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A method for evaluating the performance of green buildings with a focus on user experience

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ABSTRACT

Since the early 1990s, various green building rating systems have been proposed and continuously elaborated through exhaustive studies. Most efforts in this area can be divided into two main parts; (i) development of green building rating systems through identifying relevant rating criteria; (ii) assessment of building rating systems for validity. Studies on the rating criteria for green buildings have mainly focused on the development of the items for evaluating buildings' energy performance. Studies on the assessment of building rating systems have emphasized the effectiveness of such systems. The existing studies in this area adopt mostly quantitative methods, so there is a lack of qualitative evaluation regarding users' interaction with green buildings. Our research aims to develop a method for evaluating green building performance, which includes user experience. In order to assess the proposed method, we conducted a case study, in which we used Korea's Green Building Certification Criteria (KGBCC) to evaluate the performance of a KGBC-certified green apartment. We have used a customized method, with a focus on user-oriented factors, to present the results.

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1. Introduction

In the era of climate change, many efforts to reduce greenhouse have been made. These efforts encompass issues such as energy efficiency, conservation of natural resources, carbon-free manufacturing, environmentally friendly materials and alternative energy resources. Research on environmentally friendly design and management systems has been conducted over the life cycle of buildings [1–3]. In this context, since the early 1990s, various green building rating systems have been proposed. These systems include: Great Britain's Building Research Establishment Environmental Assessment Method (BREEAM); the United States' Leadership in Energy and Environmental Design (LEED); Japan's Comprehensive Assessment System for Built Environment Efficiency (CASBEE); the European Union's Energy Performance of Buildings Directive (EPBD); Canada's Building Environmental Performance Assessment Criteria (BEPAC); Korea's Green Building Certification Criteria (KGBCC); and, in an international collaboration framework, the Green Building Tool (GBTool). These green building rating systems have been launched at different stages over the past twenty years. Different rating systems emphasize different aspects of building performance and, through exhaustive studies, have been continuously elaborated in both scope and detail [4,5].

Most research on green building rating systems can be divided into two main areas. One of these is identification of criteria for the development of rating systems. The other research area concerns assessment and validation of green building rating systems. Such studies mostly emphasize energy performance in buildings and generally adopt quantitative methods; if qualitative methods are used, these are limited. In particular, there is a lack of qualitative evaluation methods for exploring user experience of buildings. In order for a green building rating system to be widely recognized, it is critical that the system reflects understanding of end-users' needs [4,6]. Therefore, research on green building rating systems should deal with user experience, focusing on user needs and satisfaction.

The Post Occupancy Evaluation Method (POE) is a representative method of measuring users' satisfaction with buildings. The purpose of the POE is to improve future building design in future by finding desirable elements missing from current buildings. The POE examines users' expectations regarding specific aspects of a suitable living environment in numerous respects, including occupant health [7–11]. Most research based on POE has tried to propose alternative designs or design guidelines by evaluating current users' satisfaction levels. Researchers using POE have several visualization methods for analysis of data, but most of the visual information is not easily understood. A variety of methods are used in the fields of web and product design for visualizing website or product performance and user satisfaction. Research on

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green building performance could also benefit from a user-centered approach, focusing on user needs and satisfaction. Accordingly, recent studies on the user experience of web and product design could be used to modify the POE, thus offering a new system for evaluating user experience of green buildings.

The purpose of this research is to develop a new method for evaluating user experience of green buildings. It is expected that elements crucial to users' needs and satisfaction would be identified by evaluating the user experience, accordingly new green rating systems reflecting residents' experiences could be introduced as a improvement on current systems. For the user-centric approach, we reviewed previous research on user-concerned green building rating systems as well as building performance and POE. We also reviewed methods for evaluating users' experience of web and product design. From this review, we established a new user-centered green building rating system. In order to validate our proposed rating system, a case study was conducted in a KGBCC-certified apartment complex. This research forms a basis for exploring green building rating systems that emphasize user experience of buildings.

2. Related work

There are various methods for assessing the performance of buildings. Many of these methods emphasize the impact of buildings on the global environment and individual health, focusing on energy use, indoor climate and other environmental issues [12]. GBTool, BREEAM, and LEED tools representing building performance evaluation for sustainability, and provide authoritative sustainability ratings for dwellings. The LEED green building rating system is a national standard to assist development of high performance, sustainable buildings [13]. Since 2002, Korea has also been operating the KGBCC system to address global 'green' concerns [14].

There are three general, inter-related issues to be considered in understanding sustainable intelligent buildings:

- people (owners, occupants),
- products (materials, structure, equipment, controls, services),
- processes (maintenance, performance, management).

Through all the phases of their life span, environmentally friendly built environments should be associated with safety, security, wellbeing, convenience, reasonable cost and long term adaptability. Satisfaction of these criteria achieves an optimal combination of environmental, social and economic values for buildings [15–18]. Social, economic, environmental and technological dimensions are all important in evaluating building performance [19]. A wide range of criteria have been developed in order to assess building performance, however, there is a lack of consensus on what factors constitute excellence in this area. Recently, several quantitative and qualitative approaches have emerged for assessing sustainability of buildings [20–23].

A considerable amount of research effort has been applied to assessing intelligent building performance. Newsham et al. [24] and Scofield [25] identified shortcomings of LEED by comparing the energy performance of a LEED-certified building with Commercial Buildings Energy Consumption Survey (CBECS) data and then proposed ways in which LEED could be improved. Alwaer and Clements-Croome [26] developed a new model for measuring sustainability of intelligent buildings, using key performance indicators (KPIs). These KPIs were used to test stakeholder's perceptions of environmental, social, economic and technological factors in intelligent buildings. Wong and Li [27] derived a particular set of attributes of intelligent buildings by reviewing previous research. They adopted a multi-criteria analytic hierarchy process (AHP) as a new method to weight criteria in a survey. According to Wong and Li, 'work efficiency' is perceived as the most important criterion for intelligent building systems. In particular, 'reliability' and 'operating and maintenance costs' are the crucial factors in selecting intelligent building systems [27].

Many researchers have explored quantification of public perceptions regarding environmental issues. Attitudes to the natural environment exist within a spectrum of other psychological dimensions [28,29]. People's feelings about the natural environment are incorporated into wider cultural predispositions that include beliefs, intentions and characteristic behaviors. For this reason, it is difficult to directly measure attitudes to the natural environment [30]. As a result attitudes to the natural environment need to be inferred from indirect investigation, and various measurements have been proposed to assist with this [31]. However, the validity of such measures is doubtful [28,32].

3. Methods for evaluating user experience

End-users' characteristics are regarded as one the most important factors to be considered in the software and other product industries. Recently, the importance of user experience (UX) – as a combination of users' sensibilities, emotions and affections – has been much emphasized. Much systematic research has been carried out in the product, software and web design areas on methods of evaluating user experience. We expect that evaluation methods emphasizing UX will be adjusted and, in future, applied to the architectural design area. 'Usability' is a very important issue in UX. The International Organization for Standardization's guideline ISO 9241-11 [33] defines usability as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use'. The term 'effectiveness' means the accuracy and completeness with which users achieve specified goals, whereas 'efficiency' represents resource expenditure in relation to effectiveness.

Some researchers distinguish 'usability' from 'UX'. In general, usability is regarded as a user's ability to utilize resources for performing a given task successfully, while UX refers in a broad sense to such attributes as thoughts, feelings and cognition resulting from interaction with objects. Usability metrics in UX evaluation methods include three aspects of the interactions between users and objects: effectiveness, efficiency and satisfaction. The role of UX evaluation is to make product design user-responsive, so that products function effectively and efficiently. For evaluating UX questionnaires, the System Usability Scale (SUS) is often used. Lund [34] developed a customized UX radar chart, as shown in Table 1, for data evaluation. This radar chart is an effective multi-dimensional visualization of UX values. AttrakDiff [35] has proposed an effective 2D method for visualizing UX, also shown in Table 1.

4. A proposed method, emphasizing user experience, for evaluating the performance of green buildings

4.1. Green building evaluation factors and classification of indicators

Green building rating systems are methods for evaluating green buildings. Most of these systems classify evaluation factors and conduct a performance evaluation of the building for each factor. As mentioned above, usability metrics of UX evaluation methods in product and software design represent interactions between users and objects and measure attributes such as effectiveness, efficiency and user satisfaction. By adopting these three aspects of usability metrics, green building metrics can be extended to include factors related to usability, satisfaction and user interaction with buildings

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