Energy and Buildings 104 (2015) 287–301

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Development of a systematic model for an assessment tool for sustainable buildings based on a structural framework

Hae Jin Kang*

SAMOO Architects and Engineers, Seoul 138-240, South Korea

ARTICLE INFO

Article history:
Received 4 March 2015
Received in revised form 4 July 2015
Accepted 6 July 2015
Available online 10 July 2015

Keywords:
Sustainable building
Assessment tool
Environmental impact assessment
Comparison analysis
A structural framework
Algorithms and data flows of systematic model

ABSTRACT

There has been much progress in recent years in the development of sustainable building assessment tools as a means to promote sustainable buildings. However, many assessment tools face issues with assessment methods and system frameworks, which greatly undermine their credibility and applicability. If these problems persist, the role of sustainable building assessment tools as decision making aids during the design stage will be greatly limited. The objective of this study is to suggest a systematic model for sustainable building assessment tools by establishing a logical performance assessment framework. For this purpose, analysis of performance assessment tools for sustainable buildings was conducted using the EIA framework. Based on the results of the analysis, a framework for the performance assessment of sustainable buildings was established. According to the structural framework, a sustainable building assessment model was developed.

1. Introduction

The international negotiations on climate change since the 13th conference of the Parties of UNFCCC in 2007 have aimed to derive a comprehensive framework to enhance action on climate change after the Kyoto Protocol has lapsed in 2012. However, many years' negotiations fell short of the expectation of delivering a meaningful climate treaty. The cause of this fall-out may be traced to the differentiation between sustainable development and climate change [1].

Sustainable development is a more established concept with a much larger scope compared to that of climate change. It is generally acknowledged that sustainable development can be achieved through balancing the three bottom lines (TBL); society, the environment and the economy [2]. At the heart of these climate change negotiation issues lies disconnection, and TBL hints at a meaningful approach to address the deadlock [3].

In the building sector, realization of sustainable building remains at a low rate, despite the increased need for it [4]. This low rate is thought to be due to the challenges of balancing the environmental and economic performances. There is a pervasive perception amongst investors that an increase in the initial investment cost of a building with improved environmental performance is a financial burden [5]. This financial burden can be addressed by a meaningful application of TBL. From the perspective of the building's life cycle, environmental preservation and the building's economic aspects are integrated when thinking of the building's operating period. This is because the operating period of the building is longer, resulting in larger operating costs. However, many architects and building owners have not been exposed to the realities of life-cycle energy cost (LCC), or its social implications [6]. One method to introduce LCC to architects and building owners at the early design stage is the development of decision supporting tools that quantify the life cycle cost, which clarifies the environmental load reduction in the early stages of the development [7].

There are many assessment tools to support decision making for building owners and designers. However, most do not solve the stakeholders' concerns with the increase of initial investment because those tools do not deal with financial aspects [8]. This means that unclear targets and definition of sustainable building, which can be made through balancing the three bottom lines (TBL) have been used in existing tools. It is therefore difficult to determine the direction in which sustainable building should progress. Additionally, many tools lack objectivity and accuracy [9]. These factors reduce the reliability of performance assessment results and prevent realization of sustainable building performance. In Korea, as there is increased recognition of the need for sustainable buildings, there has been movement towards developing a tool for supporting

* Tel.: +82 2 22845665/+82 2 2184 5974.
E-mail address: hjkang@samoo.com

http://dx.doi.org/10.1016/j.enbuild.2015.07.015
0378-7788/

Table 1
Categories of sustainable building.

Category	Sub-Categories
Environment	Reduction of environmental load from buildings
	Mitigation of climate change
	Diversity and protection of ecosystem
	Improvement of quality
	Depletion of resource
Economic	Cost-saving
	Direct cost-saving
	Indirect cost-saving
Social	Improvement of life quality
	Improvement of comfort
	Improvement of health
	Social inclusion & community safety
	Transparency
	Equity

decision making for sustainable buildings. However, if existing performance assessment tools are benchmarked without systematic analysis, the limitation of existing performance assessment tools will remain unchanged. Therefore, to develop new performance assessment tools, the limitations of existing tools should be systematically analyzed and a framework and model of performance assessment should be established based on the analysis.

This study analyzed the limitations of conventional performance assessment tools on the basis of reviewing the assessment framework used for EIAs (Environment Impact Assessments) and core elements of sustainable building assessment tools. Afterwards, the structural framework for assessment of sustainable building was established based on the outcome of the analysis. A systematic model for assessment of sustainable building tools was developed using the structural framework of established sustainable building assessment tools. Finally, case studies were conducted to verify the proposed tool.

2. Definition of sustainable building

Sustainable building is represented through the efforts made in the building sector for the sake of sustainable development. Therefore, the concepts of sustainable building and sustainable development overlap. Sustainable building is grounded on the three pillars of sustainable development; the environment (environmental load reduction), economic aspects (financial profit maximization), and social impacts (improvement of the quality of life, equity, and achievement of social welfare) [10].

There are several research groups that have been developing a definition of sustainable building based on the three pillars. The ISO instituted a technical committee, ISO/TC 59 'building construction' to publish technical specifications on sustainable building with a focus on the development of indicators for buildings and on the evaluation methods of environmental and economic efficiency [11]. The European Committee for Standardization (CEN) also established a Technical Committee, CEN/TC 350, 'sustainability of construction works' [12]. Additionally, OECD [13], BRE [14], AIA [15], US DOE [16], ASTM [17] and others have definitions of sustainable building. The definitions published by the organizations usually possess common sub-categories, but in the case of the 'social' concept, the definition had more variation between organizations. The definitions are summarized in Table 1 [18].

3. Comparative analysis of performance assessment tools

The purpose of this comparative analysis is to ascertain the core elements of which assessment tools consist, which will be used as the basic structure of a framework for assessment tools.

Table 2
Sustainable building performance assessment tools.

Rating tool	Life cycle assessment tool
BREEAM [20]	ATHENA [23]
	BEES4.0 [24]
CASBEE [21]	EcoEffect [25]
	Eco-Profile [26]
	Eco-Quantum [27]
LEED [22]	EQUER [28]
	ENVEST2 [29]
	GreenCal [30]

3.1. Sustainable architecture assessment

During the last two decades, many sustainable building assessment tools have been developed to assess, rate, and certify the energy and, more generally, the performance of sustainable building. Reijinders and van Roekel [19] divided many assessment tools into two categories: one is a rating tool based on the score and criteria; the other is a LCA (Life Cycle Assessment) tool based on quantitative input/output data by the flow of materials and energy.

The rating tool refers to criteria-based tools, which rely on the evaluation of several criteria, leading to the total score. Amongst the criteria-based tools, the most common are: BREEAM, LEED and CASBEE. The LCA tools, mainly devised in the research field, are based on LCA methodology. LCA views environments as systems of energy and material use and links environmental pollution and resource depletion caused by buildings with relevant inputs and outputs. ATHENA, BEES4.0, Eco-Quantum, EcoEffect and Envest2 are well-known LCA Tools.

3.2. Analysis framework

3.2.1. Selected tools

The rating and LCA tools selected for the analysis are shown in Table 2. These selected tools are well-recognized and have been used widely in many countries. As LCA tools require precise analysis of huge amounts of data, most of the assessment tools utilize computer programs.

3.2.2. EIA framework for analysis

The EIA(Environmental Impact Assessment) was first developed as a legal system (National Environmental Policy Act: NEPA, USA) for preventing environmental disasters in advance when the necessity for sound environment management and environmental sustainability had come to the fore. EIAs provide comprehensive information not only on the environmental effects of proposed developments but also on the economic and social effects [31]. During the last 30 years, it has also been found to be the case with EIAs that newly developed EIAs repeatedly encounter similar limitations to previous ones. To solve this problem, the structural assessment framework for EIAs was developed. This framework provides the direction and rules of development for EIAs to prevent copying of the limitations of previous tools [32].

In the building sector, the EIA structural assessment framework is used as an analytic method by Jönsson [33] in order to make an initial comparative analysis of building material assessment tools, and was also used by Forsberg [34] as criteria for analysing LCA assessment tools. In the latter study, the framework for EIAs is also used for comparative analysis of assessment tools. The framework for EIAs consists of: dimension of performance, nature of performance, scope of assessment (temporal modelling and spatial modelling), method of assessment (emphasis on procedure and emphasis on modelling), presentation of results, data aggregation, etc.