Assessment of Criteria Importance for Sustainable Buildings

تقييم أهمية معايير الأبنية المستدامة

Prof. Dr. Angham E. Al-Saffar
University of Baghdad
College of Engineering
Department of Civil Engineering
Construction Management(07901412565)
anghamalsaffar@yahoo.com

Ass. Lect. Hussein Ali Mohammed
University of Karbala
College of Engineering
Department of Civil Engineering
Construction Management(07804071504)
alhamamy70@yahoo.com

Abstract

This research aims to highlight and demonstrate the role of sustainability and its criteria in the construction sector, and determine the weights of these criteria in the Iraqi construction environment. For the purpose of achieving the objective of this research, data have been collected from the literature and references that deal with the issue of sustainability, personal interviews with specialists, as well as the field questionnaire, and finally the use of analytical hierarchal process (AHP) software to assess the sustainability criteria for green buildings.

The results of the data analysis of the sample questionnaire show that the highest importance (priority) is given to the criterion of resourceful energy, and less importance is given to the criterion of construction duration; the remaining percentages are distributed to the other criteria.

الخلاصة

يهدف هذا البحث إلى إبراز دور مبادئ الاستدامة ومعاييرها في الحقل الإنشائي وتحديد أوزان تلك المعايير وفق بيئة الإنشاء العراقية . ولغرض تحقيق هدف البحث فقد تم جمع البيانات الخاصة به من الأدبيات والمراجع التي تناولت موضوع الاستدامة ومن المقابلات الشخصية مع ذوي الاختصاص ،وكذلك من البيانات التي تم جمعها من الاستبيان الحقلي ،وأخيرا من استخدام البرنامج الحاسوبي عملية التدرج التحليلي (AHP) لتقييم معايير الاستدامة للأبنية الخضراء.

أظهرت نتائج تحليل البيانات لأفراد عينة الاستبيان إن أعلى أهمية (وزن) أعطيت لمعيار مصادر الطاقة المتعددة ، بينما حصل معيار مدة الإنشاء على اقل أهمية (وزن) ، أما النسب الباقية فقد توزعت على بقية المعايير.

1.0 Introduction

In the past two decades, there has been a growing awareness of the importance of Sustainable Development (SD) within the construction industry. This subject play crucial roles in realizing quality, reliability and durability as well as enhancing performance throughout the life of a project. Although most countries in the world currently give increased importance to the issue of sustainable construction, as it has a positive impact on air pollution, greenhouse gas carbon dioxide and global warming, such topic has not been given adequate required attention in Iraq.

The construction industry is one of the main contributors to depletion of natural resources in the world . Currently this industry consumes around 43% of the energy, 72% of the electricity, 17% of the water, and 32% of the materials and resources; in addition to that, it produces 40% of global green house emissions, 40% of solid waste generation, soil loss, reduction in air quality, and has a higher negative impact on biodiversity. In addition, in many countries, people spend almost 90% of their life inside buildings. In response to this high impact, emerges the concept of sustainable construction [1] , [2] .

The term of sustainability has several other labels such as sustainable building (SB), sustainable construction, green building, environmentally friendly buildings, sustainable design, green cities and sustainable development, the last term which is a more general concept of the other terms.

2.0 What is Sustainability ?

Sustainable development can be defined as a development that allows for economic well-being, environmental protection, and overall quality of life for people today without compromising the ability of future generations to meet their needs [3] .

"Green" or "sustainable" buildings use key resources like energy, water, materials, and land more efficiently than buildings that are just built to code. With more natural light and better air quality, green buildings typically contribute to improved employee and student health, comfort, and productivity [4] .

While Waziry regarded green building as the process of building design style that respects the environment, takes into consideration the reduced consumption of energy and materials and resources while reducing the effects of construction and use on the environment while maximizing harmony with nature [5] .

In general the term green building is used to describe design and construction of buildings with some or all of the following characteristics [6] :

- Buildings that have minimal adverse impacts on local, regional, and even global ecosystems;
- Buildings that reduce reliance on automobiles;
- Buildings that are energy-efficient in their operation;
- Buildings and grounds that conserve water;
- Buildings that are built in an environmentally responsible manner from low-environmental-impact materials;
- Buildings that are durable and can be maintained with minimal environmental impact;
- Buildings that help their occupants practice environmentalism, e.g. by recycling waste; and
- Buildings those are comfortable, safe, and healthy for their occupants.

3.0 Dimensions of Sustainability

In general the sustainability challenge is about finding the balance between environmental considerations, society requirements and economic constraints ,these three dimensions of sustainability are shown in the Figure (1).

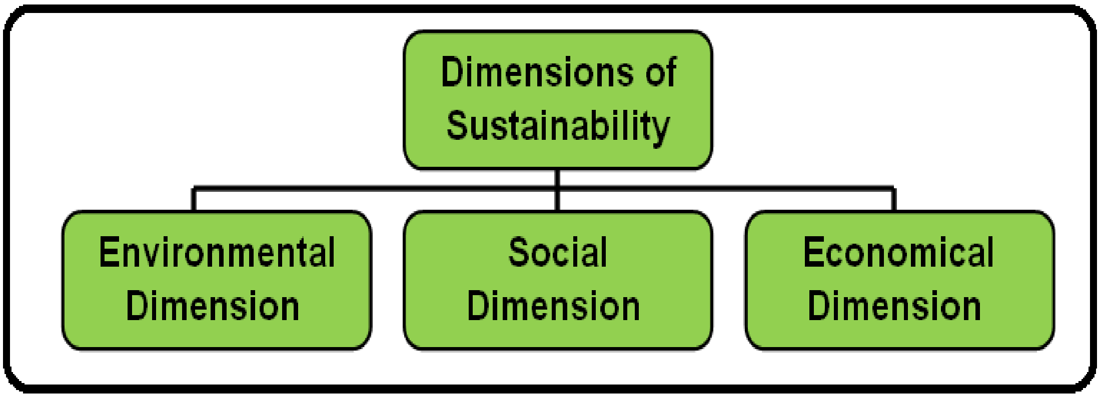

Fig. (1) Dimensions of sustainability [1]

3.1 Environmental Dimension of Sustainability:

This dimension focuses on [1] , [7] , [8] :
1-Reducing waste, effluent generation, emissions to environment.
2-Reducing impact on human health.
3-Using renewable raw materials.
4-Eliminating toxic substances.
5-Energy efficient technologies and practices (renewable sources)

6-Treatment of waste, the quality of water services, and air, water and soil quality.
7-Reducing carbon emissions.
8-Increasing water efficiency.
9-Reducing stormwater runoff.
10-Improving stormwater quality.
11-Expanding local material use.

3.2 Social Dimension of Sustainability:

This dimension focuses on [1] ,[7], [8],[9] :
1-International and national law.
2-Occupants and workers health and safety(structural safety,health safety ,fire safety ,public safety).
3-Urban planning and transport (promote sustainable travel choices through public transport and cycling provision).
4-Local and individual lifestyles and ethical consumerism.
5-The relationship between human rights and human development.
6-Preserving natural resources.
7-Corporate power and environmental justice.
8-Global poverty and citizen action.
9-Impacts on local communities and quality of life.
10-Accessibility requirements for people with disabilities.
11-Social equity.
12-Improve site aesthetics.
13-Increase pedestrian connectivity.
14-Enhancing urban environment.

3.3 Economic Dimension of Sustainability:

This dimension focuses on [1], [7], [8],[9] :
1-Integrating ecological concerns with social and economic ones.
2-Improving quality of life.
3-Providing opportunities for local businesses.
4-Increasing market share due to an improved public image.
5-Creating new markets and opportunities for sales growth.
6-Reducing cost through improving efficiency and reducing energy and raw material inputs.
7-Creating additional added value.
8-Increasing confidence in products and services .
9-Consolidating innovation, and contributing to dissemination of new technologies and best practices.
10-Optimizing maintenance requirements.
11-Increasing systems durability.
12-Value Engineering.

4.0 LEED Standards

Leadership in Energy and Environmental Design (LEED) was developed and piloted in the U.S. in 1998 as a consensus-based building rating system based on the use of existing building technology.(LEED) Green Building Rating System, developed by the U.S. Green Building Council (USGBC), provides a suite of standards for environmentally sustainable construction. LEED certification is obtained after submitting an application documenting compliance with the requirements of the rating system. LEED provides building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions [10].

4.1 LEED Categories

A target LEED rating indicates in the building program (certification levels) as follows [11] :
LEED Certified ……….. 26-32 points
LEED Silver Level ……. 33-38 points
LEED Gold Level ………. 39-51 points
LEED Platinum Level …… 52-69 points
The sum of the points above are assembled according to the following LEED categories [12] :
Sustainable Sites (SS) ………………….. 14 Points
Water Efficiency (WE) …………………. 5 Points
Energy and Atmosphere (EA) ………….. 17 Points
Materials and Resources (MR) ………… 13 Points
Indoor Environmental Quality (IEQ)….. 15 Points
Innovation and Design Process (ID) ……. 5 Points

4.2 Identifying the Criteria and Sub-criteria for Sustainable Building

Based on theoretical study, personal interviews, experts opinion, and the authors practical experience, the following main criteria and considerations for each sub-criterion are established to be the foundation stone in assessing sustainable buildings as well as the assessment of sustainable building alternatives.

The main criteria and sub-criteria for sustainability are listed as follows:

1- Sustainable Site (SS)
  a- Brownfield and Urban redevelopment
  b- Construction-related pollution prevention
  c- Development density and community connectivity
  d- Heat island effect
  e- Impact on ecosystems and waterways
  f- Improve site aesthetics
  g- Light pollution
  h- Promote reduction of erosion
  i- Site development impacts
  j- Stormwater management
  k- Transportation alternatives
2- Water Efficiency (WE)
  a- Indoor water use reduction
  b- Landscaping water use reduction
  c- Wastewater strategies
3- Resourceful Energy (RE)
  a- Fundamental building systems commissioning
  b- Measurement and verification
  c- Refrigerant management
  d- Renewable energy use
  e- Systems and lighting
  f- Whole building energy performance optimization
4- Materials and Resources (M&R)
  a- Building reuse
  b- Construction waste management
  c- Materials reuse
  d- Materials with recycled content
  e- Rapidly renewable materials
  f- Recycling collection locations
  g- Salvaged materials

   h- Storage and collection of recyclables
   i- Sustainably forested wood products
   j- The purchase of regionally manufactured materials
   k- The selection of sustainably grown, harvested, produced and transported products and materials

5- Indoor Environmental Quality (IEQ)
   a- Construction Indoor Air Quality (IAQ) management plan
   b- Controllability of thermal and lighting systems
   c- Environmental tobacco smoke control
   d- Improve acoustics
   e- Increase ventilation
   f- Indoor chemical and pollutant source control
   g- Outdoor air delivery monitoring
   h- Provide access to natural daylight and views
   i- Use low emitting materials
   j- Quality of life and local communities

6- Innovation and Design Process (I&D)
   a- Innovative strategies for sustainable design
   b- Sustainability professional person on the team
   c- The school or university as a teaching tool

7- Risk and Security (R&S)
   a- Design risks
   b- Implementation risks
   c- Financial risks
   d- Political risks
   e- Durability
   f- Structure security
   g- Fire protection ability
   h- Burglary protection ability
   i- Water protection ability
   j- Workers' safety and health

8- Economic Factors (EF)
   a- Create new markets
   b- Operation and maintenance cost
   c- Productivity benefits
   d- Provide opportunities for local businesses
   e- Reduce life cycle cost
   f- Social cost
   g- Use of new technologies
   h- Social equity (poverty)

9- Construction Duration (CD)

The majority of the previous criteria are included in the LEED system (U.S.); the researcher after taking experts opinion has added some criteria and sub-criteria to provide a comprehensive overview of all aspects of sustainability to be taken into consideration in sustainable buildings.

Figure (2) shows the main criteria and sub-criteria for SB.

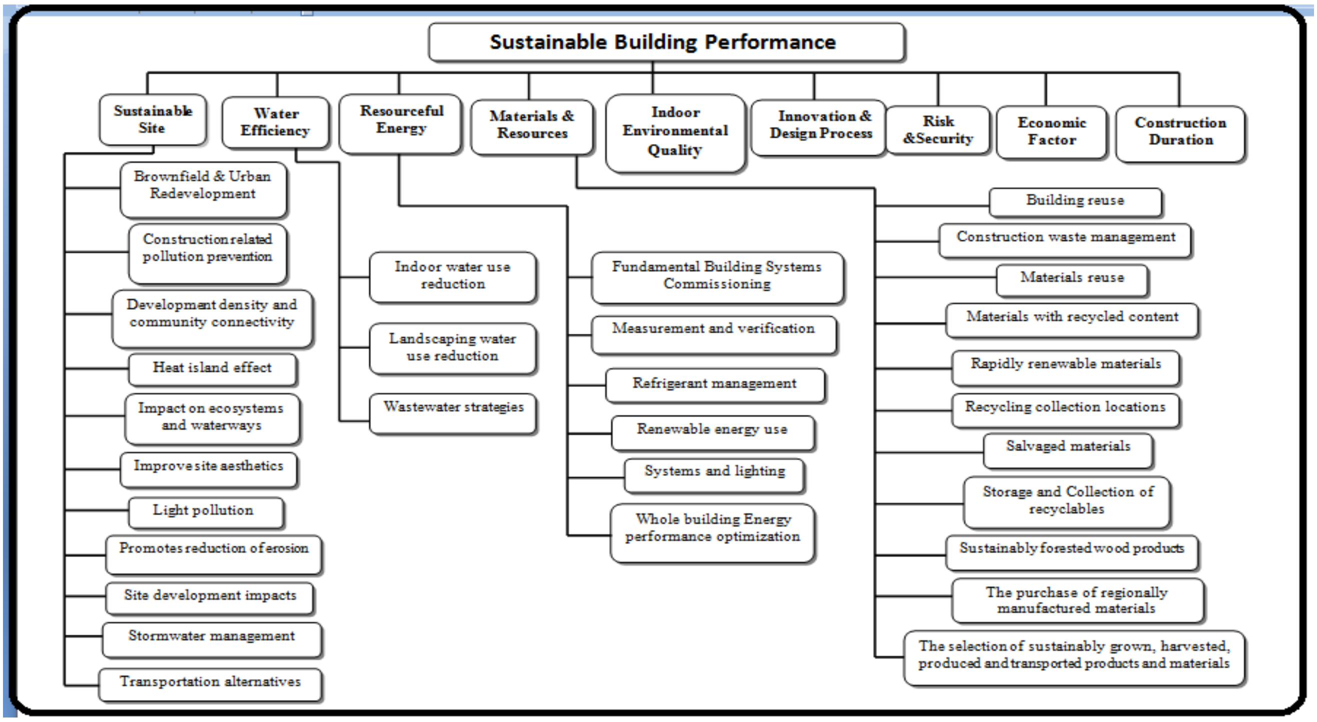

Fig. (2) Main criteria and sub-criteria for sustainable building performance(Researcher)

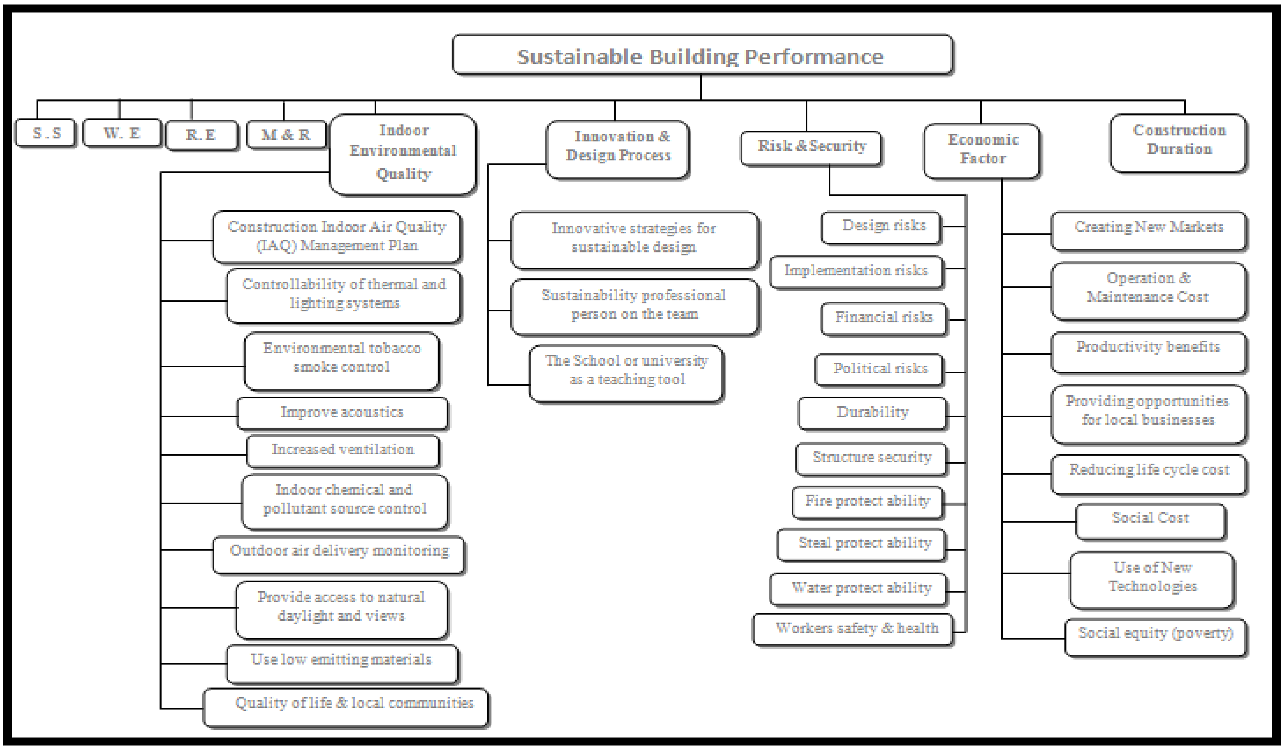

Figure (2) Main criteria and sub-criteria for sustainable building performance (continued)

5.0 Assessment of Criteria Importance (weights)

For the purpose of determining the importance of criteria (weights), this research has relied on the field questionnaire, and the improved AHP program (Analytic Hierarchy Process) method is used to determine the weight for different indicators (criteria). The program will identify these important criteria through the pairwise comparison between criteria; as will be explained later, for access to indicators (indexes) for the comparison, the researcher embarked on a field survey of local engineering professionals. The tool of this survey took the form of a closed questionnaire distributed to engineers of various disciplines working in the public sector. The following explains the details of the questionnaire.

5.1 Closed Questionnaire

This phase includes field study, the use of the closed questionnaire contrivance of theoretical study, and personal interviews as the key to collect field data used to assess the criteria and find items of specific importance. This phase includes the following:

A-Preparation of Questionnaire Questions

The questionnaire form consists of two sections:

Section I: includes personal information from selected respondents such as educational attainment and number of years of experience in the field of engineering.

Section II: includes assessment of the importance of the criteria specified for sustainable buildings according to the conditions and requirements of our country (Iraq), where selected sample respondents are asked to assess the importance of criteria for sustainable buildings according to a scale ranging from 9 to 1 (9 degree = the criterion Importance is a very important significantly, to 1 degree = the criterion Importance is the few important significantly).

Thus, the researcher distributed an appendix to the questionnaire form on the sample which demonstrates what sustainable buildings are, and what are the considerations regarding sustainability criteria for those who have no idea about the principles of sustainability.

Appendix (1) shows the contents of the questionnaire form.

B- Selection of the Research Sample

The researcher distributed 80 questionnaire forms to professors and experienced engineers in the fields of sustainability, design and implementation of construction projects from different engineering disciplines. Only 67 forms were returned, and Table (1) shows the research sample and the number of questionnaires distributed and received.

The researcher wanted to include in the research sample some engineers who have experience in the field of sustainability; to help the remaining engineers who had little or no knowledge of it, the researcher included some explanatory details in the questionnaire to give a complete idea of the principles of sustainability. The researcher has emphasised to the research sample that they should take the conditions and requirements of Iraq into account when filling in the questionnaire form.

Table (1) Characteristics of the questionnaire's research sample

NO.	The Ministry	Office	No. of Forms Distributed	No. of Forms Received
1	Ministry of Higher Education & Scientific Research	University of Karbala – Department of Engineering Affairs	12	11
2	Ministry of Higher Education & Scientific Research	University of Karbala – Consultant Bureau	8	8
3	Ministry of Higher Education & Scientific Research	University of Karbala – College of Engineering	23	19
4	Ministry of Higher Education & Scientific Research	University of Baghdad – College of Engineering	8	5
5	Ministry of Higher Education & Scientific Research	University of Babylon – College of Engineering	3	2
6	Ministry of Environment	Directorate of Karbala Environment	12	10
7	Ministry of Science & Technology	Ministry of Science & Technology- branch of Karbala	14	12

5.2 **Analysis and Discussion of the Questionnaire Results**

For the purpose of presenting results in a simple and understandable manner, they have been provided in the form of histograms, in addition to the display in a Pie Diagram.

A- Personal Information

1.Education attainment: at least educational attainment of the degree of BSc. Figure (3) shows the frequency distribution of respondents according to academic degree: 38.8% have a BSc, 35.8% have an MSc, and 25.4% have a PhD.

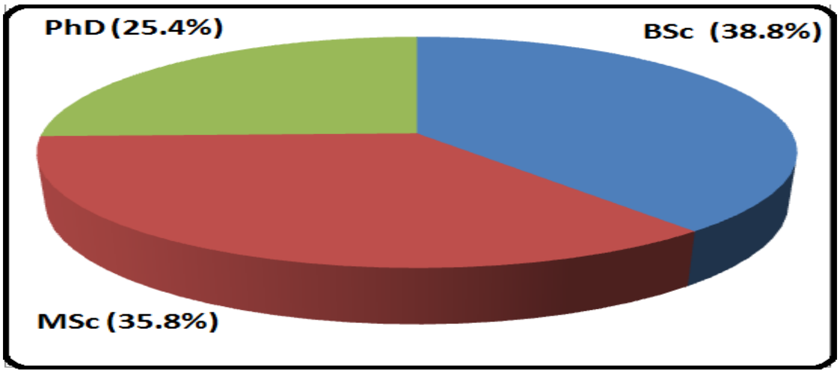

Figure (3) Frequency distribution of respondents according to academic degree

2. Years of Experience: Figure (4) shows the number of years of experience for the research sample, where the emphasis was the sample member showed have a minimum of five years of practical experience.

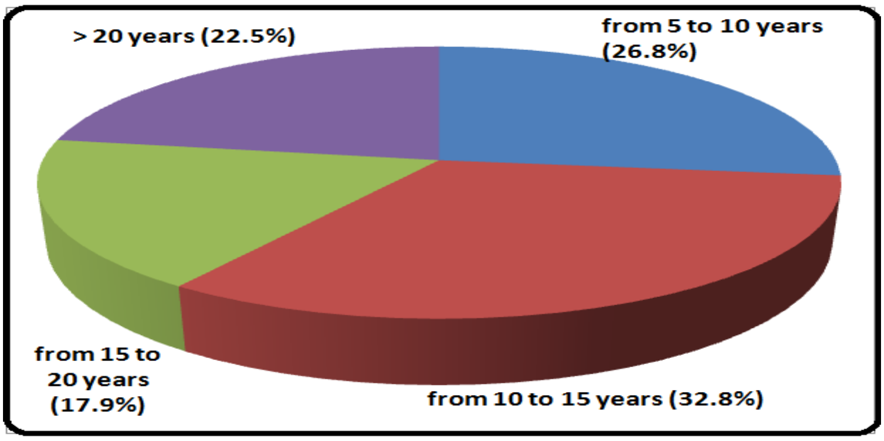

Figure (4) Frequency distribution of respondents according to number of years' experience

3. Engineering field : Figure (5) shows that most of the research sample (35.8%) is from the field of civil engineering .

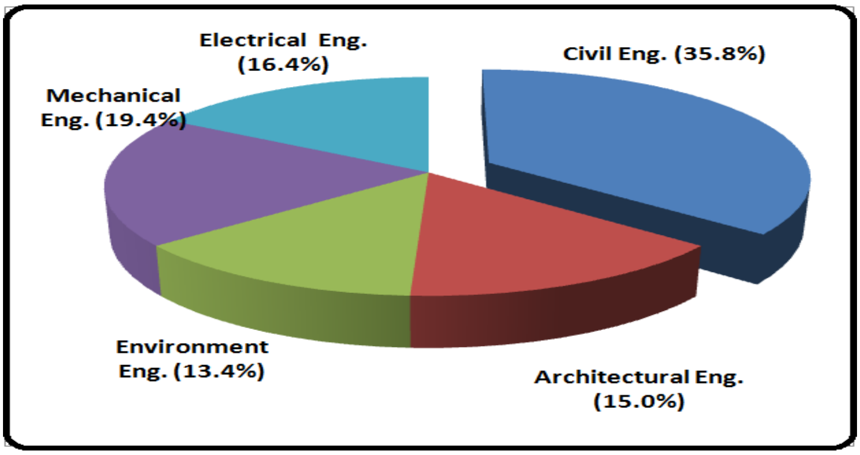

Figure (5) Frequency distribution of respondents according to their engineering discipline

4.Job Location: Figure (6) shows job location for the research sample: 43.3% are university lecturers, 31.3% are engineers, 10.4% are heads of departments, and 15% are division administrators.

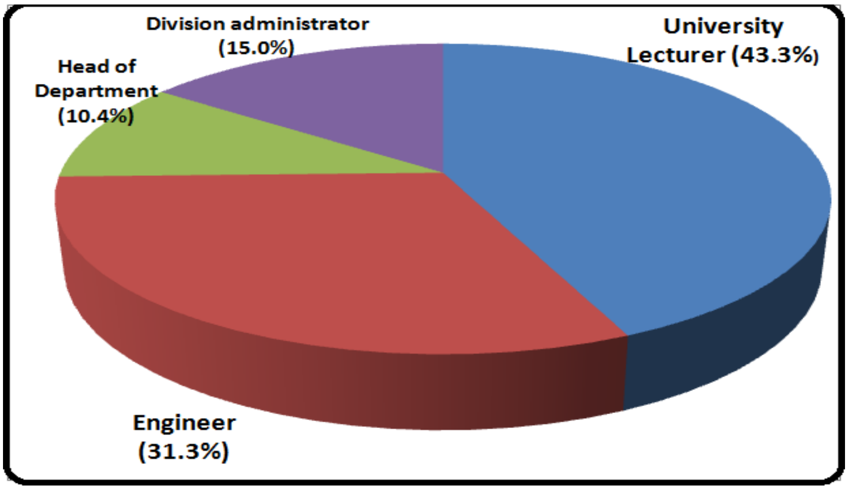

Figure (6) Frequency distribution of respondents according to job location

C- Questionnaire Answers and the Statistical Analysis

The results of the questionnaire are scheduled depending on the answers that were obtained, and Table (2) shows these results.

Table (2) Frequency of degrees of respondents for criteria

No.	Criteria	Frequency of degrees									Total of freq.
		1	2	3	4	5	6	7	8	9	
1-	Sustainable Site (S.S.)				2	6	20	12	27		67
2-	Water Efficiency (W.E.)		1	4	7	3	23	6	23		67
3-	Resourceful Energy (R.E.)					5	1	20	33	8	67
4-	Materials & Resources (M.&R.)			1	3	12	18	11	22		67
5-	Indoor Environmental Quality (I.E.Q.)					6	9	18	32	2	67
6-	Innovation & Design (I.&D.)			4	9	7	30	5	12		67
7-	Risk &Security (R.&S.)			1	5	4	14	5	38		67
8-	Economic Factor (E.F.)			1		18	6	22	18	2	67
9-	Construction Duration (C.D.)		9	5	18	3	24	5	3		67

The questionnaire results have been statistically analyzed, based on the work of Hines 2003 [13], utilizing three methods to determine the results.

1- Calculate the arithmetic mean for respondents for each criterion based on the following equation:

$$\overline{X} = \frac{\sum_{i=1}^{k} xi \, . \, fi}{\sum_{i=1}^{k} fi} \qquad \text{.........................} \quad \textbf{(1)}$$

where :

$\overline{X}$: Arithmetic Mean

Xi : Degree of the criterion's importance

fi : The Frequency

Results of the arithmetic mean for the criteria are shown in Table (3).

2- Calculate the standard deviation for respondents for each criterion based on the following equation:

$$S = \left[\sum_{i=1}^{k} (xi - \overline{X})^2 * fi \,) / (\sum_{i=1}^{k} fi \,) \right]^{1/2} \qquad \text{...............} \quad \textbf{(2)}$$

where :

S: Standard deviation

$\overline{X}$: Arithmetic Mean

Xi: Degree of the criterion importance

fi : The Frequency

Results of the standard deviation for the criteria are shown in Table (3).

3- Test the quality of the questionnaire results: for the purpose of checking the quality of the answers recorded in the questionnaire, and for access to the correct forecasts by using high confidence level (95%), Z test will be used.

Through the following equation, find (Z calculated) and compare with (Z tabular) at a confidence level equal to 95%. If the (Z calculated) is greater than (Z tabular), we will accept the values of the questionnaire in relation to size of the sample, and vice versa.

$$Z_{calculate} = \frac{\overline{X}}{\frac{S}{\sqrt{n}}} \quad \text{.........................} \quad (3)$$

where :
$\overline{X}$: Arithmetic Mean
S : Standard deviation
n : Size of the sample

If [Z calculate > Z tabular] then accept the results of questionnaire
If [Z calculate < Z tabular] then reject the results of questionnaire
Values of the (Z calculate) for criteria are shown in Table (3).

The value of (Z tabular) depends on the table of (Z values) , in which the value of Z, is equal to 1.67 after the level of confidence required and the sample size were specified.

From the comparison between the two values, it is note that values of (Z calculated) for each criterion are greater than that of (Z tabular) and therefore could depend on these results at 95% confidence level.

Table (3) Statistical results for questionnaire form respondents

Criteria	Arithmetic Mean	Standard Deviation	Z calculate
Sustainable Site (S.S.)	6.835821	1.140791	49.048
Water Efficiency (W.E.)	6.283582	1.618973	31.769
Resourceful Energy (R.E.)	7.567164	0.980769	63.154
Materials & Resources (M.&R.)	6.507463	1.308675	40.702
Indoor Environmental Quality (I.E.Q.)	7.223881	1.019524	57.998
Innovation & Design Process (I.&D.)	5.880597	1.398532	34.418
Risk &Security (R.&S.)	6.955224	1.386856	41.050
Economic Factor (E.F.)	6.641791	1.289469	42.161
Construction Duration (C.D.)	4.820896	1.674438	23.567

6.0 The Super Decisions Software (Analytical Hierarchy Process AHP)

This software builds the simplest decision model that has a goal, criteria, sub-criteria and alternatives, which makes judgments (paired comparisons), and computes the results to find the best alternative.

The researcher used this software for determining the weights of the main criteria and sub-criteria, as well as determining the optimal alternative.

A hierarchical decision model has a goal, criteria that are evaluated for their importance to the goal, and sub-criteria that are evaluated for their importance to the main criteria, and alternatives that are evaluated for how preferred they are with respect to each criterion.

An abstract view of such a hierarchy is shown in Figure (7).

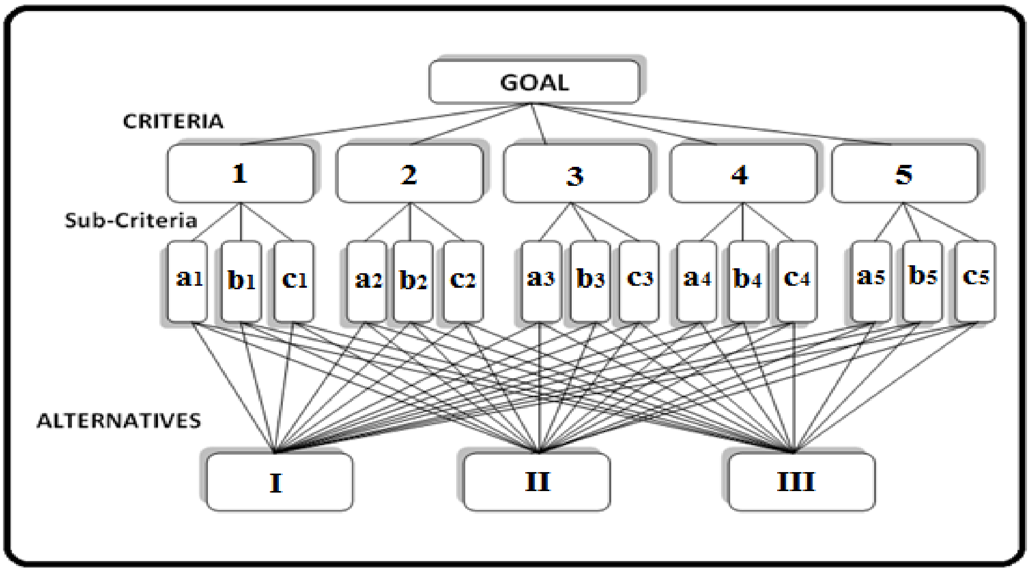

Fig. (7) Analytic Hierarchy Process (AHP) model (Researcher)

The lines connecting the goal to each criterion mean that the criteria must be pairwise compared for their importance with respect to the goal. Similarly, the lines connecting each criterion to the alternatives mean the alternatives are pairwise compared to which is more preferred for that criterion; and similarly for the sub-criteria.

A Super Decisions model which consists of clusters of elements (or nodes), rather than elements (or nodes) is arranged in levels. The simplest hierarchical model has a goal cluster containing the goal element, a criteria cluster containing the criteria elements, a sub-criteria cluster containing the sub-criteria elements, and an alternatives cluster containing the alternative elements - as shown in Figure (7). When clusters are connected by a line it means nodes in them are connected. The cluster containing the alternatives of the decision must be named Alternatives. Nodes and Clusters are organized alphabetically in the calculations, so an easy way to control the order is to preface the names with numbers.

In general, AHP captures priorities from paired comparison judgments of the elements of the decision with respect to each of their parent criteria; paired comparison judgments can be arranged in a matrix, and priorities are derived from the matrix as its principal eigenvector, which defines an absolute scale. Thus, the eigenvector is an intrinsic concept of a correct prioritization process. It also allows for the measurement of inconsistency in judgment.

6.1 Eigenvector Concept

The comparison is done in pairs and placed in matrix A of the following form; this is what is referred to as the pairwise comparison [14] .

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \vdots & & & & \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix} \quad \dots\dots\dots\dots\dots (4)$$

Each a_{ij} entry of A reflects the factor by which criteria (or alternatives) i dominate criteria (or alternatives) j as follows :
$a_{ii} = 1$ where $i = j$ and $i , j = 1, 2, 3,\ldots,n$.

$$aij = \frac{1}{aji}$$

where a_{ij} is the relative scale or judgment of criteria i to criteria j
Then $aij = \frac{Wi}{Wj}$

Wi is intensity scale 1-9 of preference one over the other; Table (4) shows fundamental scale of absolute numbers for Wi or Wj.

Table (4) Fundamental scale of absolute numbers[15]

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very,very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Then comparison matrix is presented below [14] :

$$\begin{array}{c} \\ A1 \\ A2 \\ \vdots \\ An \end{array} \begin{array}{c} \begin{array}{ccccc} A1 & A2 & A3 & \ldots\ldots & An \end{array} \\ \begin{bmatrix} \frac{W1}{W1} & \frac{W1}{W2} & \frac{W1}{W3} & \ldots\ldots & \frac{W1}{Wn} \\ \frac{W2}{W1} & \frac{W2}{W2} & \frac{W2}{W3} & \ldots\ldots & \frac{W2}{Wn} \\ \vdots & \vdots & \vdots & & \vdots \\ \frac{Wn}{W1} & \frac{Wn}{W2} & \frac{Wn}{W3} & \ldots\ldots & \frac{Wn}{Wn} \end{bmatrix} \end{array}$$

The eigenvector could be found from column matrix W
$W = (W_1 , W_2 , W_3 , \ldots\ldots, W_n)$ …………. (5)
Saaty suggests geometric mean to generate eigenvector by multiply in each raw in matrix, then taking nth root of the multiplication, finally normalization is made by dividing on the total after deriving it.

$$a = \sqrt[n]{\frac{W1}{W1} * \frac{W1}{W2} * \frac{W1}{W3} * \cdots\cdots * \frac{W1}{Wn}} \quad \cdots\cdots (6)$$

$$b = \sqrt[n]{\frac{W2}{W1} * \frac{W2}{W2} * \frac{W2}{W3} * \cdots\cdots * \frac{W2}{Wn}} \quad \cdots\cdots (7)$$

$$c = \sqrt[n]{\frac{W3}{W1} * \frac{W3}{W2} * \frac{W3}{W3} * \cdots\cdots * \frac{W3}{Wn}} \quad \cdots\cdots (8)$$

$$n = \sqrt[n]{\frac{Wn}{W1} * \frac{Wn}{W2} * \frac{Wn}{W3} * \cdots\cdots * \frac{Wn}{Wn}} \quad \cdots\cdots (9)$$

Total = a + b + c + ……+ n

$$\text{eigenvector} = W = \begin{bmatrix} W1 \\ W2 \\ W3 \\ . \\ . \\ . \\ Wn \end{bmatrix} = \begin{bmatrix} a / total \\ b / total \\ c / total \\ . \\ . \\ . \\ n / total \end{bmatrix} \quad \cdots\cdots (10)$$

6.2 Checking Inconsistency

AHP program provides a method for measuring the degree of consistency among the pairwise comparison (judgments) provided by the decision-maker.

If the degree of consistency is acceptable; the decision process can continue. If it is not acceptable; the decision-maker should revise the pairwise comparison judgment.

For example, if you were to say that A is more important than B and B is more important than C, and then say that C is more important than A you are not being consistent. In general, the inconsistency ratio should be less than **0.1** (10%) or so to be considered to indicate a reasonable level of consistency in the pairwise comparison.

Saaty (1980) suggests the following consistency index(CI):

$$C.I. = \frac{\lambda max - n}{n - 1} \quad \cdots\cdots (11)$$

where : $\lambda_{max} = \max(\lambda_1, \lambda_2, \ldots\ldots, \lambda_n)$

$$\lambda_i = \sum_{j=1}^{n} aij \frac{Wj}{Wi} \qquad \text{then} \quad \lambda_{max} = \max(\lambda_i)$$

Consistency ratio (CR) is computed by the following :

$$CR = \frac{CI}{ACI} * 100 \quad \cdots\cdots (12)$$

where : ACI average consistency index of randomly generated weights

6.2 Sensitivity Analysis

The AHP computer program was used to conduct a sensitivity analysis of the alternatives according to the criteria. This is done using the following steps:

a- Select computations - sensitivity command.

b- Edit independent variable in order to change it to the goal (optimum sustainable building performance).

c- In the selected node box highlight the current node and click edit.

d- In the input parameter box select parameter type: supermatrix, goal as wrt node, and one of the criteria as the first other node, for example, the researcher selected the resourceful energy criterion.
e- Click done and update to see the sensitivity graph for that criterion.

That is illustrated in Figure (8).

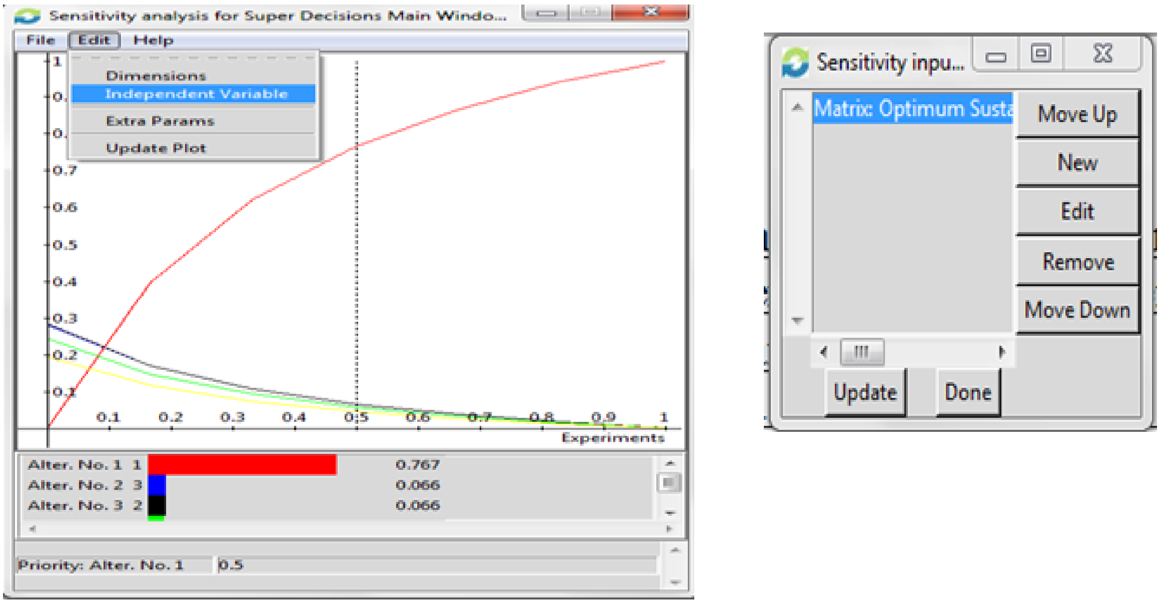

Figure (8) Sensitivity analysis for the alternative with respect the criterion

6.3 **Build a Hierarchical Decision Model (AHP)**

To build the model, follow these steps:
1. Identify the goal, that it established "Optimum Sustainable Building Performance" as a goal in the model to which access to the best performance for sustainable building, as shown in plate (1).

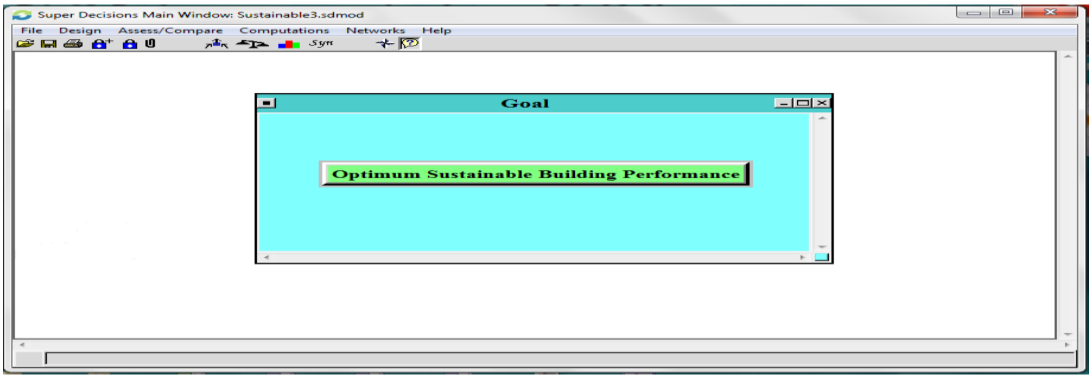

Plate (1) The goal of the model

2. Limit the main criteria for sustainability which have been previously identified and are considered as objectives and functions for the sustainable building, as well as linking criteria to the goal; this is illustrated by the arrow form, as in Plate (2).

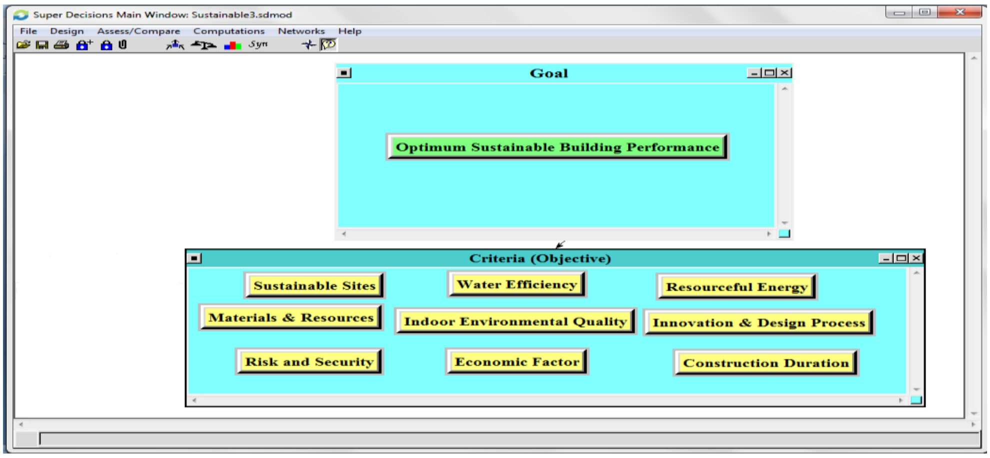

Plate (2) The main criteria insert into the program (AHP)

2. Insert sub-criteria (considerations) for each criterion, which has been previously identified in the model by linking each criterion to sub-criteria, as shown in the plates (3) to (11).

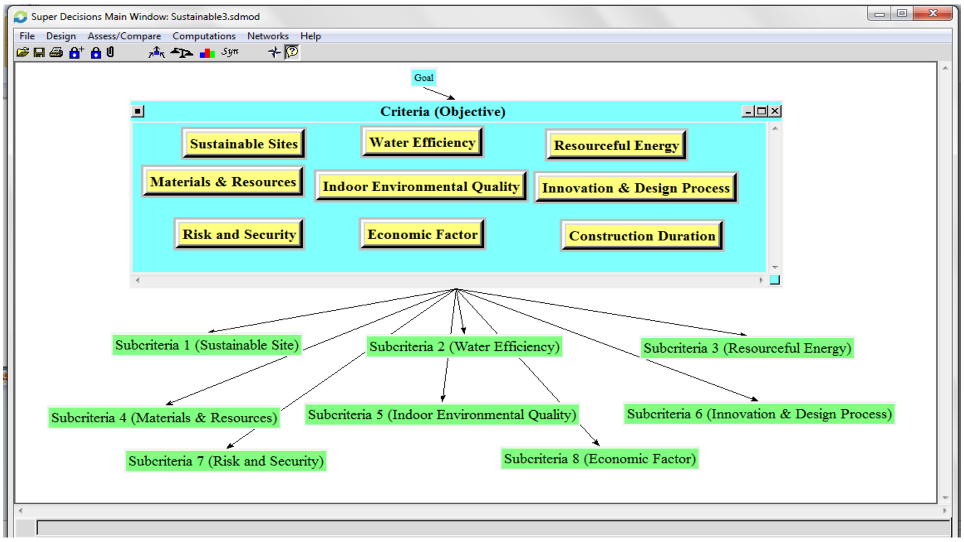

Plate (3) The sub-criteria insert into the program (AHP)

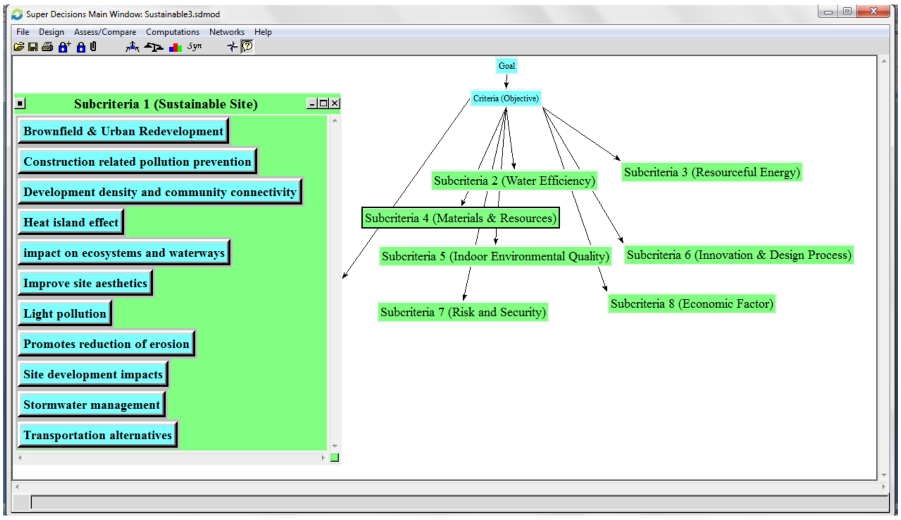

Plate (4) The sub-criteria for sustainable site

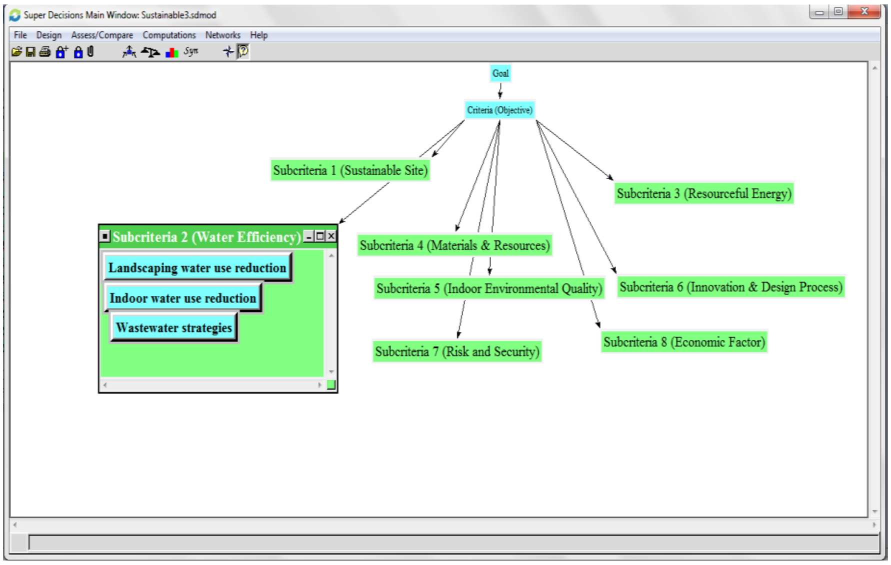

Plate (5) The sub-criteria for water efficiency

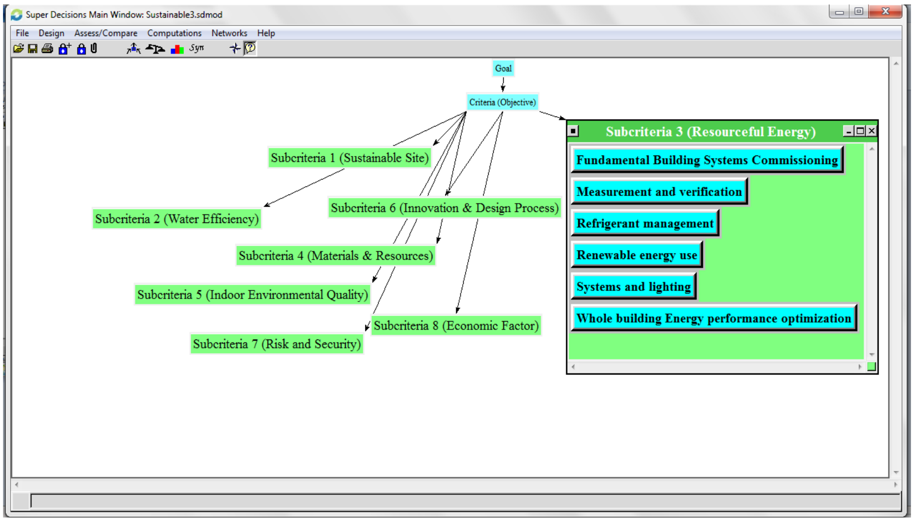

Plate (6) The sub-criteria for resourceful energy

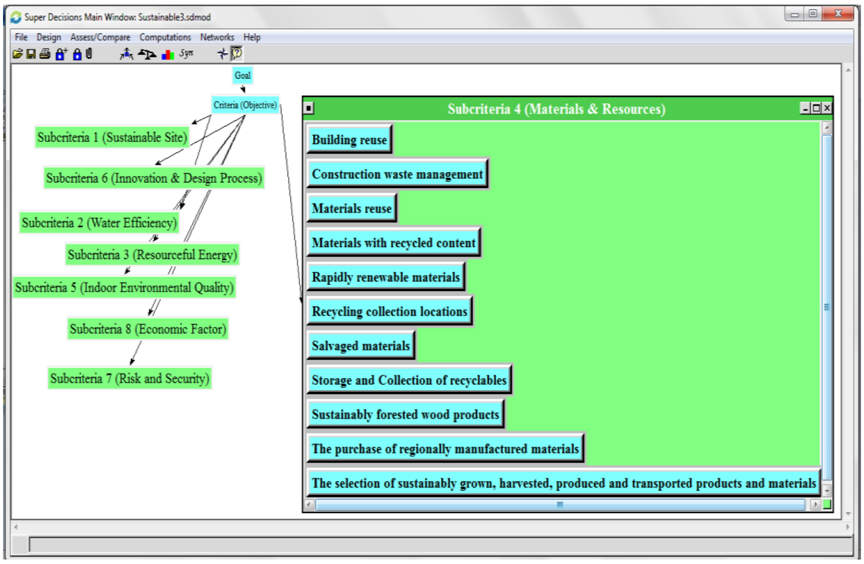

Plate (7) The sub-criteria for material and resources

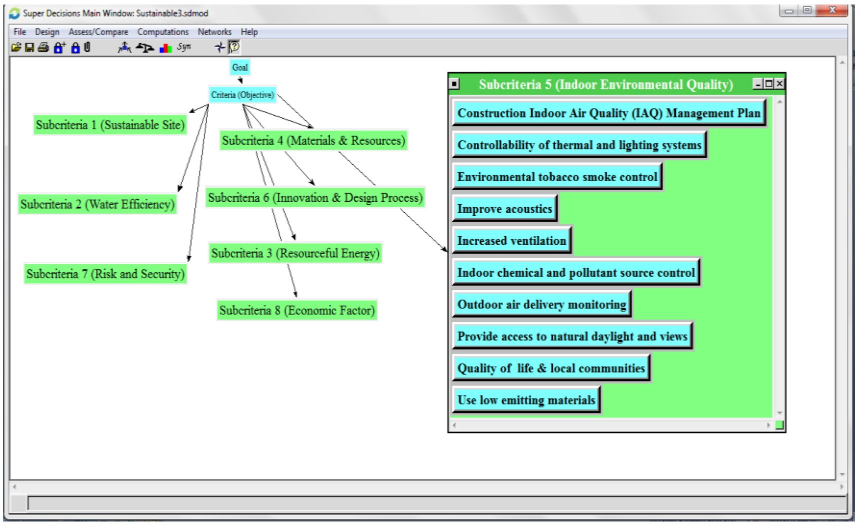

Plate (8) The sub-criteria for indoor environmental quality

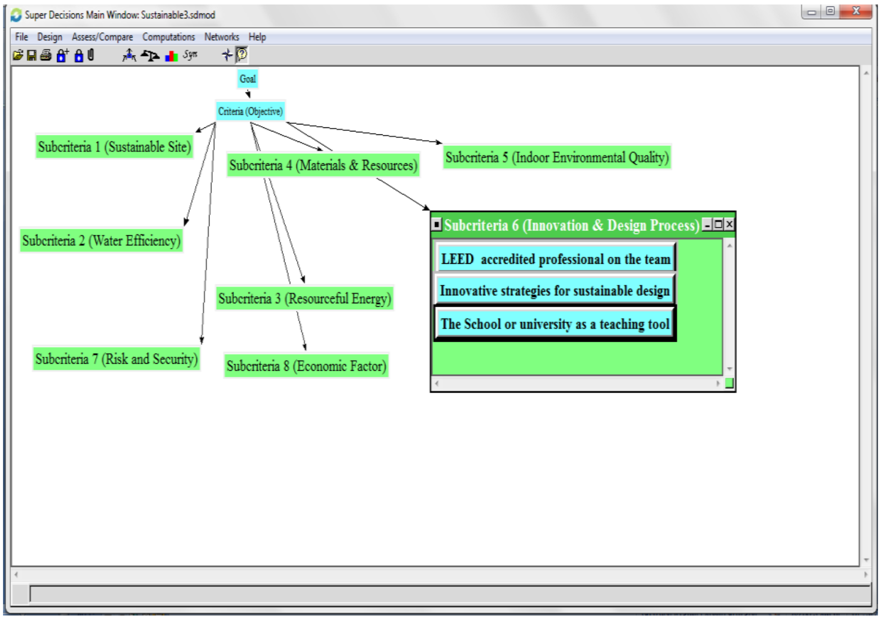

Plate (9) The sub-criteria for innovation and design

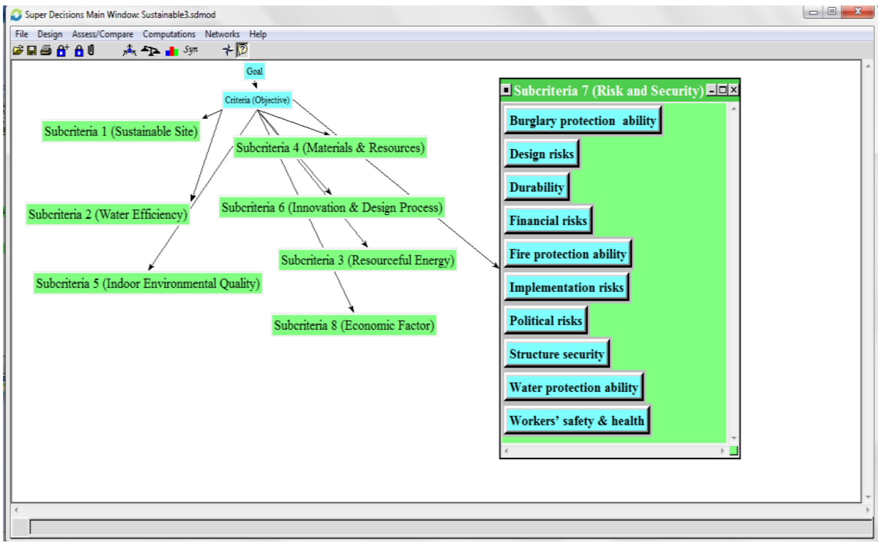

Plate (10) The sub-criteria for risk and security

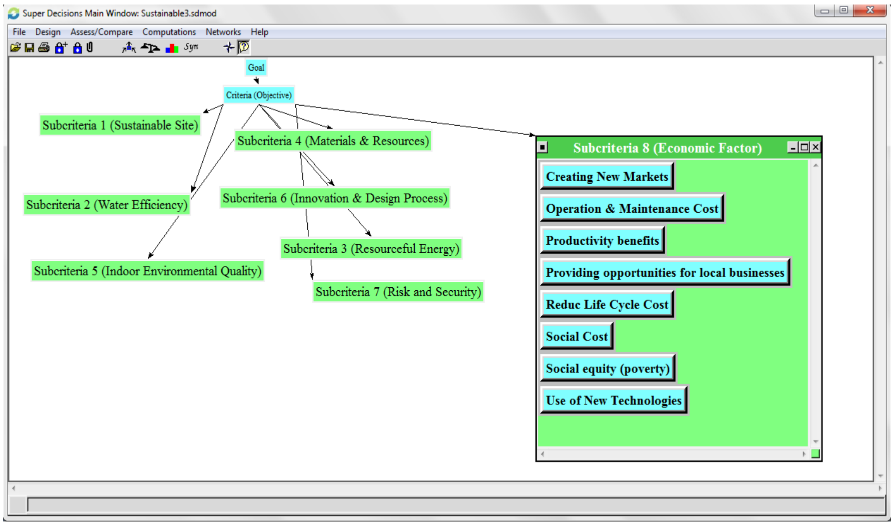

Plate (11) The sub-criteria for economic factor

6.4 Weights of Criteria Using the (AHP) Program

After the results of the questionnaire are analyzed, the weights of criteria are specified for sustainable construction; that will be found by using a program (AHP), which will make pair comparisons between criteria depending on the values of arithmetic mean which have been identified previously.

The Figure (9) shows the pairwise comparisons between criteria:

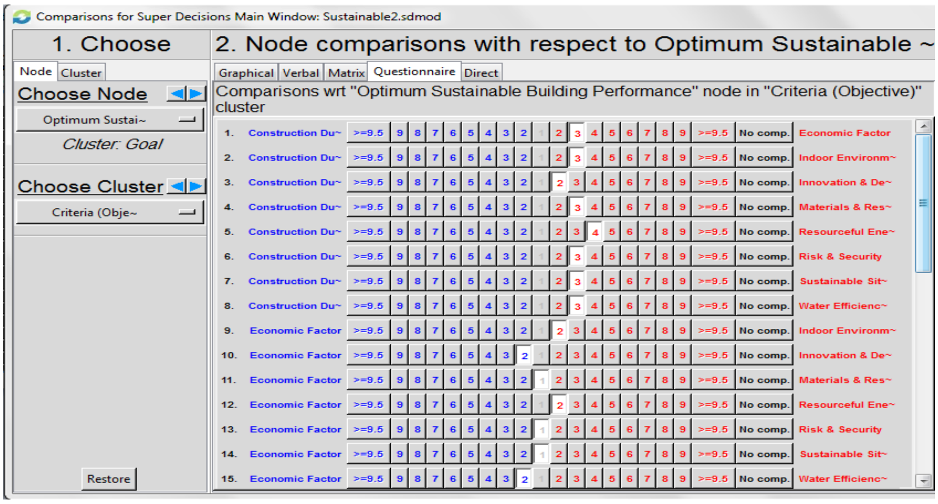

Figure (9) Pairwise comparisons for criteria with respect to the goal

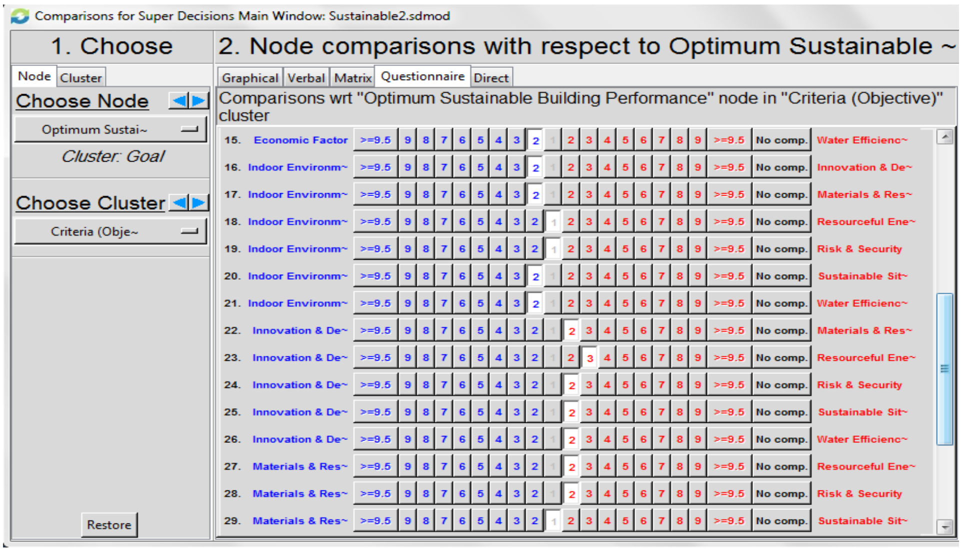

Figure (9) Pairwise comparisons for criteria with respect to the goal (continued)

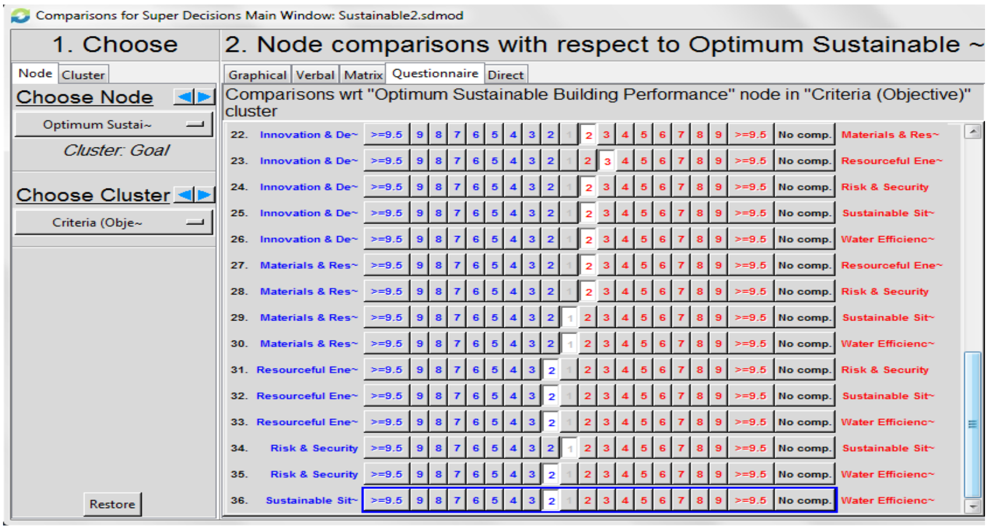

Figure (9) Pairwise comparisons for criteria with respect to the goal (continued)

The Super Decision program shows priorities (weights) of criteria with respect to the goal in Figure (10), these results will illustrate in Table (5) and Figure (11) .

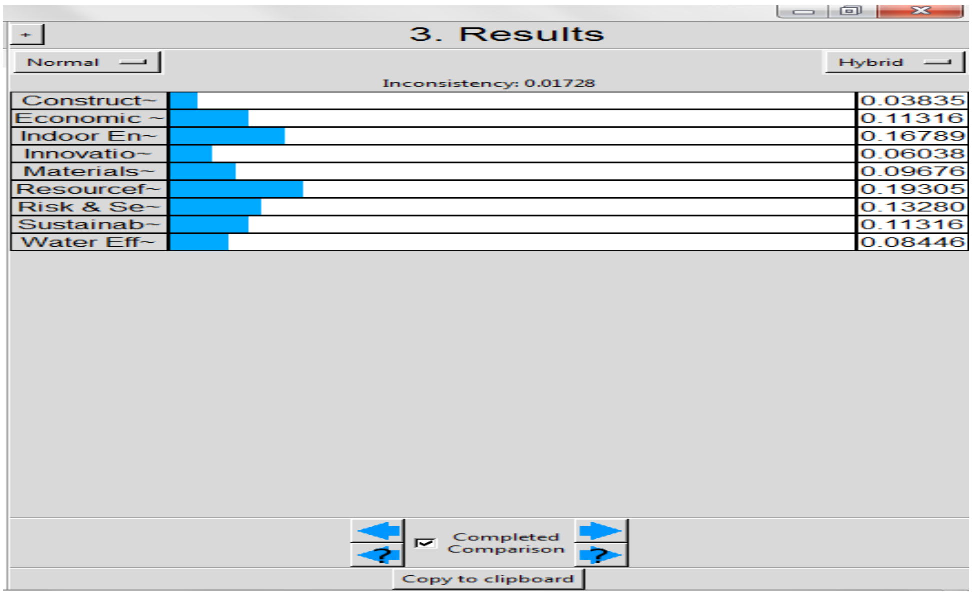

Figure (10) Weights of main criteria with respect to the goal

Table (5) Weights of main criteria for sustainability

Criteria (Inconsistency=0.01728)	Weight(%)
Sustainable Site (S.S.)	11.316%
Water Efficiency (W.E.)	8.446%
Resourceful Energy (R.E.)	19.305%
Materials & Resources (M.&R.)	9.676%
Indoor Environmental Quality (I.E.Q.)	16.789%
Innovation & Design Process (I.&D.)	6.038%
Risk & Security (R.&S.)	13.280%
Economic Factor (E.F.)	11.316%
Construction Duration (C.D.)	3.835%

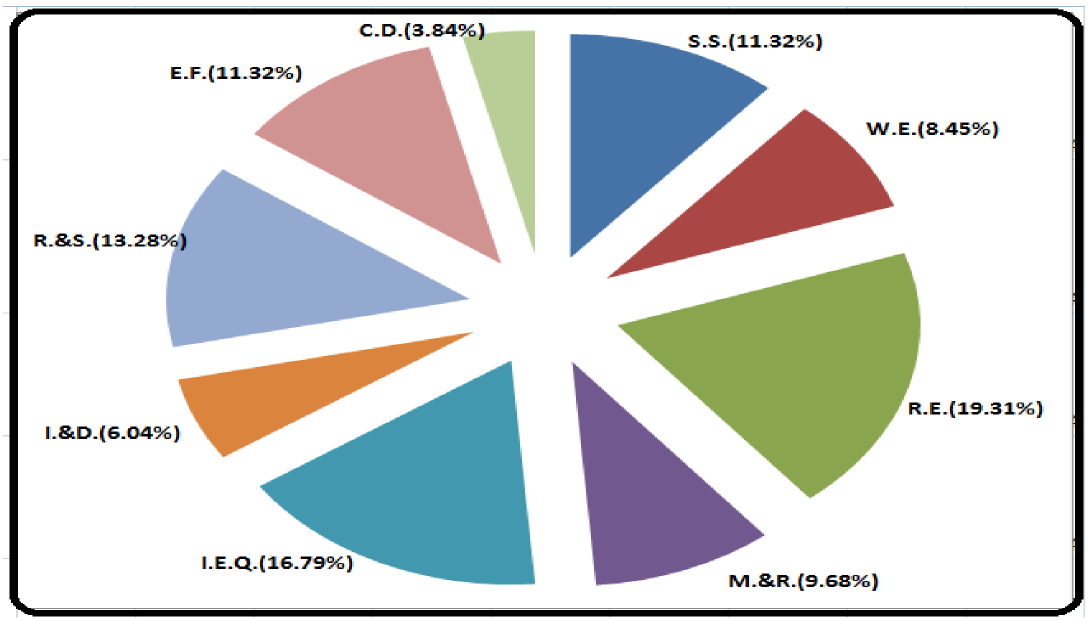

Figure (11) Weights of main criteria for sustainability

7.0 The Results

7.1 Questionnaire Results

Evaluation of the importance of the main criteria: The answers to the questionnaire have enabled the researcher to establish the following points:

1- For criterion Sustainable Site, 88% of the sample respondents gave the importance of the score between 6 and 8 (important to very important), while the arithmetic mean of the criterion is equal to 6.836 (which is between important and very important).
2- For criterion Water Efficiency, 77.6% of the sample respondents gave the importance of the score between 6 and 8 (important to very important), while the arithmetic mean of the criterion is equal to 6.284 (important).
3- For criterion Resourceful Energy, 91% of the sample respondents gave the importance of the degree between 7 and 9 (very important to very important significantly), while the mean is equal to 7.567 (very important): this is a criterion which won a higher degree of importance.
4- For criterion Materials and Resources, 76% of the sample respondents gave the importance of the score between 6 and 8 (important to very important), while the mean is equal to 6.507 (important to very important).
5- For Indoor Environmental Quality criterion, 77.6% of the sample respondents gave the importance of the score between 7 and 9 (very important to very important significantly), while the mean is equal to 7.224 (important to very important).
6- For criterion Innovation in Design, 70.15% of the sample respondents gave the importance of the score between 6 and 8 (important to very important), while the mean is equal to 5.881 (average to important).
7- For criterion Risk and Security, more than 85% of the sample respondents gave the importance of the score between 6 and 8 (important to very important), while the mean is equal to 6.955 (important to very important).
8- For criterion Economic Factor, 62.68% of the sample respondents gave the importance of the score between 7 and 9 (very important to very important significantly), while the mean is equal to 6.641 (important to very important).
9- For criterion Construction Duration, 67.2% of the sample respondents gave the importance of the score between 4 and 6 (average important to important), while the mean is equal to 4.82 (between moderate and important); this is the criterion which scored the lowest degree of importance.

7.2 AHP Software Results

AHP software was applied to determine the weights of the criteria, and the following points are obtained :

1- The highest weight is received by the criterion of Resourceful Energy, which got 19.305%; and this gives the result that this criterion is of great importance in sustainable buildings, from the point of view of the selected sample and the researcher.
2- In second place comes the criterion of Indoor Environment Quality, which earned the weight 16.789%, and it deserves this importance, from the viewpoint of the researcher, because of its significant impact on sustainable buildings.
3- Equal in importance are the criteria of Sustainable Site and Economic Factor, because each has received a weight of 11.316%. This ratio gives an indication of high importance of these two criteria for sustainable buildings.
4- The criterion of Water Efficiency obtained a proportion of importance (priority) of about 8.4%, which is a moderate proportion, because water is available in Iraq, and there is no real problem with water in Iraq, from the viewpoint of the sample selected.
5- The criterion of Materials and Resources obtained a proportion of importance (priority) of almost 9.6%, which is a medium proportion.

6- The criterion of Risk and Security obtained a proportion of importance (priority) of 13.2%, which is a high proportion, which indicates the importance of this criterion for sustainable buildings.
7- Less weight was obtained by the criterion of Construction Duration, which received 3.835%, and the reason is due to the fact that this criterion has little impact on sustainable buildings.
8- When doing a pairwise comparison between criteria in the program (AHP), the inconsistent index is equal to 0.01728, which is less than the highest value (0.1), so it is satisfactory according to the program conditions and requirements.

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Appendix No. (1) Closed Questionnaire Form to Assess the Main Criteria Questionnaire

Mr. Expert
Best regards
I enclose herewith a questionnaire, has been developed for the purpose of assessing the importance (weights) the criteria specified in sustainable projects, and hope your cooperation with us and make what you see appropriate, in order to be the study of meanings scientific and economic correct and to facilitate our mission in the assessment right and proper for this study. thankful your cooperation with us ....
Researcher

First: general information

Company Name : Career Center:
Academic achievement: Years of Experience:

Second: Assessment

Please assess the importance of the criteria in the attached questionnaire form through marked (X) in front of what is you see for you according to the importance of the following scale:

The importance of little importance criterion significantly for sustainable buildings	1 degree
The importance of a few important criterion for sustainable buildings	2 degree
Important criterion is located between the few and the average importance for sustainable buildings	3 degree
Average standard critical importance for sustainable buildings	4 degree
Importance is located between the average standard and important for sustainable buildings	5 degree
Importance of an important standard for sustainable buildings	6 degree
Important criterion is located between the important and very important for sustainable buildings	7 degree
The importance of a very important standard for sustainable buildings	8Degree
The importance of a very important criterion significantly for sustainable buildings	9 degree

Criteria	1 degree	2 degree	3 degree	4 degree	5 degree	6 degree	7 degree	8 degree	9 degree
Sustainable Sites									
Water Efficiency									
Energy & Atmosphere									
Materials & Resources									
Indoor Environmental Quality									
Innovation & Design Process									
Risk & Security									
Economic									
Construction duration									