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Impact evaluation of the indoor environmental performance of animate spaces in buildings

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ABSTRACT

Passive design has been widely identified as one of the most economical and effective strategies for sustainable building. The use of "animate" building space is one significant passive strategy in architectural design. It has two properties -organic and dynamic—and its type includes such as atriums, courtyards, wind towers, light wells, patios, sunspaces, etc. This study introduces a logical, scientific method of assessing building space performance. A multi-criteria approach was developed to validate and optimize the influence of animate spaces on sustainable buildings, with an emphasis on their influence on building environment quality and occupant satisfaction. Considering both the relationship between the building and people, and the building and the environment, and focusing primarily on of building design and building environment control, this research introduces an evaluation tool called SCTool. SCTool includes compasses that measure occupant satisfaction and indoor physical environment performance, and a Satisfaction—Comfort matrix that evaluates the fluctuating performances of animate spaces and the building's overall sustainable performance in building operating phase. This research chose atrium to represent one of typical animate spaces, and adopted a pair-group analysis method to isolate and analyze a single variable. Four typical atriums were chosen and divided into two categories: 3-direction atriums and high rise building atriums. Each test group of buildings included one green building and one conventional building. The results indicate the level of environmental performance of each object building, and highlight optimized possibilities for the atrium and the entire building in both the design and renovation phases.

1. Introduction

1.1. Research background

Sustainable development generally includes three factors: the environment, economics, and society. The environmental factor calls for organic, effective, comfortable, and safe designs. Its social benefits include directly improving people's quality of life, raising health levels, and improving a societal sense of wellbeing [1]. Buildings constructed to be in line with current sustainable design and green building research focus on addressing occupants' health, comfort, and overall satisfaction with the building [2]. Improving a building's sustainable performance in the operation phase and from an architectural design prototype perspective has widely been identified as one of the most economical and effective strategies for improving a building's environmental performance and reducing energy demand [3–6]. The literature indicates that passive strategies can reduce more than 50% of the primary energy source's consumption [7], as well as better fulfill occupants' requirements for advancing the building's utilization efficiency. Strategies such as building orientation, layout, utilization of the surrounding environment, space function, space form, materials, construction details of the building envelop, and natural resource utilization such as solar heat, light, wind, and water can all help designers avoid many possible discomfort-causing and high energy consumption factors [8–10]. As a result, a building's prototype basically determines the "sustainable" level of the building.

Researchers have accumulated certain useful knowledge on

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post-occupied building environment study and testing. For example, for the past several years the Center for the Built Environment (CBE) at the University of California, Berkeley has been developing a web-based survey system for post-occupancy evaluation (POE) studies, and has surveyed occupants' satisfaction with the indoor environments of LEED-certified buildings [11–13]. Based on Fanger's PMV thermal comfort model, they also have developed a Thermal Comfort Tool [14]. The British Council for Offices (BCO) has stated that a POE can provide helpful feedback regarding how successful a workplace is in supporting the occupying organization and individual end-user requirements [15]. Based on a number of comparison studies of occupants' overall comfort questionnaire surveys and actual indoor environments' measured values, researchers at Tsinghua University have calculated the respective weights of four factors that determine indoor environment quality: thermal condition, lighting, acoustics, and the indoor air quality environment [16,17].

1.2. Animate space

1.2.1. Character

Philologically, the word “animate” has two kinds of meanings. The first is to live, indicating that biological life can survive and grow; it is an antonym for the verb “die”. The second meaning is to be vivid, indicating that anon-biological entity has a dynamic flexibility and responds characters; it is an antonym for the adjective “stationary” [18].

Correspondingly, there are two possible meanings for the word “animate” with regards to a building:

The first corresponds to a living status that is embodied in an organic view of architectural design. “Organic” refers to a harmonious, dialectical relationship between the whole and a part; it also refers to natural processes such as life, death, and growth. The modernist architect Frank Lloyd Wright argued in his “organic architecture theory” that buildings should be like nature. One of the basic harmonious elements of nature is the ground; what belongs to nature grows from the ground [19]. Wright believed in the integrality of a structure's character to each part of its form and substance. Therefore, every living object is organic. Conversely, anything inorganic or unorganized is not alive [20]. The British architectural theorist David Pearson presented his idea of a “living organic architecture” in his book *New Organic Architecture: The Breaking Wave* [21]. Portuguese architect Vitor Ruivo Forte wrote that “in order for space to be transformed into a living vibrating body or sustainable edifice it must be given expression through rhythm, force, and dynamism, and it must be gifted with light which will then constitute its soul” [22].

The second element corresponds to the vivid behavior that embodies the dynamic adjustment mechanisms of buildings. The dynamic adjustment capacity of a building can be categorized as one of three types. The first is related to the dynamic balance struck between climate change and the built environment. This dynamic adjustment can adapt to climate change, which is in response to “stress” as a kind of living organism. This kind of “responded building” is the essence of change as climate change [23]. The second category references the dynamic adjustment of users' habits, such as changes to the interface status to form a better level of indoor environment comfort, or changes to space form, volume, or function to adjust a space's adaptability to the occupants' requirements [24]. The third category addresses dynamic function adjustments that correspond to the entire building's lifecycle. Because changes to the building's adjustments are part of a predesign procedure, it is necessary to comprehensively consider various possible factors from both the short-term and long-term points of view [25].

1.2.2. Boundary

A typical animate space is endowed with two kinds of features: organic organization and dynamic compounds. This kind of space includes multiple attributes, such as applicable value, ornamental value, and ecological value [26]. Its organic character is embodied in the organic connection between the space and the overall architecture, vitality of natural growth, and harmonious organic symbiosis with the natural environment. Its dynamic character is embodied in its dynamic adaptability to the climate, dynamic changes corresponding to the users' habits, and dynamic functions that adjust its abilities throughout the building's entire lifecycle.

According to form and location attributes, an animate space can be classified into one of four categories, including outdoor open “courtyard space”, closed and semi-closed “atrium space”, closed and semi-closed “well space”, and semi-open “interface space” (as shown in Table 1).

1.3. Objective of this study

This research focuses on the influence of animate space validation and its optimization design, and pursues three goals:(1) emphasizing both the necessity of monitoring a building's physical environment and collecting responses regarding occupants' subjective feelings, to comprehensively optimize animate space design for efficiency and from the perspective of sustainable architectural design prototypes [27]; (2) developing methods to parameterize investigate an objective physical environment and subjective occupant satisfaction in animate spaces and overall buildings; and (3) evaluating animate space efficiency and existing significance to further the greater goal of enhancing the sustainable value of urban building design.

2. Methodology

Evaluations and feedback regarding the study of the effects of animate space not only affect the design quality of the building space and the interior layout (both in the scope of the architecture and the environmental psychology, such as when evaluating if a building space might meet the occupants' material and psychological requirements and bring them pleasure and satisfaction), but they also relate to the requirements that the building space facilitate health, provide a comfortable environment for living and working, and reach the goal of energy savings in the construction and operating phases. As a result this research, on the one hand, is based on an architectural aspect in order to evaluate the effectiveness of animate space according to the method of occupancy subject satisfaction voting. On the other hand, this research is based on a building environment science aspect, through objective physical environment performance testing of building spaces, integrating both subjective and objective factors. This research endeavors to uncover the corresponding relationships among objective physical environments, occupants' subjective judgments, and building space information. Because this is a correlation evaluation among various systems, we have adopted a multi-criteria analysis method.

There are two problems that need to be solved when setting up a multi-criteria analysis evaluation index. The first is the index of dimensionless processing, and the second is determining a comprehensive weighting contexture [28]. The evaluation is a combination of subjective and objective processes, and is a foundation for decision making [29].

2.1. Field survey

This research is based on actual tests of the building's practical