Using AHP to Prioritize Design Criteria for School Building Projects in Iraq: A Decision Model Approach

Ivan Petrov[*1], Andrei Pavlov[*2] & Olga Ivanova[3]

[*1]Faculty of Physics, Moscow State University, Moscow, Russia
[*2] Department of Applied Mathematics, St. Petersburg State University, St. Petersburg, Russia
[3]Faculty of Computer Science, National Research University, Moscow, Russia

ABSTRACT

For purpose of determining the importance of main criteria and sub-criteria (weights),as well as for choose the best alternative from a set of the proposals, this research relies on the field questionnaire, and (Analytic Hierarchy Process) used to determining the weights for various indicators .The program used will assess these criteria and identify important criteria by means of a pairwise comparisons of criteria, to access comparable indices, the researcher began a field survey of local engineers. The questionnaire was used as a closed questionnaires distributed to designers and consultants from various disciplines

Keywords: *Design Criteria,WeightsAssessment,Analytic Hierarchy Process.*

I. INTRODUCTION

The new types of public school building projects in Iraq can be classifies into three types; traditional building schools, steel structure building schools and precast concrete building schools. Most of these buildings are delayed beyond the contractual execution duration.

According to the Regulations of Executing Public Governmental Contracts (no. 1) of year (2008), one of the following three procurement methods is allowed to hire consultants, contractors and suppliers to do the work required in the execution of construction projects which are: Open tendering, Direct invitation and Direct assignment. These methods are used in assigning public school buildings contracts to companies. The open tendering method is mostly traditional buildings and structural steel projects, while the direct invitation method was used for (796) precast concrete projects assigned to the companies of Ministry of Construction and Housing, in addition a the direct assignment method was used for (420) precast concrete buildings where they assigned to the companies of the Ministry of Industry and Minerals[1].

The Synopsis of National Development Plan (2013-2017) stated that Iraq need to build (7220) kindergartens, (2,250) primary schools and (791) secondary schools, in order to put an end to the problem of dual and triple time of occupancy and to rebuild mud schools. In addition, it is clear that there will be a great new demand on future school buildings due to the population natural growth which is about (3.3%) yearly[2].

II. IDENTIFYING THE MAIN CRITERIA AND SUB-CRITERIA FOR SCHOOL BUILDING DESIGN

The criteria to be reviewed can be summarized as follows:

A. Constructability

Constructability can be defined as "optimal integration of executive experience and knowledge in the planning, design, configuration, on-site activities to accomplish the overall objectives of the project".

Since the first moment in the design of the project should be considered to facilitate the implementation process to ensure the quality of work and commitment on time and cost specified [3].

These factors should be considered in construability deliberations related to design configuration for efficient constructions[5].

1- Simplicity is a desirable element of any construction design.
2- Flexibility: for the field construction personnel to select alternative method.
3- Sequencing of installation: is much a design consideration as it is procurement and construction consideration.
4- Substitutions or alternative warrant attention: improperly considered material applications will impact construability, resulting in costly modifications.
5- Labor skill availability should be fully explored, the absence of either skill levels or availability of the work force can have a costly impact on project and require consideration during the design.

B. Performance requirements in the design phase

Performance means "interest of origin after the completion of its creation." So there are several requirements to improve the quality of performance should be considered during the design phase and these requirements:

1- Safety

Safety is, in any case, of great importance in all stages of the life cycle of the building and start from the design stage. The terms of danger and risk are frequently used when analyzing the subject of safety. The hazard is the recipe for the product that can lead to harmful results. The risk is the possibility of injury because of the hazard when the product is turned on by the user[4].

2- Reliability

Reliability of a product under the operating conditions is known as, "the probability of failure-free operation and for a certain period of time".

So to preserve the reliability and lifetime of the product scheme, it should be coupled with maintainability [4].

3- Maintainability

Maintainability can be defined as, "the function of the design and installation characteristics that affect the programmed or under environmental operating conditions Maintenance"[6].

4- Durability

Durability is the ability of a material, product, or building to maintain its intended function for its intended life-expectancy with intended levels of maintenance in intended conditions of use.

5- Target Cost

The design according to the specific methodology of the cost of moving the designer on the light toward a target cost of the product and tries to match the target cost in exchange for details Required [4].

C. Sustainability

The term of sustainability has several other labels such as sustainable building, 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.[7]

Many countries around the world have developed their own classification systems aimed at measuring and quantifying the use of sustainable construction technology in their property, and in the architectural and construction industries. Enter code as a means of measuring the implementation of sustainable construction technology establishes a standard that organizations can measure and improve and the implementation of sustainable building principles.

With a view to identifying what is sustainable and what is not, to unify it measurement, different classification systems have been developed. across the world there are many sustainable project appraisal systems. This review deals with these Global systems such as LEED (Leadership in Energy and Environmental Design) in the United States, BREEAM (Building Research Establishment Environmental Assessment Method) in the United Kingdom, CASBEE (Comprehensive Assessment System for Built Environment Efficiency) in Japan, and Green Star in Australia.

The U.S Green Building Council (a nonprofit organization established in (1993) made a voluntary program called "Leadership in Environment and Energy Design -LEED" and released its first version in (2000). The aim of the program is to insert sustainability principles in buildings development in order to provide more efficient operating and maintenance activities with reduced cost. The first version (LEED-V1) was directed to new considerations only and aided by a rating system based on standards and benchmarks that were easy to achieve. The (LEED) certification is an independent third-party verification that a building is designed and built using strategies that aim at achieving high performance in main areas of environmental and human health, as shown in table (1)[8].

Table(1): Information on how to achieve LEED credits

Categories	Details
Sustainable Sites	Construction related pollution prevention, site development impacts, storm water management, transportation alternatives, heat island effect and light pollution
Water Efficiency	Landscaping water use reduction, indoor water use reduction and wastewater strategies.
Energy and Atmosphere	Commissioning, whole building energy performance optimization, refrigerant management, renewable energy use and measurement and verification.
Materials and Resources	Recycling collection locations, building reuse, construction waste management, purchase of regionally manufactured materials, materials with recycled content, rapidly renewable materials, salvaged materials and sustainably forested wood products.
Indoor Environmental Quality	Environmental tobacco smoke control, outdoor air delivery monitoring, increased ventilation, construction indoor air quality, use low emitting materials, source control and controllability of thermal and lighting systems.
Innovation and Design Process	(LEED) accredited professionals and innovation strategies for sustainability in design.

Table (2) Main criteria and Sub-criteria for School building design

The Main Criteria	**Sub-Criteria**
Project Performance	a. Safety b. Reliability c. Maintainability d. Durability e. Target Cost
Constructability	a. Simplicity b. Flexibility c. Sequencing of installation d. Substitutions or alternative warrant attention. e. Labor skill availability
Materials and Resources	a. The purchase of regionally manufactured materials b. Salvaged materials c. Construction waste management
Sustainable Site	a. Site selection b. Brownfield and Urban redevelopment c. Construction-related pollution prevention d. Open spaces e. Improve site aesthetics
Water Efficiency	a. Indoor water use reduction b. Outdoor water use reduction c. Wastewater strategies
Energy & Atmosphere	a. Renewable energy use b. Measurement and verification c. Refrigerant management d. Systems and lighting
Indoor Environmental Quality	a. Controllability of thermal comfort b. Improve acoustical performance c. Increase ventilation d. Indoor chemical and pollutant source control.
Innovation	a. Innovative strategies for sustainable design b. LEED professional person in the team

III. PREPARATION OF THE QUESTIONNAIRE

The questionnaire consists of two parts:
Part 1: Includes personal information from respondents sample such as academic achievement and years of experience in engineering field.
part II: includes assessment the importance of criteria for the design of school buildings according to the conditions and requirements of our country (Iraq), where a sample of respondents is asked to assess the importance of school building design criteria on a scale ranging from (9 to 1).

The researcher then distributed the questionnaire on a sample showing the considerations regarding the design criteria used in this questionnaire. Interviews were conducted to clarify these criteria for those who have no idea of design principles.

Research sample selection
60 Questionnaires were distributed to academics and engineers in the fields of design and implementation of school building projects of various engineering disciplines. Only 49 samples were returned. The researcher wanted to include in the research sample some engineers and consultants who have experience in the field of design. To help the remaining researchers with little or no knowledge, the researcher included some explanatory details in the questionnaire to give a complete idea of the design criteria that include: criteria for project performance requirements, constructability criteria, LEED criteria (sustainability criteria) and the requirements and requirements of Iraq were in mind when filling out the questionnaire form.

Statistical results for questionnaire form respondents
The questionnaire results have been statistically analyzed, based on the work of Hines 2003, utilizing two methods to determine the results.

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Calculate the arithmetic mean and the standard deviation of the responses for each criterion based on the following equations

$$\bar{x} = \frac{\sum_{i=1}^{k} Xi \cdot fi}{\sum_{i=1}^{k} fi} \text{......(1)}$$

$$s = \left[\frac{\sum_{i=1}^{k} (Xi-\bar{x})^2 * fi}{(\sum_{i=1}^{k} fi)}\right]^{1/2} \text{........(2)}$$

Where
$\bar{x}$: Arithmetic Mean
S: Standard Deviation
Xi: degree of importance for criterion
fi: Frequency of degrees
Testing the quality of the questionnaire results: To check the quality of the responses recorded in the questionnaire, and to access at the correct predictions using a confidence level (95%), the Z test will be used.

Through the following equation, find (Z calculate) and compare it with (Z Tabular) at a confidence level of 95%.
If the (Z calculate) is greater than (Z tabular), we will accept the values of the questionnaire, and vice versa.

$$Zcalculate = \frac{\bar{x}}{\frac{S}{\sqrt{n}}} \text{.........(3)}$$

Where
$\bar{x}$: Arithmetic Mean
s: Standard Deviation
n: sample size

"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.
The value of (Z tabular) depends on the table of (Z values) shown in table (3), in which the value of Z, is equal to 1.684 after the level of confidence required and the sample size were specified. From the comparison between the two values, it is noted 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

No.	Criteria	Arithmetic Mean	Standard Deviation	Z calculate
1.	Performance	7.4286	1.69558	30.6681
1.1	Safety	7.5102	1.91619	27.4354
1.2	Reliability	6.5714	2.00000	22.9999
1.3	Maintainability	7.1429	1.54110	32.4446
1.4	Durability	7.4082	1.69458	30.6019
1.5	Target Cost	7.1837	2.01736	24.9266
2.	Constructability	6.5510	1.81500	25.2656
2.1	Simplicity	6.5102	1.72146	26.4725
2.2	Flexibility	6.1429	1.54110	27.9023
2.3	Sequencing of installation	6.1633	2.02430	21.3126
2.4	Substitutions or alternative warrant attention	6.3878	1.63065	27.4213
2.5	Labor skill availability	6.6939	1.73450	27.0149
3.	Materials & Resources	6.429	1.8371	24.4968
3.1	The purchase of regionally manufactured materials	5.9388	2.03519	20.4264
3.2	Salvaged materials	5.5102	1.96980	19.5814
3.3	Construction waste management	5.4694	2.03206	18.8409
4.	Sustainable Site	5.6531	1.97432	20.0432
4.1	Site selection	7.2653	1.80018	28.2511
4.2	Brownfield and Urban redevelopment	6.9592	1.56736	31.0805
4.3	Construction-related pollution prevention	6.8980	1.83989	26.2440
4.4	Open spaces	6.5306	1.74526	26.1933
4.5	Improve site aesthetics	6.4898	1.78095	25.5081
5.	Water Efficiency	5.6735	2.08554	19.0428
5.1	Indoor water use reduction	6.1020	1.82853	23.3597
5.2	Outdoor water use reduction	5.8776	2.12752	19.3386
5.3	Wastewater strategies	6.7551	1.98463	23.8260
6.	Energy and Atmosphere	5.7143	1.90394	21.0091
6.1	Renewable energy use	6.1837	2.19539	19.7167
6.2	Measurement and verification	6.4898	1.87219	24.2650
6.3	Refrigerant management	6.8571	1.73205	27.7127
6.4	Systems and lighting	7.0816	1.49773	33.0976
7.	IndoorEnvironmental Quality	7.2041	1.69533	29.7457
7.1	Controllability of thermal comfort	7.1020	1.88464	26.3785
7.2	Improve acoustical performance	6.8776	1.94329	24.7741
7.3	Increase ventilation	7.6327	1.33376	40.0589
7.4	Indoor chemical and pollutant source control.	7.0612	1.71280	28.8582

8.	Innovation	6.0816	2.01904	21.0849
8.1	Innovative strategies for sustainable design	6.5714	1.79118	25.6813
8.2	LEED professional person in the team	6.4286	2.15058	20.9247

Build an AHP decision model

Analytic Hierarchy Process (AHP) is one of the most widely used in decision-making methods and is one of the most used algorithms for selecting the optimal alternative. This method was designed by Professor Thomas L. Saaty at the University of Pittsburgh in the mid-1970s and can be defined as a method of arranging decision alternatives and selecting the best alternative when a decision maker has multiple objectives or criteria on which the decision is based. While (Wang Et. 2004) defines it as the decision-making tool that analyzes or disassembles the complex problem into a multi-level hierarchical structure of goal, criteria, sub-criteria and alternatives. The basic idea of this approach is to transform objective estimates of relative importance into a set of degrees or total weights. By having this method of fundamental property, which is based on the Pairwise Comparison, it complements the various quantitative and qualitative measures to combine them into one comprehensive degree that expresses the order of the alternative between a set of decision alternatives[10].

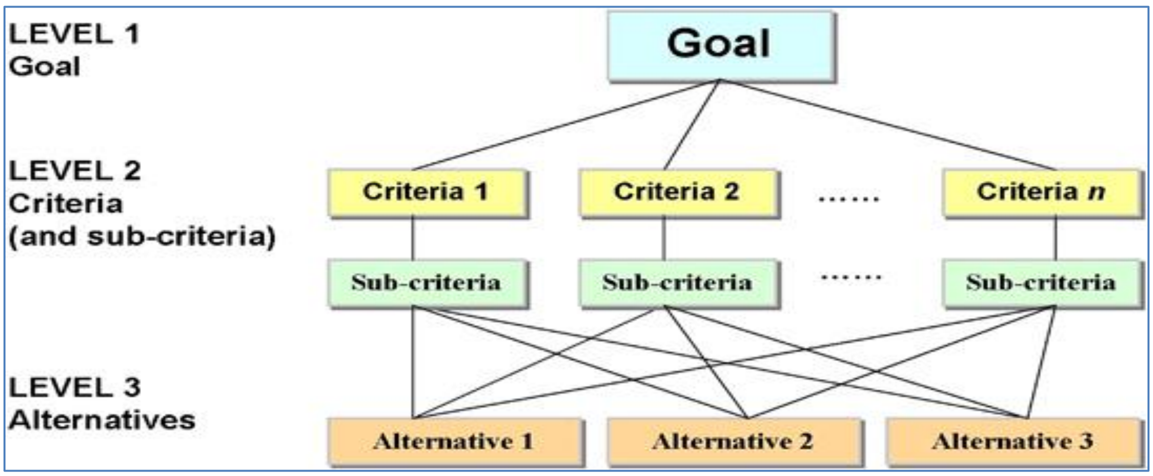


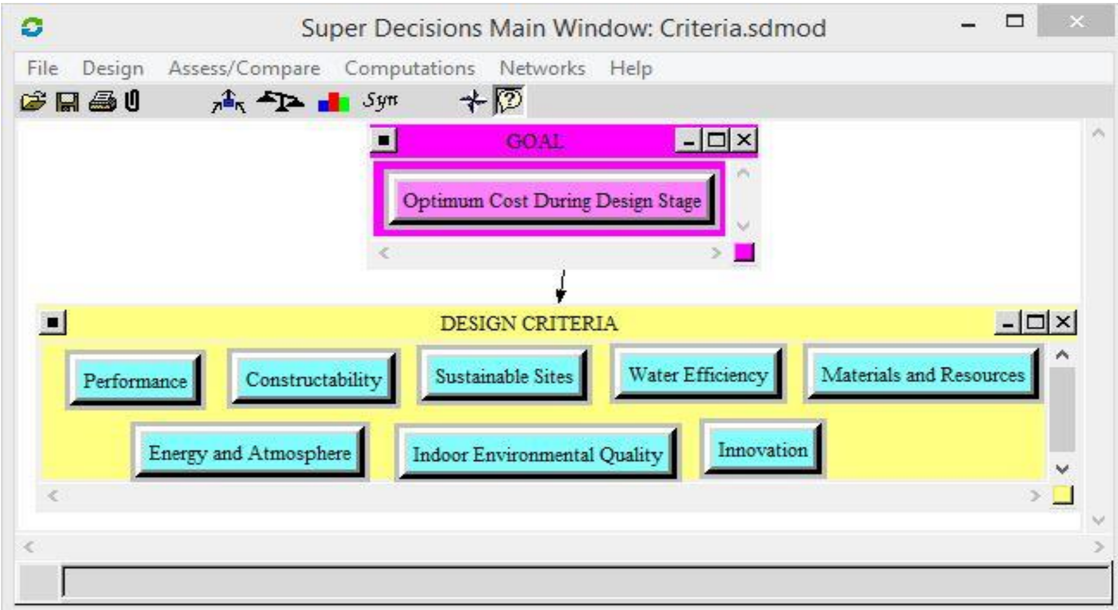
Figure (1) Analytic Hierarchy Process (AHP) model

Table (4) Fundamental scale of absolute numbers[8].

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 dominancedemonstrated in practice
8	Very,very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

5-6-5 Use Super Decisions Software to build AHP decision model
To build the model, follow these steps:
Identify the goal, that established "Optimum Cost During Design " as a goal in the model.

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



Figure(2) Building an AHP hierarchical decision model.

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 figures

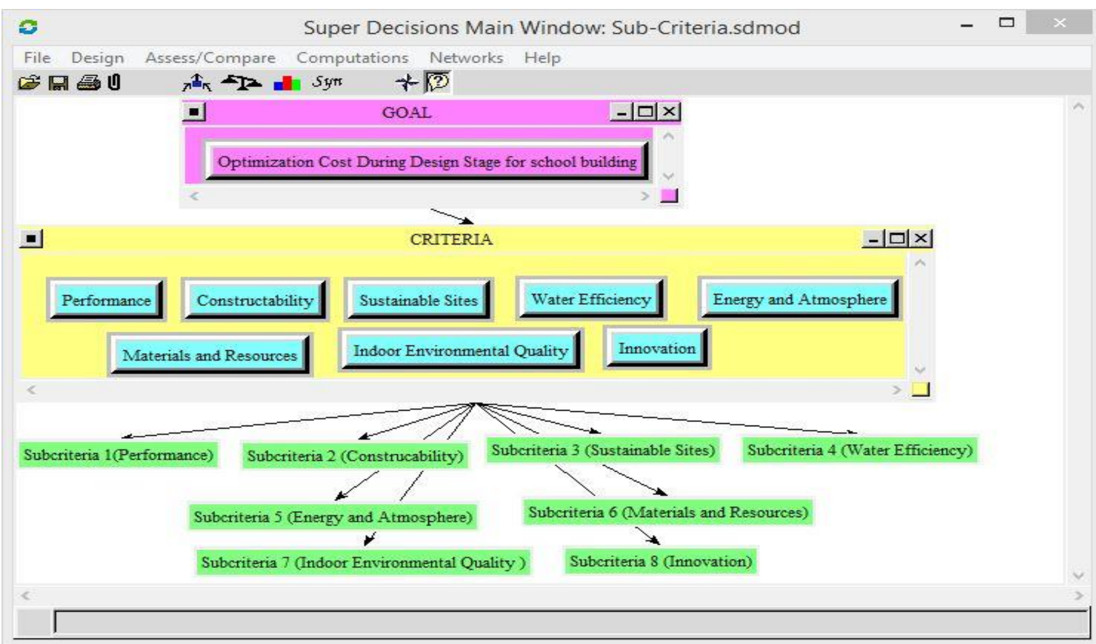


Figure (3) Insert sub-criteria for each main criterion into the program

Specify Weights of Main Criteria and Weights of Sub-criteria Using Super Decisions Software

After the results of the questionnaire are analyzed, the weights of criteria are specified for building design; that will be found by using a program (AHP), which will make pair comparisons between criteria depending on the values of arithmetic mean, as shown in the figure . The figure shows matrix of pairwise comparisons for criteria.

	Constructability	Energy and Atmosphere	Indoor Environmental Quality	Innovation	Materials and Resources	Performance	Sustainable Sites	Water Efficiency
Constructability	1	2	1/2	2	1	2	2	2
Energy and Atmosphere	1/2	1	1/3	1	1/2	1/3	1	1
Indoor Environmental Quality	2	3	1	3	2	1/2	3	3
Innovation	1/2	1	1/3	1	1/2	1/3	2	2
Materials and Resources	1	2	1/2	2	1	1/2	2	2
Performance	1/2	3	2	3	2	1	3	3
Sustainable Sites	1/2	1	1/3	1/2	1/2	1/3	1	1
Water Efficiency	1/2	1	1/3	1/2	1/2	1/3	1	1

Figure (4) Pairwise Comparisons Matrix for the main criteria

The Super Decision program gives priorities (weights) of criteria with respect to the goal and the weights of sub-criteria with respect to the main criteria as shown in the table (5).

Table (5)Weights of main criteria and sub-criteria for school buildings design

Criteria	**Priorities (weights)%**	
Inconsistency = 0.03294		
Main Criteria for design buildings	weight	Ranking
Constructability	16.71%	3
Energy and Atmosphere	6.82%	6
Indoor Environmental Quality	20.94%	2
Innovation	8.34%	5
Materials and Resources	12.79%	4
Performance	21.75%	1
Sustainable Sites	6.32%	7
Water Efficiency	6.32%	8
Sub-Criteria for Project Performance	**weight**	**Ranking**
Inconsistency = 0.0000		
Durability	28.57%	1
Maintainability	14.29%	3
Reliability	14.29%	4
Safety	28.57%	2
Target Cost	14.29%	5
Sub-Criteria for Constructability	**weight**	**Ranking**

Inconsistency = 0.0661		
Flexibility	22.17%	2
Labor skill availability	31.77%	1
Sequencing of installation	12.74%	5
Simplicity	18.91%	3
Substitution	14.41%	4
Sub-Criteria for Sustainable Sites	**weight**	**Ranking**
Inconsistency = 0.0435		
Brownfield and Urban redevelopment	32.29%	1
Construction-related pollution prevention	18.54%	3
Improve site aesthetics	10.65%	5
Open spaces	14.05%	4
Site selection	24.47%	2
Sub-Criteria for Water Efficiency	**weight**	**Ranking**
Inconsistency = 0.0516		
Indoor water use reduction	31.08%	2
Outdoor water use reduction	19.58%	3
Wastewater strategies	49.34%	1
Sub-Criteria for Energy and Atmosphere	**weight**	**Ranking**
Inconsistency = 0.0454		
Measurement and verification	19.53%	3
Refrigerant management	27.61%	2
Renewable energy use	13.81%	4
Systems and lighting	39.05%	1
Sub-Criteria for Materials and Resources	**weight**	**Ranking**
Inconsistency = 0.0516		
Construction waste management	19.58%	3
Salvaged materials	31.08%	2
The purchase of regionally manufactured materials	49.34%	1
Sub-Criteria for Indoor Environmental Quality	**weight**	**Ranking**
Inconsistency = 0.0227		
Increase ventilation	39.52%	1
Indoor chemical and pollutant source control	16.34%	3
Minimum acoustical performance	16.34%	4
Thermal comfort controlling	27.81%	2
Sub-Criteria for Innovation	**weight**	**Ranking**
Inconsistency = 0.0000		
Innovative strategies for sustainable design	66.67%	1
professional person on the team	33.33%	2

IV. CONCLUSIONS

AHP software was applied to determine the weights of the criteria, depending on the answers to the questionnaire which enabled the researcher and the following points are obtained :
The highest weight is received by the performance criterion of which got 21.75%; and this gives the result that this criterion is of great importance in school buildings design, from the point of view of the selected sample and the researcher.

In second place comes the criterion of Indoor Environment Quality, which earned the weight 20.94%, and it deserves this importance, from the viewpoint of the researcher, because of its significant impact on school buildings design.
The criterion of Constructability obtained a proportion of importance (priority) of about 16.71%, which is a moderate proportion.
The criterion of Materials and Resources obtained a proportion of importance (priority) of almost 12.79%, which is a medium proportion.
The criterion of Innovation obtained a proportion of importance (priority) of almost 8.34%, which is a low proportion.
Equal in importance are the criteria of Energy and Atmosphere, Sustainable Site and Water Efficiency because each has received approximately a weight of 6.5%. This ratio gives an indication of less importance of these three criteria for school buildings design.

When doing a pairwise comparison between criteria in the program (AHP), the inconsistent index is equal to 0.03294, which is less than the highest value (0.1), so it is satisfactory according to the program conditions and requirements.

When compared to sub-criteria for identifying the priorities, the inconsistent index for all comparisons is less than 0.1, which indicates the possibility of relying on judgments that have been adopted in the pairwise comparisons for main criteria and sub-criteria.

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