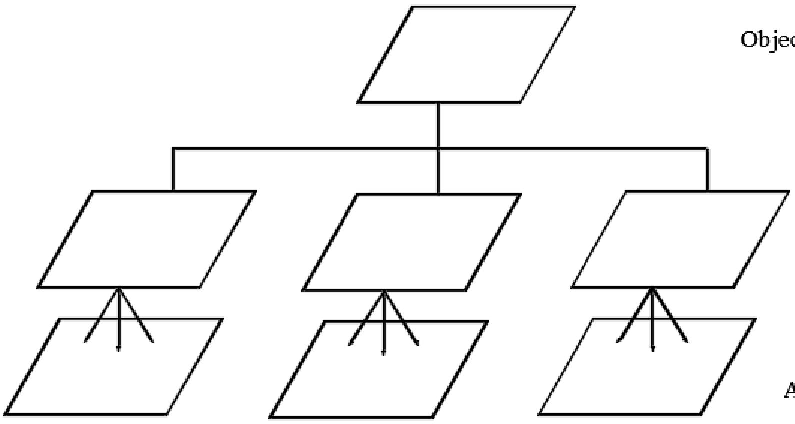


Fig.7 Hierarchical structure of a multi-criteria decision problem

Step 2: Determining the relative importance of the criteria to each other based on expert opinions, according to the following equation:

$$A = \begin{bmatrix} W_1/W_1 & W_1/W_2 & \dots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \dots & W_2/W_n \\ \dots & \dots & \dots & \dots \\ W_n/W_1 & W_n/W_3 & \dots & W_n/W_n \end{bmatrix} \quad \boldsymbol{equation\ (1)}$$

Where:

A is the binary comparison matrix:

W_1: weight of element 1, W_2: weight of element 2, ..., W_n: weight of element n.

In order to apply binary comparisons between parameters, the traditional CRISP numbers in the Saaty scale shown in Table (3) are used, as Figure (8) shows the fuzzy numbers used to represent the preference scores in the Saaty scale (Saaty,2004).

Table (3) Saaty scale

Degree of preference (linguistic scale)	**Degree of preference**		
	Numeric value	fuzzy Numeric value	The reciprocal fuzzy Numeric value
Equal preference for first over second	1	(1,1,1)	$(\mathbf{1},\mathbf{1},\mathbf{1})$
Equal to medium preference for first over second	2	(1,2,3)	$(\mathbf{1/1},\mathbf{1/2},\mathbf{1/3})$
Medium preference for first over second	3	(2,3,4)	$(\mathbf{1/2},\mathbf{1/3},\mathbf{1/4})$
Medium to strong preference for first over second	4	(3,4,5)	$(\mathbf{1/3},\mathbf{1/4},\mathbf{1/5})$
Strong preference for first over second	5	(4,5,6)	$(\mathbf{1/4},\mathbf{1/5},\mathbf{1/6})$
Strong to very strong preference for first over second	6	(5,6,7)	$(\mathbf{1/5},\mathbf{1/6},\mathbf{1/7})$
Very strong preference for first over second	7	(6,7,8)	$(\mathbf{1/6},\mathbf{1/7},\mathbf{1/8})$
Very strong to absolute preference for first over second	8	(7,8,9)	$(\mathbf{1/7},\mathbf{1/8},\mathbf{1/9})$
absolute preference for first over second	9	(8,9,9)	$(\mathbf{1/8},\mathbf{1/9},\mathbf{1/9})$

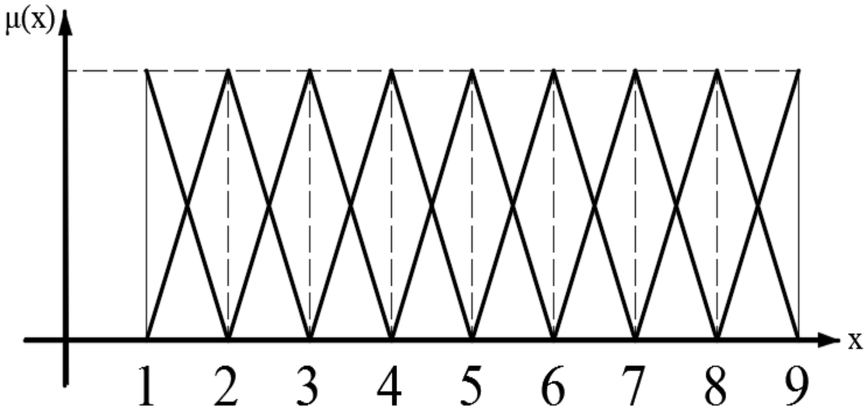


Fig.8 Triangular fuzzy numbers representing linguistic expressions in the Saaty scale

Step 3: Ensure consistency of comparisons for each expert (Ki) to determine whether the comparisons are consistent or contradictory. The consistency ratio (CR) should be calculated according to the following formula:

$$\boldsymbol{CR = \frac{CI}{RI}} \quad \boldsymbol{Equation(2)}$$

Where CI is the consistency index, and is calculated from the equation:

$$\boldsymbol{CI = \frac{\lambda_{max} - n}{n - 1}} \quad \boldsymbol{Equation(3)}$$

Where:

n: the number of criteria, λmax: the maximum value of the eigenvalue of the comparison matrix A.

Saaty showed that λmax is greater than or equal to n, and the closer its value is to n, the more stable the matrix.

The closer the value is to n, the more stable the matrix becomes.

Step 4: Transforming the binary comparison matrix for each expert K_i, where i = 1, 2, ..., n, into fuzzy form using the fuzzy numbers in the Saaty scale (Table 3). The fuzzy binary comparison matrix $\breve{A}(a_{ij})$ can be expressed mathematically as follows:

$$\breve{A}(a_{ij})_{n*n} = \begin{bmatrix} (1,1,1) & (1_{12}, m_{12}, u_{12}) & \dots & (1_{1n}, m_{1n}, u_{1n}) \\ (1_{21}, m_{21}, u_{21}) & (1,1,1) & \dots & (1_{2n}, m_{2n}, u_{2n}) \\ \dots & \dots & \dots & \dots \\ (1_{n1}, m_{n1}, u_{n1}) & (1_{n2}, m_{n2}, u_{n2}) & \dots & (1,1,1) \end{bmatrix} \quad \boldsymbol{Equation(4)}$$

Step 5: Compile the fuzzy judgment matrix for the group of experts (n) to obtain the final matrix ($\widetilde{A_{ij}} = (L_{ij}, M_{ij}, U_{ij})$)

$$L_{ij} = min(l_{ijk}) \ , \quad M_{ij} = \left(\prod_{k=1}^{n} m_{ijk}\right)^{\frac{1}{n}}, \quad U_{ij} = max(u_{ijk}) \quad \boldsymbol{Equation(5)}$$

Step 6: Calculate the weights of the criteria **w** by applying the FAHP algorithm(Chang's extent analysis). This can be summarized according to the following mathematical algorithms:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} * \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} \quad \boldsymbol{Equation(6)}$$

$$M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j\right) \quad \boldsymbol{Equation(7)}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{n} l_i , \sum_{j=1}^{n} m_i , \sum_{j=1}^{n} u_i\right) \quad \boldsymbol{Equation(8)}$$

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$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} l_i}, \frac{1}{\sum_{j=1}^{n} m_i}, \frac{1}{\sum_{j=1}^{n} u_i}\right) \quad \textbf{Equation}(9)$$

$$\textbf{Equation}(10) \quad V(\breve{S}_i \geq \breve{S}_j) = \begin{cases} 1, & IF\ m_i \geq m_j \\ 0, & IF\ l_j \geq u_i \\ \dfrac{u_i - l_j}{(u_i - m_i) + (m_j - l_j)} & Otherwise \end{cases}$$

$$\breve{S}_j = (L_j, M_j, U_j), \quad \breve{S}_i = (L_i, M_i, U_i)$$

$$w_t = \frac{V(\breve{S}_i \geq \breve{S}_j \mid j = 1, \dots, n \ , j \neq i)}{\sum_{K=1}^{n} V(\breve{S}_k \geq \breve{S}_j \mid j = 1, \dots, n \ , j \neq k)}$$

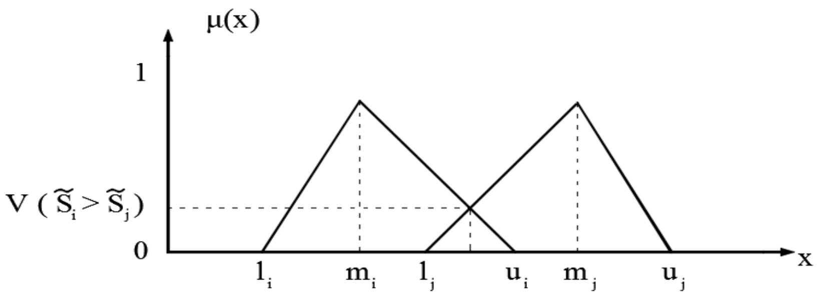


Fig.9 Degree of possibility $V(\breve{S}_i \geq \breve{S}_j)$

10. Applying FAHP steps to the assessment criteria within the BREEAM system

Data was obtained from experts working in the Syrian construction industry through a questionnaire designed to allow for immediate transition to the next step without any modifications to the experts' responses. The pairwise comparison matrix was used, mirroring the questionnaire methodology employed by (Alshamali,2020)(Ibrahim,2014)(Awad,2014). An Excel program was developed to calculate the weights of the criteria using the FAHP method. This program determined the relative importance of the criteria based on available data and input from (10) sustainability experts. The consistency of the input matrices was then verified, and finally, the weights (relative importance) of the criteria were calculated.

To obtain accurate information from experts regarding the preferential importance of sustainability assessment criteria, the criteria will be weighted using a scoring system based on importance, with the scoring scale based on Table (4).

Table (4) Grade ladder

Value	Representation that corresponds to value
9	High advantage of first over second
6	Medium advantage of first over second
3	Small advantage of first over second
1	Equal in importance
0.33	Small advantage of second over first
0.1667	Medium advantage of second over first
0.11	Large advantage of second over first

This is done by designing a suitable questionnaire that includes a binary comparison table of criteria, and it has been prepared in a way that makes it easy to move directly to the next step without the need to make any adjustments, as each expert is required to fill in the table (matrix) below with the values that match Table (4), and to fill in the items that are below or above the main diagonal only, and the model is shown in Table (5).

Table (5) Bilateral Comparison Matrix of Criteria for each Expert (E_i)

Expert	**Management**	**Health and Wellbeing**	**Energy**	**Transport**	**Water**	**Materials**	**Waste**	**Land use and Ecology**	**Pollution**
Management	1.00								
Health and Wellbeing		1.00							
Energy			1.00						
Transport				1.00					
Water					1.00				
Materials						1.00			
Waste							1.00		
Land use and Ecology								1.00	
Pollution									1.00

Table (6) shows the answers of the first expert based on the values included in Table (4). It will be sufficient to include the answer of the first expert because it is not possible to add the answers of all the experts.

Table (6) Bilateral Comparison Matrix of Standards for the First Expert

First Expert	Management	Health and Wellbeing	Energy	Transport	Water	Materials	Waste	Land use and Ecology	Pollution
Management	1.00	1	0.17	0.11	9.00	0.33	6.00	1.00	6.00
Health and Wellbeing	1	1.00	0.33	0.11	1	0.17	0.11	6	1
Energy	6	3	1.00	0.11	6	3	0.33	0.17	0.33
Transport	9	9	9	1.00	9	6	9	6	3
Water	0.11	1	0.17	0.11	1.00	0.33	0.17	1	0.33
Materials	3	6	0.33	0.17	3	1.00	0.17	0.33	0.17
Waste	0.17	9	3	0.11	6	6	1.00	9	1
Land use and Ecology	1	0.17	6	0.17	1	3	0.11	1.00	1
Pollution	0.17	1	3	0.33	3	6	1	1	1.00
Σ	**21.45**	**31.17**	**23**	**2.05**	**39**	**25.83**	**17.89**	**25.5**	**13.83**
	λ_{max} = 11.332			**CI =0.148**			**CR =0.099**		

Verifying Matrix Consistency: By reviewing Equation (2), the consistency of the comparisons for each expert (Ei) was verified to determine whether the comparisons were consistent or conflicting. Table (7) shows that the consistency ratio is achieved for all comparisons, as it is clear that CR < 0.1.

Table (7) Consistency Ratio (CR)

Experts	λ_{max}	CI	RI	CR	check
B1	11.332	0.148	1.49	0.099	**ok**
B2	11.287	0.143	1.49	0.096	**ok**
B3	11.323	0.147	1.49	0.098	**ok**
B4	11.305	0.145	1.49	0.097	**ok**
B5	11.296	0.144	1.49	0.096	**ok**
B6	11.314	0.146	1.49	0.097	**ok**
B7	11.287	0.143	1.49	0.096	**ok**
B8	11.323	0.147	1.49	0.098	**ok**
B9	11.332	0.148	1.49	0.099	**ok**
B10	11.314	0.146	1.49	0.097	**ok**

By applying the (FAHP) algorithm mentioned above [see equations No. (4) to No. (10)] the weights (relative importance) of the evaluation criteria are obtained in accordance with the Syrian construction conditions based on expert opinions, as shown in Table (8).

Table (8) The relative importance of criteria according to Syrian construction conditions

Criteria	code	Weight%
Management	W_1	5.5
Health and Wellbeing	W_2	10.7
Energy	W_3	20
Transport	W_4	4.6
Water	W_5	15
Materials	W_6	13
Waste	W_7	12
Land use and Ecology	W_8	6.9
Pollution	W_9	12.3
Total		**100%**

11. Comparing and discussing the results

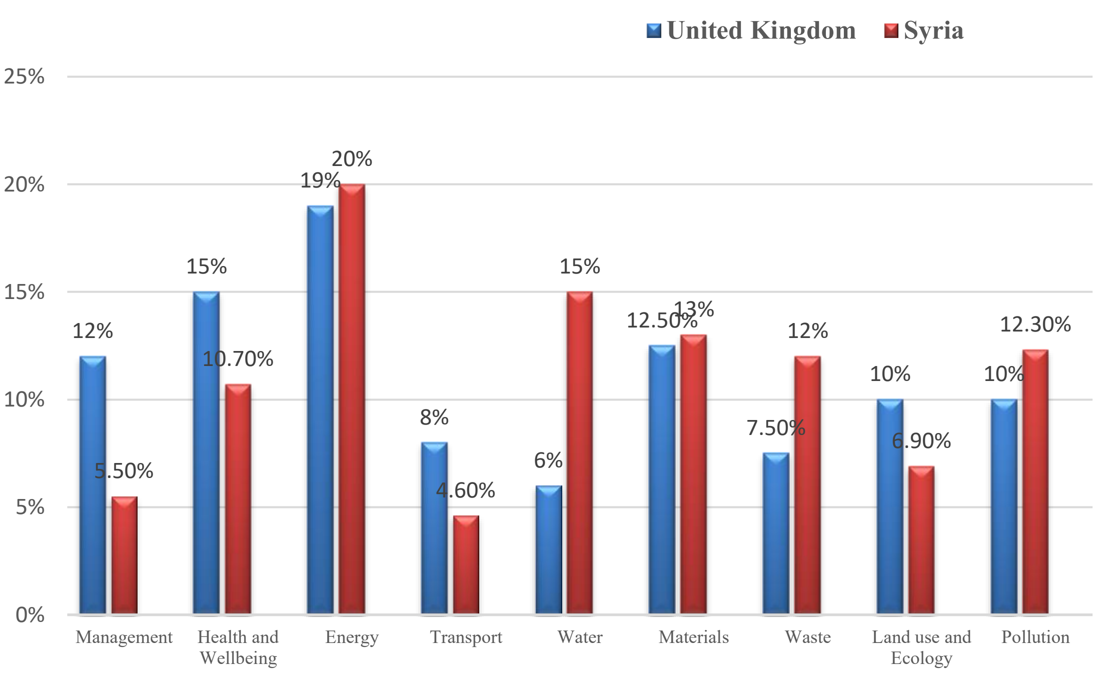
Table (9) shows a comparison between the weights of the assessment criteria adopted in the BREEAM system and listed in Table (2), with the corresponding criteria that we obtained through the knowledge of experts in the field of sustainability in Syria.

Table (9) comparison of the evaluation criteria weights according to the BREEAM system between Syria and Britain

Seq.	Criteria	Syria	United Kingdom
1	Management	5.5%	**12%**
2	Health and Wellbeing	10.7%	**%15**
3	Energy	20%	**%19**
4	Transport	4.6%	**8%**
5	Water	15%	**6%**
6	Materials	13%	**12.5%**
7	Waste	12%	**7.5%**
8	Land use and Ecology	6.9%	**10%**
9	Pollution	12.3%	**10%**

This is illustrated in the following figure (10):

Fig.10 Comparing the weights of the BREEAM system criteria between Syria and United Kingdom



It can be observed that the highest relative importance obtained under Syrian conditions is for energy standards (20%), which reflects the local context in terms of limited resources and the large depletion of non-renewable energy sources. Also, the water-related standards (15%) were given relatively high importance, so it is necessary to rely on policies to rationalize water consumption and preserve resources. That is, the weights (relative importance) between the United Kingdom and Syria differed clearly, and this can be attributed to the difference in construction conditions, lifestyles, culture, climatic conditions, and others between the two countries. This is what many reference studies available in this context have indicated, as this study proved the validity of the hypotheses stating that there is no single effective system that can be highly transparent and can be introduced into the global market.

12. Recommendations:

- This research can serve as a foundation for analyzing and studying sustainability assessment criteria that can be generalized to many countries by recalculating the relative importance and weights according to the building conditions and lifestyles within each country, relying on sustainability experts and those interested in this type of research.
- Based on the findings of this research, and given the importance of adopting sustainability standards in buildings, especially during the upcoming reconstruction phase in Syria, the research recommends the following:

1. The necessity of guiding research centers, academic and environmental institutions, and relevant authorities to adopt a sustainability assessment system specific to the Syrian construction sector. This system should include reliable, effective, and appropriate assessment criteria for local building conditions, taking into account the local context from all economic, environmental, and social perspectives.

2. The necessity of involving stakeholders (residents, owners, tenants, and real estate developers) in determining the selected assessment criteria.
3. Raising awareness of the importance of sustainability principles in their various aspects, highlighting their environmental and social benefits, and clarifying the financial advantages they provide during operation and maintenance throughout the building's lifespan, rather than focusing solely on the relatively high construction costs.

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" دراسة تأثير اختلاف ظروف البناء بين البلدان على ترجيح معايير تقييم المباني المستدامة ضمن نظامBREEAM باستخدام تقنيات المنطق الضبابي."

إعداد الباحث:

د.م.محمد علي الشمالي

دكتوراه في الهندسة المدنية، قسم الإدارة الهندسية والتشييد، جامعة دمشق، سوريا

الملخص:

مع التوجه العالمي نحو تطوير صناعة البناء وتحقيق استدامة الموارد، ظهر عدد من الأنظمة لتقييم المباني المستدامة، أبرزها (BREEAM UK/LEAD US/Green Global Canada/Green Pyramid Egypt/وغيرها الكثير). وتشير العديد من الدراسات إلى استحالة إيجاد نظام موحد وشامل لقياس وتقييم الاستدامة لجميع الدول نظرًا لاختلاف ظروف البناء وأنماط الحياة والواقع الاقتصادي والبيئي والاجتماعي من دولة لأخرى (Ali Alshamali, Ibrahim, 2023). ولتأكيد هذه الفرضية، يقدم هذا البحث دراسة تحليلية لنظام BREEAM في المملكة المتحدة، بما في ذلك معاييره الرئيسية لتقييم استدامة المباني ومعاييرها الفرعية، وتحديد الأوزان النسبية (الأهمية النسبية) لهذه المعايير داخل نظام BREEAM المتوافقة مع ظروف البناء في المملكة المتحدة. ثم تم إعادة حساب الأهمية النسبية لهذه المعايير نفسها لتناسب ظروف البناء في سوريا، وذلك باستخدام تحليل التسلسل الهرمي الضبابي (FAHP)، بالاعتماد على خبراء في الاستدامة في قطاع البناء السوري بهدف إبراز أهمية هذه المعايير وتشجيع اعتمادها في صناعة البناء السورية. ثم تم إنشاء رسم بياني لمقارنة الأوزان الناتجة والأصلية للمعايير. أظهرت النتائج اختلافًا في الأوزان النسبية للمعايير ضمن نظام التقييم نفسه بين المملكة المتحدة وسوريا، وذلك بسبب الاختلافات في ظروف البناء وأنماط الحياة في البلدين. تم وضع مجموعة من التوصيات لزيادة اعتماد تقنيات البناء المستدامة في قطاع البناء السوري. يمكن أن يكون هذا البحث أيضًا بمثابة أساس لتحليل ودراسة معايير تقييم الاستدامة التي يمكن تطبيقها على العديد من البلدان من خلال إعادة حساب الأهمية النسبية والأوزان وفقًا لظروف البناء وأنماط الحياة في كل بلد، بالاعتماد على خبراء الاستدامة وأصحاب المصلحة في هذا النوع من الأبحاث داخل كل بلد.

الكلمات المفتاحية: الاستدامة ، أنظمة تقييم المباني المستدامة ، نظام BREEAM ، معايير تقييم الاستدامة.