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A review on green building assessment tools: rating, calculation and decision-making

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Abstract

Today, the consciousness of the world toward sustainable development derived from climatic changes caused by the frantic growth of the carbon emission rate has increased. Developed countries are finding themselves responsible in fighting to have a better and more sustainable future. They have established many sustainable development assessment tools, particularly in the field of construction. The Building Research Establishment (BRE) in the UK established the first environment assessment tool for buildings in 1990, and since then, many environmental assessment tools have been introduced to practice a better relationship between three major sustainable development key factors, namely, society, environment and economy. Based on these factors, many criteria have been proposed for different assessment tools. In this paper, we aim to make a review on three major tools embodied in every building sustainable assessment tools: rating tools, calculation tools and decision making tools. Almost every sustainable assessment tool practices these three aiding tools to generate more accurate and more realistic results.
Keywords: green building, rating tools, decision making tools, calculation tools, sustainable building.

1 Rating tools

The rating tool is a major part of the green building assessment process. It demonstrates the result of calculation and decision tools, it also includes many criteria in different categories which reflect priorities in various regions. In order to give priority to categories and criteria, decision making tools are needed, in order to understand which category is more important in a specific region or zone. Rating tools are adaptable and flexible, meaning that the criteria are able to be adjusted; changed or tailored depending on the conditions which the rating tool is being utilized for.

After determining the precedence over criteria, they receive points in order to change them into quantitative criteria which could be measurable. The relationship between rating tools and calculation tools are usually relevant to quantitative criteria such as carbon emissions, energy performance, water and resource consumption, etc. Some criteria like aesthetics, cultural aspects, and project management are qualitative criteria. However, quantity measurements are tried to be established but it still highly depends on expert judgment. Table 1 shows the main categories for different rating tools.

Rating tools are being practiced in different phases of a building's life cycle; for example Indoor Environment Quality in SBtool is determined on Design and Operation phases. However, other rating tools such as LEED determine this category without dividing any specific phase and examine the category in every possible phase.

Table 1: Nine different rating tools and their sub-categories.

Rating tool	SBtool	CASBEE	Green Star
Year	1995	2001	2002
Developer	iiSBE	JaGBC	GBCA
Country	International	Japan	Australia
Sub Categories	Site Characteristics Site Regeneration Energy and Resource Environmental Loadings Indoor Environmental Quality Service Quality Social/Cultural Aspects Cost and Economic	Q1 Indoor Environment Q2 Quality of Service Q3 Outdoor Environment LR1 Energy LR2 Resources and Materials LR3 Off-site Environment	Management Indoor Environmental Energy Transport Water Material Land use and Ecology Emissions Innovation

Table 1: Continued.

Rating tool	HQE	Green Globes	Green Mark
Year	1994	2000	2005
Developer	HQE	GBI	BCA
Country	France	Canada and the US	Singapore
Sub Categories	Environment Energy and Savings Comfort Health and Safety	Project Management Site Energy Water Material and Resource Emissions Indoor Environment	Energy Efficiency Water Efficiency Environmental Protection Indoor Environmental Quality Green Features and Innovation

Rating tool	LEED U.S	BREEAM	DGNB
Year	1998	1990	2007
Developer	USGBC	BRE	DGNB
Country	U.S	UK	Germany
Sub Categories	Location and Transportation Sustainable Sites Water Efficiency Energy and Atmosphere Materials and Resources Indoor Environmental Quality Regional Priority Innovation	Management Health and Wellbeing Energy Transport Water Materials Waste Land Use and ecology Pollution Innovation	Ecological Quality Economic Quality Quality of Planning Standard Quality Social Cultural Technical Quality

2 Calculation tools

In this section of the paper, it is intended to describe some of the most prominent calculation tools developed along with sustainable building assessment tools.

Rating systems are developed to assess the sustainability of a building in accordance with the economic, cultural and ecological environment they are being used in. Therefor rating systems may define sustainability differently and allocate diverse weight factors or scores to each category [1]. To explain more, as an example LEED's main assessment aim is to reduce annual expense on energy in a building while BREEAM aims to decrease carbon emission caused by energy consumption in a building [1]. Therefore, energy performance of a building seems to have considerable impact on the sustainability level [2].

Consequently, rating systems use different calculation tools to estimate the energy consumption of a building. For instance, Building Performance Simulation Tools (BPS) are computer-aided programs which assist better understanding of a building's energy consumption by simulating its performance regarding energy. In this matter, BREEAM has approved a number of software tools to simulate the energy performance of a building. Simplified Building Energy Model (SBEM), Front-End Interfaces to the Simplified Building Energy Model (FI-SBEM) and Dynamic Simulation Model (DSM) which includes other tools namely IES-VE, Tas and Hevacomp Simulator [1] are just some examples. LEED on the other hand, takes advantage of tools which comply with ASHRAE requirements. Commonly approved tools practiced in LEED are Energy Plus, DOE-2, IES-VE, Tas and EnerSim [1]. CASBEE introduces two concepts, Built environment Efficiency (BEE) and Life Cycle CO_2 ($LCCO_2$).

These two concepts are core concepts of CASBEE in evaluating a building and its built environment. BEE is derived from a concept introduced by the World Business Council on Sustainable Development (WBCSD) namely Eco-efficiency. It is defined as "maximizing economic value while minimizing environmental impact" [2]. BEE is a parameter resulting from an equation, where Q (Environmental Quality of Building) is the nominator and L (Environmental Load of Building) is the dominator. BEE aids better understanding of a building's environmental performance assessment result [3]. $LCCO_2$ considers the amount of CO_2 emission during a building's life cycle. From construction phase (materials, transportation, manufacturing, machinery, etc.) to operation and finally to maintenance, upgrade or demolition phase. Undoubtedly, the required calculation to determine the amount of CO_2 emission seems quite difficult.

Therefore, a couple of ways are introduced by CASBEE to gather rough CO_2 estimations based on LCA methods. Moreover, CASBEE has developed a simple spreadsheet assessment software for New Constructions in accordance with its assessment manual. A Green Building Index (GBI) is developed by Malaysian Institute of Architects (PAM) and Association Consulting Engineers Malaysia (ACEM) as Malaysia's first comprehensive rating system toward building sustainability [4].

Building Energy Intensity Tool (BEIT) is a computer based program developed by the (ACEM) that enhances easy Overall Thermal Transfer Value (OTTV) calculations and Roof Thermal Transfer Value (RTTV) calculations in accordance with the domestic climatic conditions of Malaysia. It is designed to support the Green Building Index rating system. BEIT compares two scenarios, one, the baseline building model which demonstrates the current conditions of the building as it is and two, the proposed building model that reveals the proposed conditions that the building would have after being retrofitted [5].

3 Decision-support tools

This section of the paper, introduces and compares Decision- Support (or Decision-making) Tools based on sustainability criteria. The following five Decision-Support tools have been designed and developed in the field of construction and infrastructure (see Table 2). Decisions are made based on tools which offer better support toward the approach taken for projects. Decision-Support tools are typically produced by engineering consultancies and occasionally by academia. These tools are developed to assist engineering consultants who are advising project clients. They are called Process tools, because they plan a process which maps onto the conventional project cycle and applies different tools to support more sustainable decision-making. They are flexible enough to be tailored to a range of projects. including advising a specific project phase (such as site selection), advising an entire project, or devising organizational practices and corporate social responsibility (see Fig. 1) [6]. These tools can provide decision-makers with relevant environmental, economic and /or social data.

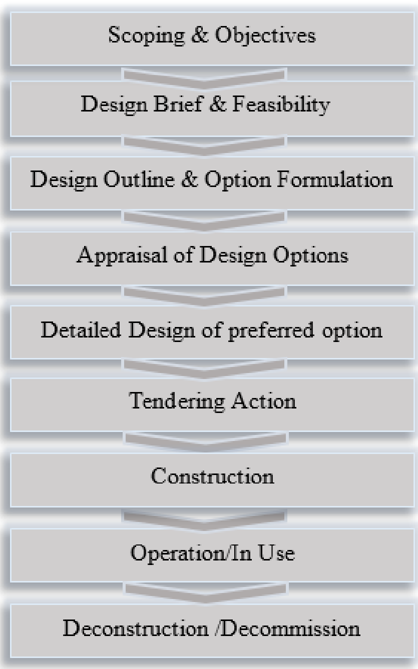


Figure 1: Stages of a project and decision-support tools.

The most common specification of these tools is an assessment framework that applies multi-criteria analysis methods to assess the sustainability performance of different design options during the assessment of the design options stage. These tools have been developed so that they can be applied to monitor and assess project performance and aid informed decision making throughout the project life cycle.

At the beginning of a project they might be used to carry out a baseline evaluation, analysis, or identify key performance indicators and to offer sustainability consulting services to clients and even to help project clients prepare for rating and certification.

In Table 3, as a comparative table of the criteria, sub-criteria, scoring and graphical outputs of these tools have been evaluated.

During the design stage these tools can be applied to compare and assess the pros and cons of various design options, to identify key risk areas, to guide decision making and stakeholder's participation, or to assess the implications of design changes. Decision making tools can also be applied to undertake evaluation on completion or during operation which can inform organizational learning and approaches to further projects.

A main feature of these tools is a set of sustainability criteria and indicators (sub-indicators), called the Sustainability Criteria Set, and serves different functions of the project's cycle. The graphical outputs can be in the form of a wheel, barometer or a color-coded table (see Table 3).

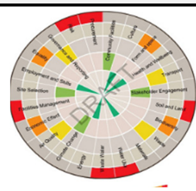
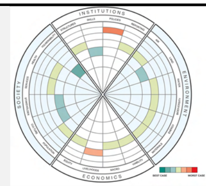
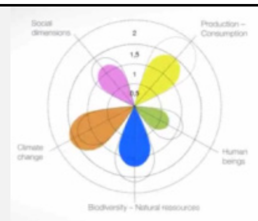
Table 2: Decision-support tools.

Tool	**Developer**	**Sector**	**Country**
SPEAR [7]	ARUP	All infrastructure	UK
ASPIRE [8]	ARUP	All infrastructure	UK
HalSTAR [9, 10]	Halcrow	All infrastructure	UK
Tandem Empreinte [11]	Egis	All infrastructure	France
Sustainability Matrice [12]	Max Fordham	Buildings	UK

4 Conclusion

Rating tools are the interface of green buildings. They included different categories and criteria. Criteria are quantitative and qualitative. They highly rely on expert's view and decision tools which affect weighting. Weighting of criteria shows the importance of them in various regions. In the field of calculation tools, there are a number of developers of which has produced some basic to sophisticated calculation applications. These applications vary from a simple spreadsheet to a sophisticated computer program. The primary aim in almost all of them is to evaluate a building's performance toward a specific criteria. Energy consumption is a crucial factor of concern in most calculation tools. Life cycle carbon emission ($LCCO_2$) and Built Environment Efficiency (BEE) developed by

Table 3: Comparison of decision-support tools.

Tools	Criteria	Rating scale and usage	Graphical outputs
SPeAR	Social Environmental Economic	between -1 and +3 world wide	
ASPIRE	Society Environment Economics Institutions	between +1 and +5 developing countries	
HalSTAR	Social Human Natural Financial Manufactured	between +1 and +10 world wide	
Tandem Empreinte (based on LOGBOOK)	Social/Society Environment Economic Governance	a rating scale must be set world wide	
Sustainability Matrices	Energy Criteria Wider Sustainability Parameters	four cases world wide	

CASBEE in form of a spreadsheet and BEIT developed by Green Building Index Malaysia in form of a computer based program are two famous calculation tools next to a variety of other calculation tools developed by other sustainable development front runners. Decision-Support tools help engineering consultancies and project stakeholders to select the most appropriate options in terms of sustainability and a comparison of these tools offer different methods for selecting the best approach in order to find specific requirements of each project. This selection can be based on major parts of sustainability and environmental and regional, cultural and economic in the world.

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