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Developing a green building assessment tool for developing countries – Case of Jordan

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ABSTRACT

The purpose of this research is to contribute to a better understanding of the concept of green building assessment tool and its role for achieving sustainable development through developing an effective green building rating system for residential units in Jordan in terms of the dimensions through which sustainable development tools are being produced and according to the local context. Developing such system is becoming necessary in the Developing World because of the considerable environmental, social and economical problems. Jordan as one of these countries is in need for this system, especially with poor resources and inefficient use. Therefore, this research studied international green building assessment tools such as such as LEED, CASBEE, BREEAM, GBTool, and others. Then defined new assessment items respecting the local conditions of Jordan and discussed them with (60) various stakeholders; 50% of them were experts of sustainable development. After selecting the assessment items they were weighted using the AHP method. The outcome of the research was a suggested green building assessment tool (SABA Green Building Rating System) – computer based program – that suits the Jordanian context in terms of environmental, social and economical perspectives.

1. Introduction

Green building has now become a flagship of sustainable development in this century that takes the responsibility for balancing long-term economic, environmental and social health [1,2]. It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants is reduced. Rating system provides an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes; as it can be used as a design tool by setting sustainable design priorities and goals, developing appropriate sustainable design strategies; and determining performance measures to guide the sustainable design and decision-making processes [2,3]. It can also be used as a management tool to organize and structure environmental concerns during the design, construction, and operations phases.

Green design does not only make a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, increases occupant productivity, and helps create a sustainable community [4]. Generally, green buildings are energy efficient, water conserving, durable and non-toxic, with high-quality spaces and high-recycled content materials, which presents solution for large part of Jordan resources problems.

Cam and Ong (2005) defined the roles of building environmental performance domain that can assure innovative design. They argued that there are roles should be taken in concern, particularly the following three: first; being an institutional setting to raise awareness of building environmental to different players in the design and construction sectors in delivering environmental-friendly housing, second; setting benchmarks for building environmental practice to safeguard the minimum performances standards, and evaluating architectural design against these benchmarks; and finally providing a platform for inspiring new designs, ideas and technical solutions [5]. Cooper (1999) on the other hand, clarified the issues that are needed to be defined at first; which are the issue of absolute vs. relative assessments – absolute assessments are considered to be more appropriate and meaningful in assessing sustainability, and the issue of scale – individual building is considered as too small a scale to address sustainable development issues [6].

Using green rating (assessment) system in the design/build process can produce significant benefits that are not likely to result

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from standard practices. Assessment measurements based on building life cycle can produce significant long-term benefits for building owners and occupants [7]; as this system helps for solving existing building problems, limiting environmental impacts, creating healthier and more productive places, and reducing building operations cost. Life cycle analysis takes into account all costs of acquiring, owning, and disposing of a building system. It is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings.

However, making green building practices easier to implement; we should develop technical services and resources for determining the "greenness" of building based on an appropriate green rating system that suits the Jordanian local context.

Building sector has witnessed the development of two types of assessment tools. The first group of these tools includes those, which purely based on criteria system. The second group includes those tools that use life cycle assessment (LCA) methodology. The criteria-based tools can be defined as a system of assigning point values to a selected number of parameters on a scale ranging between "small" and "large" environmental impact. These tools are considered as comprehensive environmental assessment schemes. Among the criteria-based tools are BREEAM (Great Britain) – BREAM (2005); GBTool (Canada) – IISBE (2005); LEED (US)-USGBC (2005); EcoProfile (Norway) – Byggforsk (2005) and Environmental Status (Sweden) –Miljöstatusföreningen (2005) [8–12]. However, since the late 1990s methods for environmental assessment of buildings based on LCA have been developed for the building sector. Most of these methods have aimed to be used for selection of building design, building material, and local utility options (energy supply, waste management and transport type) during the design phase. Within life cycle assessment, different weighting methods based on different basis for valuation are used. Examples of tools of this category that contain LCA component are Bees (USA)-OAE (2004), Beat (Denmark)-DBRI (2005); EcoQuantum (Netherlands) and KCL Eco (Finland) – KCL (2005) [8–12].

Another comprehensive framework for classification of green building assessment tools was established according to the potential functions (applicable areas) of the tools. According to this classification there are two types of tools; the first (D-Tool), tools within the stakeholder and building activity category that are designed primarily to optimize, select, check, predict and evaluate decisions, they include issues describe the methods of green building practice which lead toward certain performance targets. The second (P-Tool), tools within the performance category that are designed for performance comparison and rating, they include issues describe the targets of building activities, which are raised from building environmental science researches. Such issues are in nature more general and stable. In existing tools, P issues and D issues are usually mixed together and listed in one hierarchy framework [13].

Gibberd (2005) stated that sustainable development in developing countries should address social and economic issues as a priority; he suggested, that environmental sustainable development objectives should be acknowledged and addressed in interventions designed to address urgent social and economic priorities [14]. Libovich (2005) also believed that nations of the developing world, cannot afford to be looking at environmental performance only. The social and economic problems are at the top of these countries' agendas. As a result, the development of building assessment methods is becoming necessary in the developing countries in order to diagnose the building-stock's performance and to encourage the building industry to get into sustainable track, and thus by default will directly support social and economical aspects [15].

2. Concept of green buildings in Jordan

According to Agenda 21 (Johannesburg Summit 2002); "Jordan is highly dependent on its poor environment, ensuring that environmental resources -water, soil, plants and so on - are used in a sustainable manner is one of the most urgent obligation to the principles of sustainable development confirmed at the Earth Summit in Rio de Janeiro in 1992" [16].

Jordan is a developing country suffering from the global problems of energy and the increasing of pollution, especially with poor resources of energy and inefficient use of it. In light of this situation, the development plan in Jordan which is being implemented to improve the quality of life for the Jordanian expected that the demand for energy will grow to high levels reaching 3% annually and around 6% annually for the electric consumption. This situation, in addition to the regional development of 2003 have pushed the energy bill to around 800 million JD annually constituting 13% of the gross domestic product (GDP) and around 45% of the value exported goods which is considered by international standards as a heavy burden in addition to the burden of investing in energy production, refining, transport and distribution which amounts to around 150 million JD annually [16–19]. Due to economic growth and increasing population, energy demand is expected to increase by at least 50% over the next 20 years. This state force Jordan to adopt a number of policies that enhance energy efficiency, develop investment energy proposals, supports the sustainable development by using clean and environmentally friendly resources, and apply baseline parameters in accordance with international standards [17].

Jordan has a range of geographic features from the Jordan rift valley in the west to the desert plateau of the east, with a range of small hills running in between. It can be divided into three physiographic regions, each with a distinct climate:

1. The highlands consist of mountainous and hilly regions that run through Jordan from north to south. Their altitude varies from 600 to 1600 m above sea level. Generally wet and cool, also varies from one area to another. The average temperature in Amman ranges from 8.1 °C in January to 25.4° C in July. The temperature during the hottest spells reached 42.8° C.
2. The desert region is an extension of the Arabian Desert, and forms around eighty percent of the country. There is an extreme variation in the climate of the desert between day and night, and between summer and winter. Summer temperatures can exceed 45 °C, while winter nights can be bitterly cold, dry and windy.
3. The Jordan Rift Valley which also runs along the entire length of Jordan. The Rift Valley plunges to over 400 m below sea level at the Dead Sea, becoming the lowest spot on earth, and reaches a maximum width of 15 km. The Rift Valley ends in the south at Aqaba, a tropical resort surrounded by mountains [20].

Jordan is classified among few countries of the world with limited water resources and it is one of the lowest on a per capita basis. The available water resources per capita are falling as a result of population growth and are projected to fall from less than 160 m^3/capita/year at present to about 90 m^3/cap/year by 2025, putting Jordan in the category of an absolute water shortage. The scarcity of water in Jordan is the single most important constrains to the country growth and development because water is not only considered a factor for food production but a very crucial factor of health, survival and social and economical development [21].

The concern of environment and sustainable development has been increased recently in Jordan. Therefore, Jordan established different institutions that concern sustainable issues – environmental, social, and economical – beside other non-governmental organizations. Even Jordan emphasizes the role of laws and regulations as an approach ensuring sustainable development through reducing waste and providing adequate supplies at an affordable cost that limit human wrong practices.

In the last twenty five years, the construction practices in Jordan were shifted toward modern (western) building systems to cope with the modernization style of living. They replaced the mud and stone as major traditional materials with concrete, glass and steel to become dominant construction materials and systems. Thus, Construction practices shifted from craft to industry. Accordingly, there is an urgent need to return back to the vernacular systems into modern perspective, through establishing new building systems and practices based on green thinking and applications.

As a result, Jordan in need to develop sustainable or "green" design practices; it needs to improve the environmental and economical performance of new and existing commercial, institutional, and residential buildings [22]. Making green building practices easier to implement; we should develop technical services and resources for determining the "greenness" of building based on an appropriate green rating system.

This research purposes to contribute to a better understanding of the concept of green building rating system and its role for achieving sustainable development. In addition, it aims to provide a framework model for developing an effective green building rating system for developing world; in terms of the dimensions through which sustainable development tools are being produced. And finally, this research hopes to develop a green building assessment tool – computer based program – for Jordan that ensures the right sustainable development is achieved according to its local context, stakeholders, buildings types and knowledge and technology. So this research will provide an analytical study of the key aspects of Jordan's context that are relevant to the sustainable assessment framework – infrastructure, building policy, social exclusion (needs), social and economic priorities, in addition it will discuss the limitations and major constrains that face the development processes such as rapid growth, poor economy, lack of resources, low income and others. This research has four major assumptions:

1. Developing green building rating system should be based on studying and analyzing the most famous practices of the developed countries.
2. The developed system should suit the local context – Jordan context.
3. The developed system should be directed toward the residential buildings only. Other building types were not on the scope of this research.
4. The developed system should be implemented from the preliminary stages of design – considering building life cycle: pre-design, design, post-design.

3. Methodology

3.1. Research design

The research adopted multi-dimensional design strategy that involves a variety of approaches – quantitative and qualitative. These approaches include fieldwork approach (pilot study, survey), questionnaire, interviews – structured and unstructured, empiricism approach (experiments) and critical approach. In other words the research based on interaction between archival ethnographic approach and qualitative interviews.

To determine the initial set of variables that would inform the qualitative interview guide, an analysis of the major green building rating systems which is considered by far the most comprehensive and methodological tools developed to examine sustainability issues. The review focused on the strength and weaknesses, as well as the elements of success of implementation of these systems, then this research identify the local context of Jordan – the case of this research; considering its natural and physical conditions, to classify the current conditions in to negative or positive aspects. This requires fieldwork search – ethnographic approach in which the researcher goes down to the field, observe and meet the different stakeholders of the problem using:

- Unstructured (informal) interviews with householders, investors, builders…etc
- Structured interviews (questionnaire) with the integrated stakeholders (private, public, governmental agencies)
- Observation of the situation of the residential buildings from different aspects.

The information generated in this pre-test investigation informed the conversational guide and interview process. In addition, it informed the decision to determine the main factors that should be involved in the new assessment system for Jordan.

The overall approach of the research assumed conducting interviews –structured and non-structured – within focus group to identify the categories, indicators and parameters that should be involved in the assessment system and to define weighting for each of them. The focus group includes variety of stockholders; fresh graduate architects, designers, contractors, experts, decision-makers, laymen, members of engineering association, member of governmental associations.

3.2. Data collection procedure

Individual and group interviews that were employed in this research are considered as a convenient way to collect data from several people. This method allows each person to respond to question, then asking questions, exchanging comments according to her/his experiences and points of view. The interviews used the form of questionnaire. The first part of the questionnaire aims to define the main aspects of green building assessment tool for residential units that suit the Jordanian local context. The second part defined categories of assessment. The third part defined assessment indicators and their parameters. In each part, the participant had to rank measures according to importance in establishing a green building assessment for Jordan. By using this technique, the researcher could identify the main aspects, categories, indicators, and parameters of the assessment system and their weightings. In addition, the researcher could define new assessment measures as participants had the right to add suggested measures. This method of data collection is useful in explaining results and examining what people think, how they think and why they think that way as the researcher met the recipients face to face and discussed the system with them.

The interviews took place wherever and whenever suitable for the participant, after she or he agreed to be interviewed personally. During the interviewing process, the researcher established clear roles of answering with the respondents.

3.3. Sampling procedure

The sample included a group of stakeholders from different fields; architecture, environment, renewable energy and energy efficiency, water efficiency, natural resources, urban design and others. All the participants were educated, classified into two main part groups. The first; experts of sustainable building field – academicians and authorities, designers and building industry professionals (project managers, field engineers, design engineers, and others). The sampling frame is a list of experts and professionals conducted with the help of Jordan Engineers Association, that recorded the specialty and achievements of all distinguished professionals. Purposive sampling techniques were employed to select the respondents from different branches. The second group included laymen and architectural, environmental and engineering students. The students were randomly selected from Jordan University of Science and Technology based on a list from the registration office. They should complete at least three courses in environmental and sustainable design. While the laymen included general public people such as journalists, governmental agents, economists, politicians and others. They were selected according to their role and influence on sustainable development practices. The total number of participants was (60); (50%) experts and (50%) laymen (non-professionals).

The investigation held with participants as an interview in the form of questionnaire. The interviews included one participant, two participants, three participants, or four participants each time to allow interaction as part of the method. The researchers visited the respondents on their offices, and if possible, they were invited to the department of architecture at Jordan University of Science and Technology. The second group of respondents that included students and laymen were invited to the department of Architecture. A general description of the subject was addressed and discussed, and then structured questionnaires were delivered. The questionnaires were included close and open ended questions.

3.4. Developing assessment model

Green building assessment tools offer a means to demonstrate that a building has been successful at meeting an expected level of performance in a number of declared criteria. From the previous, it can be concluded that the developed tool should have the following characteristics:

First; the developed tool should be comprehensive approach define building performance from different aspects – environmental, social, and economical; respecting different climatic, cultural and economic conditions.
Second; the aspects, categories, and indicators of the developed tool should acknowledge the local context within which the tool is developed.
Third; the developed tool should be phase-by-phase method according to the construction of building, so it could be feasible and could tell different information to us.
Fourth; the developed tool should address all stages of a long-term life cycle with regard to sustainable issues, including a building's design, construction, operation, repair, renovation, and demolition.

3.5. Assessment items

This research suggests an approach to develop assessment items for green buildings. This approach consists of three continuously steps that are cyclic. They are the following (Fig. 1):

Step1: defining the context in which items are developed
In order to develop valid assessment indicators for green buildings; the context within which indicators are developed should be defined. And thus requires identifying the field that is relevant to the assessment tool such as type of building being studied – in this research it is residential building, the climatic conditions, the economic state, the local community, the key stakeholders, the practitioners, the existing and linked systems, future opportunities and future shocks, and other factors. As well as, it is necessary to identify the goals and strategies for the process.

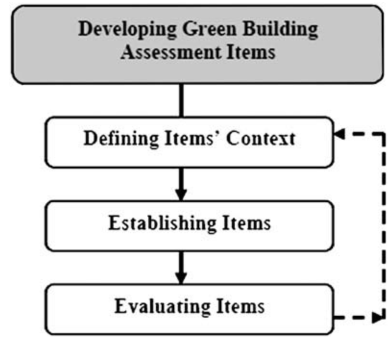

Fig. 1. Steps for developing and applying sustainability items to develop a methodological assessment tool for green buildings.

Step 2: establishing assessment items
Assessment items should be defined based on expert knowledge and scientific research. Three groups of indicators/items are defined and calculated as measurable elements for green buildings assessment. Each of the indicators represents a certain characteristic of the sector they described; they are concerned with the goals and objectives of sustainable development that are applied to buildings which are defined in stage one. Types of assessment indicators are:

- First, environmental indicators
- Second, social indicators
- Third, economic indicators.

Step 3: evaluating assessment items
Evaluating indicators is important to ensure their accuracy, reliability and sensitivity. This can be done using empirical or modeling techniques. However, Reed et al. (2006) suggested a criterion to evaluate sustainable assessment indicators that summarizes best practices. This criterion is based upon defining characteristics of best indicators; so the researcher can define how much the proposed assessment indicators are reliable and valid [22].

3.6. Assessment items weighting

Green building assessment tool is a multi-dimensional method respects different environmental, social, and economical issues. Therefore, the process of building weighting system for indicators should be comprehensive and flexible. This process should adapt different integrated methodologies such as Experts panel, Endpoint method, Economy method, AHP method, and others; by considering the advantages and avoiding the negatives of each method to build a new compatible method. For the purposes of this study, the researcher used the AHP method.

3.7. Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a mathematical decision-making technique provides an effective means to deal with complex decision-making, developed by Thomas Saaty in 1980. AHP allows consideration of both qualitative and quantitative aspects of decisions; it can reduce complex decisions to a series of one-on-one comparisons by assisting with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision-making process. In addition, AHP helps in reducing bias in decision-making, and it can minimize common pitfalls of team decision-making process, such as lack of focus, planning, participation or ownership, which ultimately are costly distractions that can prevent teams from making the right choice [23–25].

AHP methodology is based on the principles of decomposition, comparative judgments, and synthesis of priorities. Decomposition structures the problem according to its main components: focus, set of criteria for evaluation, and the decision alternatives. Comparative judgments are required for pair-wise comparison of criteria and investment alternatives to derive the criteria weights and relative priorities of investment alternatives. Finally the priorities of alternatives and the criteria for weights are synthesized into an overall rating based on which the best alternative is decided.

AHP involves the following four basic steps:

- **Step one**: model building
- **Step two**: pair-wise comparison of categories and criteria
- **Step three**: pair-wise comparison of alternatives
- **Step four**: alternative ranking.

4. Results and analysis

Green building approach should consider three dimensions – environmental, social, and economical; therefore, the assessment tool necessarily to take these three dimensions into consideration. Site selection, energy, water, resources, material and components, environmental loadings, transport, emissions, waste, and others can define environmental aspects. Comfort, health, indoor environment quality, access to facilities, participation, control, education, safety, and others can define social aspects. Finally, economical aspects can be introduced through economy, efficiency of use, ongoing costs, capital costs, operation costs, durability, adaptability, maintenance, and others.

4.1. Categories, indicators and parameters of the assessment tool

Based on analyzing the main characteristics of several building environmental performance assessment systems in different countries and studying the local context, the researcher defined seven main categories for the assessment tool. They are the following: site, energy efficiency, water efficiency, material, indoor environment quality, waste and pollution, and cost and economics.

Each assessment category is identified by a number of indicators. The number and nature of indicators varies from one category to another according to the category itself and its importance matching the local context. As well as, each indicator is defined through a number of parameters. This section introduces the criteria for selecting the assessment items of categories. In respect to these criteria, each category is required to apply main sustainable concepts according to certain classification of items (Table 1).

Table 1
Assessment categories and indicators of the assessment tool

Assessment categories	Assessment indicators
Site	Microclimate Site design Landform Land use On site energy resources Infrastructure efficiency Relation between the building and its immediate surroundings Landscape design Low-impact construction site techniques Housing density (no. of units/area) Transportation
Energy efficiency	Building envelope performance Renewable energy Natural lighting/lighting Energy-efficient heating/cooling system Mechanical systems Green house gases emission Machines/appliances
Water efficiency	Water conservation Innovative reduction water technologies/internal Water use Water efficient landscape/external
Material	Local/regional materials Renewable material Recycle material Resource reuse Environmental impact of materials
Indoor environment quality	Occupant health and safety Indoor air quality performance Quality of life Increase ventilation efficiencies Thermal comfort Daylight Acoustic and noise control Visual quality
Waste and pollution	Waste reduction and management strategies
Cost and economic	Site Energy efficiency Material and construction Water efficiency Waste management

- Assessment of aspects
  The result of the overall interviews in respect to assessment aspects revealed that environmental aspects are the most important aspects then the economical and finally social aspects. Fig. 2 indicated the mean of the ranking order of the three assessment aspects that include social, economic and environmental aspects. Each respondent asked to rank these aspects according to its importance and the mean of ranks for each aspect was calculated.
- Assessment categories
  Water efficiency is arranged as the most important category for the assessment system, this seems rational according to the local context of Jordan. The arrangement of categories from the most important to the least is the following: water efficiency, energy efficiency, indoor environment quality, site, material, cost and economics, and finally waste and pollution. Respondents were asked to rank the assessment categories according to its importance and the mean of these ranks was calculated as shown in Fig. 3.
- Assessment of indicators
  Each category consists of a number of indicators. The following presents the results of interviews in terms of indicators for each category individually. Respondents were asked to rank the assessment indicators from the highest to the lowest according to their importance, the mean of these

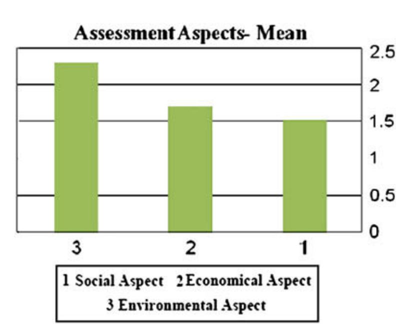

Fig. 2. Means of assessment aspects.

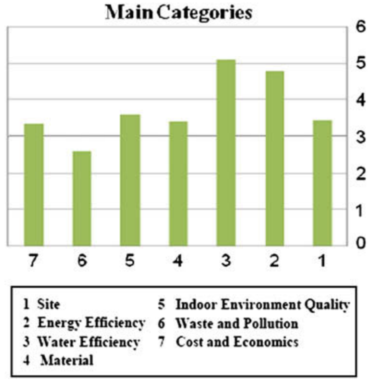

Fig. 3. Means and ranking of assessment categories.

ranks was calculated as shown in Fig. 4. They argued that all the suggested indicators are important and should be considered in the assessment criteria. There were no additions from the respondents. The ranking of site indicators from the most important to the least is the following: microclimate, site design, on site energy resources, landform, infrastructure efficiency, land use, landscape design, relation between the building and its immediate surroundings, low-impact construction site techniques, housing density, and transportation.

Building envelope performance argued as the most important indicator of energy efficiency, then respectively renewable energy, natural lighting, heating/cooling system, gases emissions, mechanical system, and house appliances. Both the two groups of participants (experts and laymen) agreed in the ranking of water efficiency indicators; water conservation is the first, then reduction technologies, water use, and finally efficient landscape techniques. Additionally, regional material that is manufactured locally considered the most important indicator for material in respect to the two groups of participants.

The ranking of IEQ indicators from the most important to the least takes the following order: occupant health and safety, quality of life, indoor air quality, ventilation efficiency, thermal comfort, daylight, acoustic quality, and finally the visual quality. Although experts consider energy efficiency cost as the most important indicator of green building

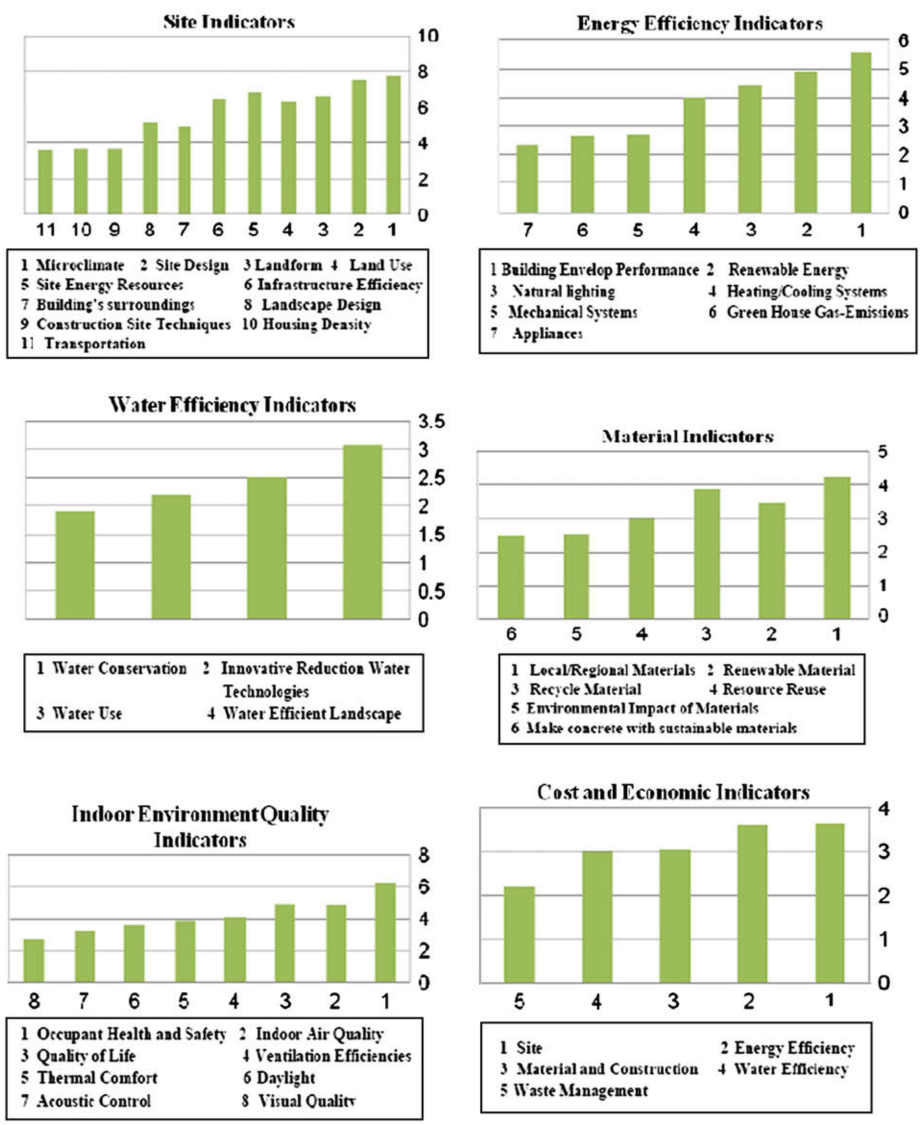

Fig. 4. Means and ranking of site, energy efficiency, water efficiency, materials, IEQ, cost and economic, indicators.

economics, the total score of all participants argues that energy efficiency and site have approximately the same importance, then material and water efficiency, and finally waste management cost.

4.2. Weighting coefficient system

Developing weighting system of indicators is considered a necessary stage for developing assessment tools; it is the second stage after establishing the indicator. This system can define the importance of each indicator according to the local context within which the tool is developed. Each assessment item is weighted so that all the weighting coefficients within the assessment category. The scores for each assessment item are multiplied by the weighting coefficient, and aggregated into summation. In this research AHP method is used to determine the weightings of items according to participant's interviews results. AHP method can transform human subjective judgment into quantitative analysis based on the principles of decomposition, comparative judgments, and synthesis of priorities. Decomposition structures the problem according to its main components: focus, set of criteria for evaluation, and the decision alternatives. Comparative judgments are required for pair-wise comparison of criteria and investment alternatives to derive the criteria weights and relative priorities of investment alternatives. The relative importance (relative weight) of each category and each criteria/element within each category was established using square matrix structure. The values of importance were taken from Saaty's 1–9 scale. The values of Saaty's scale relative importance are as follows: (1) equal importance, (3) weak importance, (5) essential or strong importance, (7) demonstrated importance, (9) absolute importance, (2,4) intermediate vales between the two, (6,8) adjacent judgments [23,24]. Alternative in the decision structure is rated with revere to each decision criterion in the evaluation model using Saaty's (1–9) scale. Relative scores for each alternative are computed within each leaf of the hierarchy. Scores are then synthesized through the model, yielding a composite score for each choice at every tier, as well as an overall score. The final step in the process in which ratings of alternatives were combined with the ratings of the criteria to form an overall rating for each decision alternative. The alternative of the highest rating is ranked the best choice.

In respect to the results of the interviews and by using the Expert Choice™ Software to calculate the weightings of the assessment items, water efficiency ranked as the most important assessment category and represents about 27.7% of the total certification. Then energy efficiency weighting with about 23%. Water efficiency and energy efficiency weightings represent more than the half of the total. The weightings of the other assessment categories are defined in Figs. 5 and 6 and Table 2.

The process which involves designing assessment tool for green building stands on background information about the major branches that make up the building among the local context of Jordan through the environmental, the social, and the economical aspects. In addition it is initiated in systematic process based on reviewing and analyzing practical international assessment systems. However, the proposed assessment tool framework is based on the focus of the following categories: water efficiency, energy efficiency, indoor environment quality, building material, site, cost and economics, and waste and pollution. Each category is defined by a number of indicators and each indicator is defined by a number of parameters.

Overall, most of the respondents assumed that the suggested criteria for assessing green building are comprehensive, efficient and appropriate for Jordan. They felt that all the proposed assessment items are important and should be considered in the assessment framework. Some participants from the expert group added other assessment items; for example, someone argued that housing density could be evaluated through geometry, while other suggested assessing it through building relation to densities of surrounding units. One suggested that adding thermostat system as assessment parameter for thermal comfort, while other suggested the adding of wind direction (for ventilation purposes) as one assessment parameter of site design. Finally yet importantly, participants granted assessment items – each item was compared with its level – different values according to their importance in green building assessment tool (residential buildings) in respect to Jordan local context. Water efficiency and energy efficiency were considered the most important assessment categories; they took half of the total assessment points – about (51%), and the other five categories weighted the other half. Then indicators of each category were weighted in respect to their importance to that category based on total (1) full point. Finally, parameters of each indicator were estimated according to their importance to that indicator based on total (1) full point.

After reviewing the results, the final framework of the system composed of (7) categories, (42) indicators, and (157) parameters. The total number of assessment items was (206). Finally, this framework is translated into assessment system (a computer based program – SABA Green Building Rating System), that identifies how much the assessed building is green in response to the assessment items.

4.3. SABA Green Building Rating System – Jordan

Based on the previous findings that included the assessment categories, assessment indicators, and assessment parameters and their weighting coefficient, a spread sheet was developed. This system is classified as a criteria-based tool that defined as a system of assigning point values to a selected number of assessment items on a certain scale ranging among three levels – fully satisfied, not fully satisfied, not satisfied. The scope of this system includes the residential building and its near environment (surroundings). This system is implemented during the preliminary stages of design – considering building life cycle: pre-design, design, post-design.

	Site	Energy Effi	Water Effic	Material	Indoor Envi	Waste and	Cost and E
Site		2.3	2.65	1.065	1.135	1.85	1.115
Energy Efficiency			1.35	2.365	2.165	3.15	2.415
Water Efficiency				2.715	2.515	3.5	2.765
Material					1.2	1.785	1.05
Indoor Environment Quality						1.985	1.25
Waste and Pollution							1.735
Cost and Economics	Incon: 0.00						

Fig. 5. Pair-wise comparison of assessment categories with respect to the goal – weighting of assessment items.

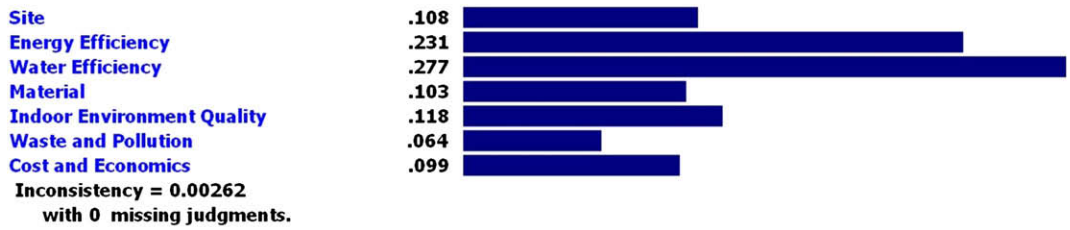

Fig. 6. Priorities of assessment categories with respect to the goal – weighting of assessment items.

This system defines environmental, economical, and social aspects of sustainability. Thus presented in assessment items which classified hierarchy in three levels; category level, indicator level, and parameter level.

A computer base program was established to calculate the overall level of greenness. The excel spread sheet consists of the main sheet that include building information, site, location, climatic regions and the main green categories. Moreover, seven other sheets including the following categories: site, energy efficiency, water efficiency, materials, IEQ, water and pollution and cost and economics. Each sheet of categories includes its indicators and parameters with their weights that derived from the AHP method by using the Expert Choice software. The total score of each category come from multiplying the score of each parameter (three ordinal scales were used to indicate the applicability of greenness for each parameter) the score result multiply by the specific parameter weight. The total sum of each parameter will appear on the indicator and finally the sum of indicator level will be shown on the category level with their relative weights. These values will be shown on the main result sheet that indicates the contribution of each category and the summation of all weights. These results will presented graphically showing the overall level of greenness. As shown in Figs. 7 and 8.

The result obtained in each assessment item level can be calculated by the following formulas:

$$\text{Parameter result}(\text{Rp}) = \text{Parameter weighting}(\text{Wp}) \times \text{Parameter Score}(\text{Sp})$$

$$\text{Indicator result}(\text{Ri}) = \text{Indicator weighting}(\text{Wi}) \times \text{Indicator score}(\text{Si})$$

$$\text{Category result}(\text{Rc}) = \text{Category weighting}(\text{Wc}) \times \text{Category score}(\text{Sc})$$

$$\text{Total assessment result} = \sum \text{Rc}$$

$$\text{Sp} = (1) \quad \text{or} \quad (0.5) \quad \text{or} \quad (0)$$

Table 2
Weightings of assessment categories

Item	Assessment categories	Weight
S	Site	0.108
E	Energy efficiency	0.231
W	Water efficiency	0.277
M	Material	0.103
IEQ	Indoor environment quality	0.118
W and P	Waste and pollution	0.064
C and E	Cost and economics	0.099

$$\text{Si} = \sum \text{Rp}$$

$$\text{Sc} = \sum \text{Ri}$$

4.4. Certification criteria

The certification criterion is based on the summation of points of the items of the assessment system. The score for each assessment item is multiplied by the weighting coefficient, and aggregated into summation. A maximum of 100 points is available. Three performance levels are considered including very green (100–80%), green (79–50%), not green (<50%). The categorization criteria of the greenness levels were based on the analyses of the developed rating systems such as LEED, BREEAM, and GBTool. In addition, the results of existing residential buildings in Jordan, that were classified as sustainable buildings, were studied and analyzed using the proposed system. These results were presented to the respondents/experts who recorded their levels of greenness and accordingly defined the certification system (Fig. 9, Table 3).

4.5. Comparison among LEED, CASBEE, BREEAM, GBTool and SABA

The concept of developing a tool to evaluate the sustainability of buildings – how much the building meets green building principles and considered as environmental-friendly – is new and needs much work and efforts to be comprehensive and includes different types of Building. LEED, CASBEE, BREEAM, and GBTool; these four tools are the most green building rating systems valuable for the purpose of this research. They provide comprehensive criteria for their regions, provide a whole building evaluation rather than an evaluation of an individual design feature, use measurable systems to reveal how much the building incorporate sustainability principles, moreover they are the most known assessment tools around the world. SABA as well, is considered comprehensive assessment system for residential buildings that takes the whole building into consideration.

The Developed countries such as the United States, Japan and United Kingdom are more conscious about environmental issues and pollution problems; they achieved high progressing in environmental management through developing sustainable practices and assessment tools. While developing countries, on the other hand are unlikely to have achieved many aspects described for a state of sustainability. Addressing sustainable development objectives is therefore likely to be a priority in developing countries.

There are common concerns between these five green rating systems; such as emphasizing the consumption of energy in the building, water efficiency, environmental quality in both indoor and outdoor, resources and material, service quality, site strategies. At the same time each system focuses on certain aspects more than the other ones according to the country local context; for example,

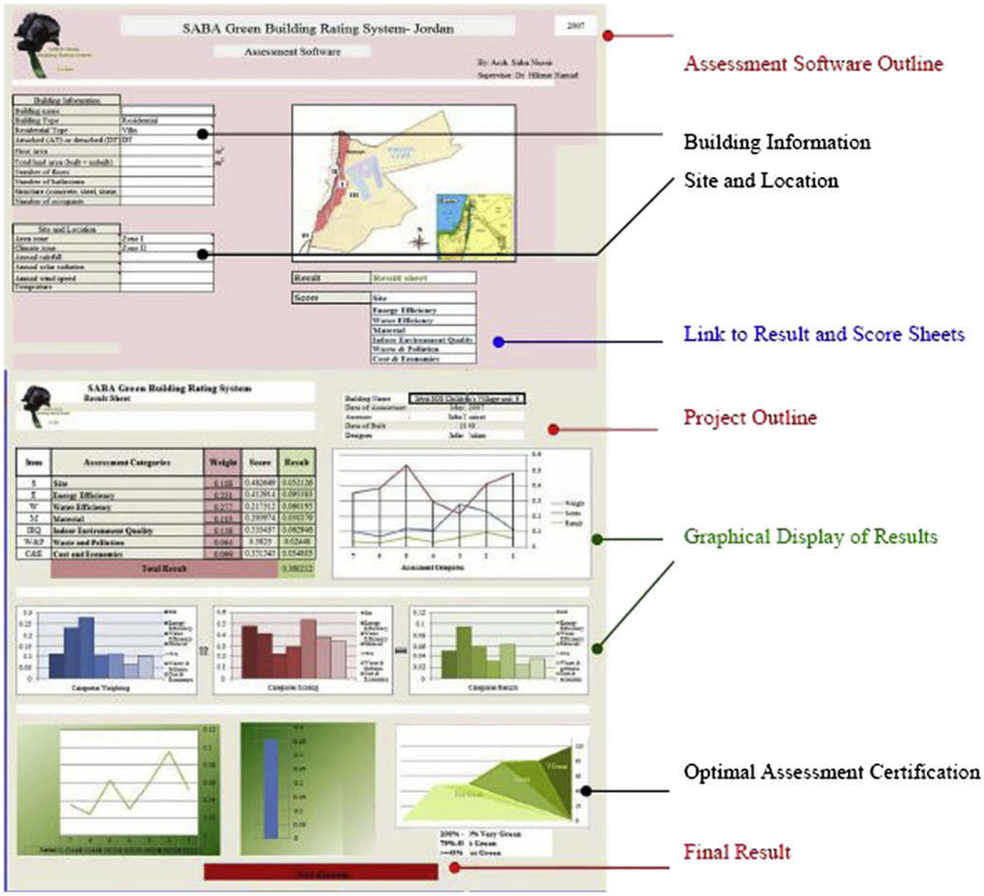

Fig. 7. SABA Green Building Rating System software – result sheet.

BREEAM considers transport and pollution as individual items in the assessment categories and gives them high credits; on the other hand LEED didn't give them this importance, and it included them within the major aspects of its assessment. Although in overall the five systems appreciate energy efficiency category highly; that it forms more than 20% of the total certification of each system, each system appreciates the assessment categories differently in respect to the local context of its country. For example SABA system

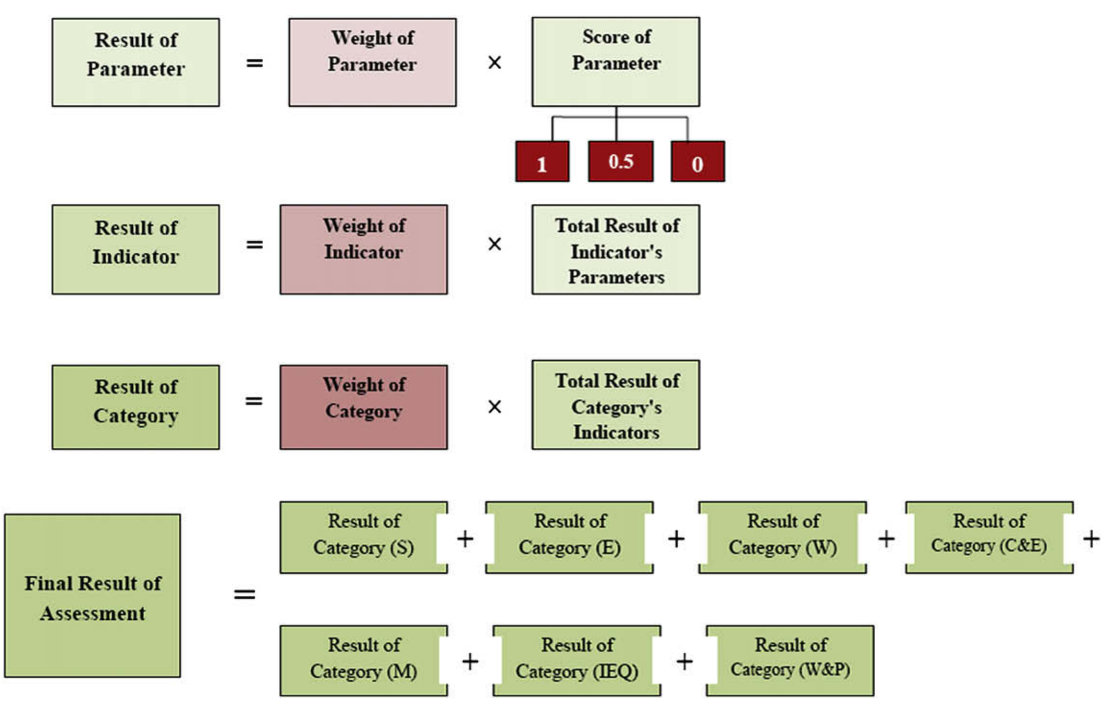

Fig. 8. Hierarchy of SABA assessment items and formulas of assessment items results.

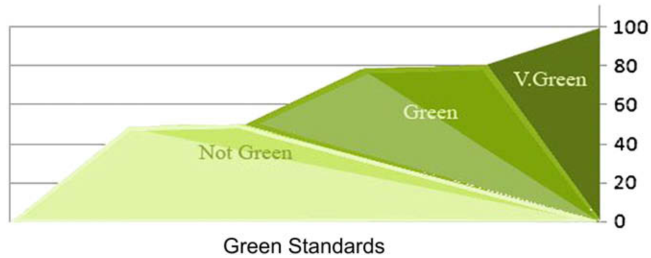

Fig. 9. Certification criteria levels of SABA Green Building Rating System.

appreciates water and energy efficiencies very highly – they weighs more than 50% of the total – as Jordan lacks water and natural resources, while the other systems don't appreciate it as well, they weight between 22 and 47 percent of the total.

The five tools use point system (numeric value) for evaluation how much the building is green, but each system has its own measurement comparison system. LEED used both checklist and benchmark comparison measurement based on accepted energy and environmental principles and strikes a balance between known effective practices and emerging concepts, according to LEED the rating system consists of the following six major categories and maximum points: sustainable sites (14), water efficiency (05), energy and atmosphere (17), materials and resources (13), indoor environmental quality (15), LEED innovation credits (05), and the total maximum possible points is 69; the certification level is based on the total number of points earned by the project, determined through a technical review process.

While CASBEE used benchmark measurement system and its scores are given based on the scoring criteria for each assessment item. These criteria applied to assessments are determined taking into consideration of the level of technical and social standards at the time of assessment. A five-level scoring system is used, and a score of level 3 indicates an "average". Weighting according to CASBEE means that each assessment item, such as Q-1, Q-2 and Q-3, is weighted so that all the weighting coefficients within the assessment category Q sum up to 1.0. The scores for each assessment item are multiplied by the weighting coefficient, and aggregated into SQ (Score for Q category); total scores for Q (Quality category) or LR (Loading category); total scores for LR respectively.

$$\mathrm{BEE} = \mathrm{Q/L} = 25 \times (\mathrm{SQ} - 1)/25 \times (5 - \mathrm{SLR})$$

$$\mathrm{SQ} = \text{Score for Q category}$$

$$\mathrm{SLR} = \text{Score for LR category}$$

BREEAM used checklist measuring and awarded its credits in each area according to performance – its checklist verifies compliance with minimum core of performance; design and operation requirements and environmental credits are granted. These set of environmental weightings then enable the credits to be added together to produce a single overall score. The building is then rated on a scale of Pass, Good, Very Good or Excellent, and a certificate awarded that can be used for promotional purposes. GBTool assessed criteria using scales that are based on local benchmarks; buildings can score between −1 and +5. All criteria must be scored, thus providing a complete assessment of the building.

Table 3
Minimum result required to achieve each grade level of SABA Green Building Rating System

Minimum result required to achieve each grade level (based on 100 full mark points)	
Very green	100–80
Green	50–79
Not green	<50

SABA on the other hand, used both checklist and benchmark such as LEED, but it is different from other systems. It has seven major categories that are in similar with some systems and different with others. The main categories are site (10.3), energy efficiency (23), water efficiency (27.7), material and resources (10.3), indoor environmental quality (11.8), waste and pollution (6.4), and economics (10). It is noticed that economics is not major factor in other system, while contribute 10 percent in Jordan. The certification system is also different in SABA tool comparing with other systems. The main categories on LEED are: sustainable sites (14), water efficiency (05), energy and atmosphere (17), materials and resources (13), indoor environmental quality (15), LEED innovation credits (05). CASBEE rating system consists of the following categories: energy efficiency, resource efficiency, local environment, indoor environment. BREEAM has the following categories: energy (21.42), transport (8.56), pollution (14.99), materials (14.98), water (10), health and well being (15.04), land use and ecology (15.01). Finally, GB Tool has the following categories with their weights: site selection, project planning and development (7.8), energy and resource consumption (25.9), environmental loadings (21.6), indoor environmental quality (15.5), service quality (5.2), cultural and perceptual aspects (21.6), social and economic aspects (2.6). Table 4 indicated the comparison among LEED, CASBEE, BREEAM, and GBTool in terms of SABA criteria assessment categories. Fig. 10 shows the performance sensitivity for LEED, GBTool, BREEAM, CASBEE in terms of SABA criteria.

The five tools provide programs involve the building life cycle process – pre-design, design and post-design (occupation). In general, the four tools are presented for existing as well new constructions for different types of buildings including new construction, renovations, and operation and maintenance – but SABA is limited to the residential buildings. Both SABA and GBTool don't include operation and maintenance of projects. In addition LEED works to develop a program for urban level according to the perception of the US market that is missing in other systems including SABA. However, LEED programs are considered the most fairly comprehensive in scope – from landscaping to renewable energy to recycling building materials.

5. Conclusions and recommendations

An assessment tool for green building is important. It is suggested that this approach can produce significant benefits that are

Table 4
Comparison among SABA GS, LEED, CASBEE, BREEAM, and GBTool in terms of SABA criteria assessment categories

Items of comparison	Green building rating system				
	SABA GS (%)	LEED (%)	CASBEE (%)	BREEAM (%)	GBTool (%)
Site selection	10.3	20	15	9 15	8 21
Energy efficiency	23	25	20	21	26 21
Water efficiency	27.7	7	2	10	–
Material and resources	10.3	19	13	15	–
Indoor environment quality	11.8	22	20	15	16
Waste and pollution	6.4	–	–	–	22
Economics	10	–	–	–	3
Others		7			

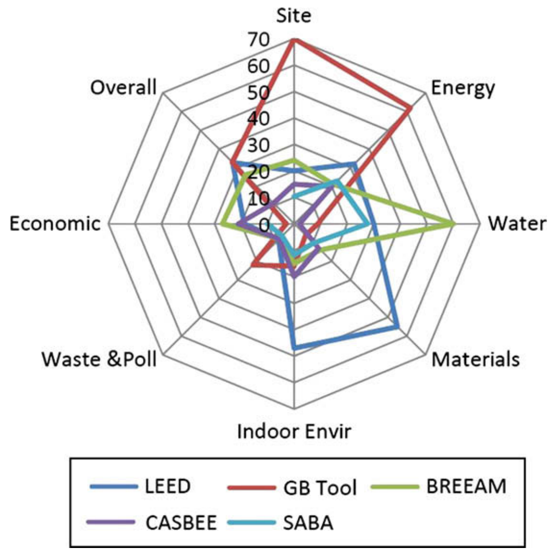

Fig. 10. Performance sensitivity for LEED, GBTool, BREEAM, CASBEE in terms of SABA criteria.

not likely to result from standard practices, as well as it can ensure maximum beneficial social and economic impact, rather than merely concentrating on the more conventional approach of minimizing environmental impact. If decisions that are made in concept and design stages of building process respond to sustainability objectives and targets, many of the negative outcomes can potentially be prevented, or at least, reduced. Such tool help assure the building can be more sustainable and adaptive, that it can be an intelligent building system.

By integrating criteria from different assessment methodological frameworks, this research builds on the strengths of each and provides a more holistic assessment approach among careful attention to local context. The outcome is a green building (residential type) assessment tool for Jordan called (SABA Green Building Rating System). It is recommended that this system is a powerful green building rating system for Jordan because it is based on scientific research and technical knowledge, participated multi-stakeholders' knowledge and experiences in collaborative process. In addition, the assessment framework suits the local context of Jordan; its culture, issues, resources, priorities, practices and institutions. As well as, this assessment system is validated regarding to sustainable goals and famous green assessment tools – LEED, CASBEE, BREEAM, and GBTool – in real building projects.

The assessment framework must consist of categories, indicators, and parameters. Categories can be defined the outer boundaries of the assessment system, indicators come on the second level and on the middle of the system, each indicator composed of several parameters that represent the core of the system. Categories are different from one region to another, and they depend mainly on the local context. In the proposed system (SABA) seven categories were addressed that included: site, energy efficiency, water efficiency, material and resources, indoor environmental quality, and economics. Each category consisted of several indicators, a total of 42 indicators were addressed in, and each indicator composed of several parameters with a total of 157 parameters. Selection of categories, indicators and parameters depended mainly on the ranking of the importance and relevance to the local situation.

Some other categories, indicators and parameters were suggested by some stakeholders, which had significant value on the weighting system (AHP system) and were considered in the system. These included indicators and parameters. Notwithstanding, some categories, indicators, and parameters were addressed, but they did not have a significant importance to be used in the system.

Although, there are similarities on the category level between developed and developing countries, there are differences in the weighting of each category. Yet, some indicators and parameters were added and others were omitted, depending on the local context of Jordan that were ranked according to their importance and represented through their weights. Because of the shortages of natural resources, water and energy efficiencies were considered as the crucial categories in the green construction practice in Jordan.

This research suggests a number of recommendations to develop green building assessment tool in general:

First, developing such assessment framework should be based on scientific research and technical knowledge.

Second, multi-stakeholders should participate in developing such approach, as it requires participating and collaborative process. Experts, designers, elected officials, working group, agency players, and others should be introduced as key participants in this process.

Third, sustainability strategies and goals should be addressed as a major aim.

Fourth; the assessment framework should suit the local context of the country; depending on its culture, issues, players, practices and institutions. It will be essential for each country to design its own indicators in its own way to serve its shared goals.

Fifth; countries can learn from each other's work and ideas and they should use the work of experts as inputs to their discussion.

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