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## Creating sustainable building through exploiting human comfort

Geun Young Yun<sup>a</sup>, Jeong Tai Kim<sup>a,\*</sup>

<sup>a</sup>*Department of Architectural Engineering, Kyung Hee University, Yongin 446-701, Korea*

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### Abstract

As Abbe Laugier elaborated in his book “Essay on Architecture”, architecture was founded on simple nature to protect occupants from harsh external environments, and thus providing comfortable indoor is one of the fundamental roles of buildings. Also, comfort along with building energy use for the provision of comfort is a key consideration for sustainable buildings. Traditional comfort theories based on experimental research imply that improving comfort levels would result in increasing energy consumption in buildings. This paper argues that new comfort theory can greatly contribute to reduction in building energy use, while satisfying occupant comfort in buildings. This paper illustrates how new comfort model based on the adaptive principle was developed from a series of field studies, and proves that the application of adaptive comfort model to the operation of buildings can lead to energy savings. This paper concludes with design considerations for sustainable buildings in order to realize energy saving potentials of the adaptive model in practice.

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### 1. Introduction

Vitruvius elaborated environmental principles in architecture and explained how buildings can be designed in a way that improves internal comfort using natural adjacent environments in his seminal book, the ten books on architecture [1]. Abbe Laugier searched for absolute beauty of architecture in his book “Essay on architecture” [2].

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\* Corresponding author. Tel.: +82-31-201-2539 ; fax:+82-31-206-2109  
*E-mail address:* jtkim@khu.ac.kr

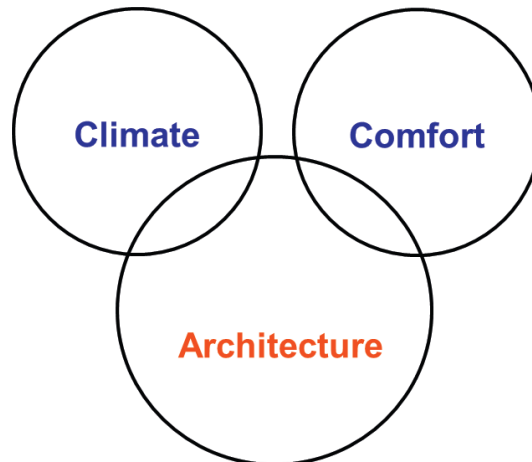


Fig. 1. Vitruvian model of environment in architecture [adapted from Ref. 3]

He found the primitive hut represents the first architectural idea as the shelter was rooted in functional basis and provided shelter from harsh nature. This confirms the importance of provision of comfort in buildings.

Creating comfortable environments has been a key consideration for architects. According to Dean Hawkes [3], architecture before the industrial revolution was designed to mediate local climate and internal environments which human activity can effectively be conducted [Fig. 1.]. After the industrial revolution, mechanical systems that use energy were widely used in architecture to provide comfortable environment, thus the environmental controls and the provision of energy play a critical role in the design of buildings [4].

Energy and comfort issues are important elements in sustainable buildings as well. The most popular rating system for sustainable buildings, Leadership in Energy and Environmental Design (LEED) is organized into five categories of sustainable sites, water efficiency, energy & atmosphere, materials & resources, indoor environmental quality, and innovation in design. The categories related to energy use and internal comfort account for about half of the total score [5].

There has been active research on the relationship between energy use and comfort in buildings. A general consensus seems that improving internal comfort would increase energy consumption in buildings [6,7], although Koen and Manchanda [8] show that there is little relationship between energy use and the level of comfort in buildings.

This paper argues that new comfort theory can greatly contribute to reduction in building energy use, while satisfying occupant comfort in buildings. This paper illustrates how new comfort model based on the adaptive principle was developed from a series of field studies, and proves that the application of adaptive comfort model to the operation of buildings can lead to energy savings. This paper concludes with design considerations for sustainable buildings in order to realize energy saving potentials of the adaptive model in practice.

## 2. New approach to human comfort

Traditional thermal comfort theory is based on the heat balance model proposed by Fanger [9]. According to the heat balance model the condition of thermal comfort is met when the heat generation from a human body is equal to heat loss to surrounding environments. Thus, thermal comfort conditions are dependent only physical factors such as air temperature, humidity, air speed, mean radiant temperature, insulation level of clothing, and activity levels. However, the reliability of heat balance model to predict thermal comfort based only on physical factors is questionable, as thermal comfort by definition refers to “condition of mind which expresses satisfaction with thermal environment [10]”.

Previous research indicates that predicted results from the heat balance model of thermal comfort showed a large difference from actual thermal sensation of occupants [11]. One of the reasons for this discrepancy between predicted and actual thermal comfort is that the heat balance model is based on climate chamber studies, which do



Fig. 2. Investigated building and monitoring equipment Equations

not necessary reflect real conditions. On the other hand, adaptive comfort theory is on the basis of field studies that investigate thermal sensation of building occupants in every-day thermal environments. Therefore, the adaptive comfort model could compensate the traditional heat balance model of thermal comfort.

A field study [12] has been conducted to derive adaptive comfort model in offices from monitoring internal and external climatic conditions and occupants' perception and responses to indoor thermal environment [Fig. 2.]. Sixty occupants participated in the questionnaire survey to reveal the subjective evaluation of the indoor thermal environments. Occupants filled in the questionnaire form five times a day.

Results indicate that there is a clear relationship between comfort temperature and external conditions. As the outdoor temperatures increase, so does indoor comfort temperature [Fig. 3. and Fig. 4.]. This is a clear evidence of occupants' adaptation to changing environments. The adaptive comfort model, which is obtained from statistical analysis of the monitoring data is given in equation 1.

$$T_{cn} = 0.113 \times T_{rmn} + 23.323 \quad (1)$$

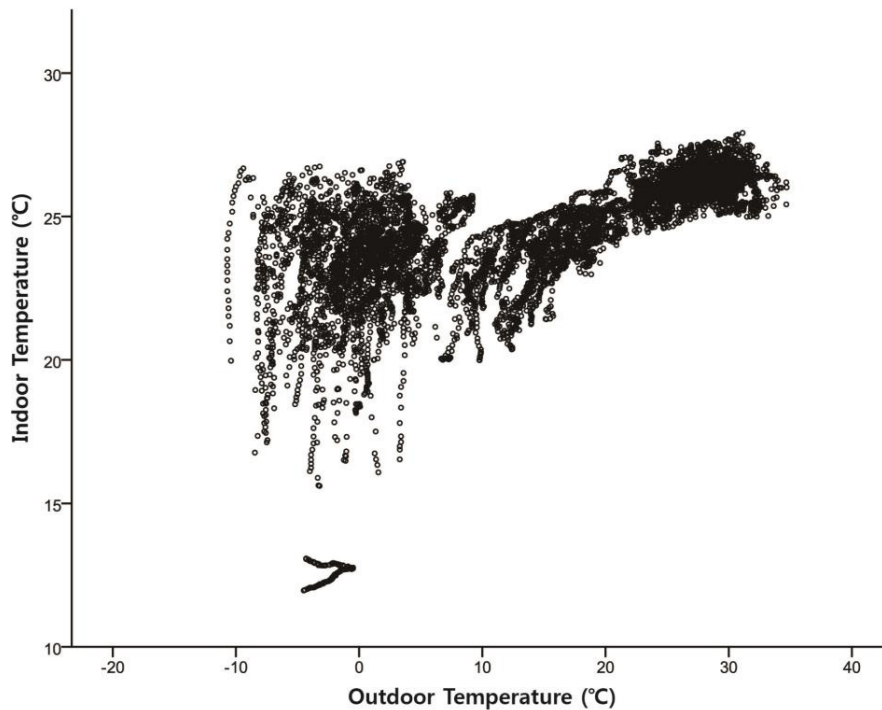


Fig. 3. Outdoor and Indoor temperatures

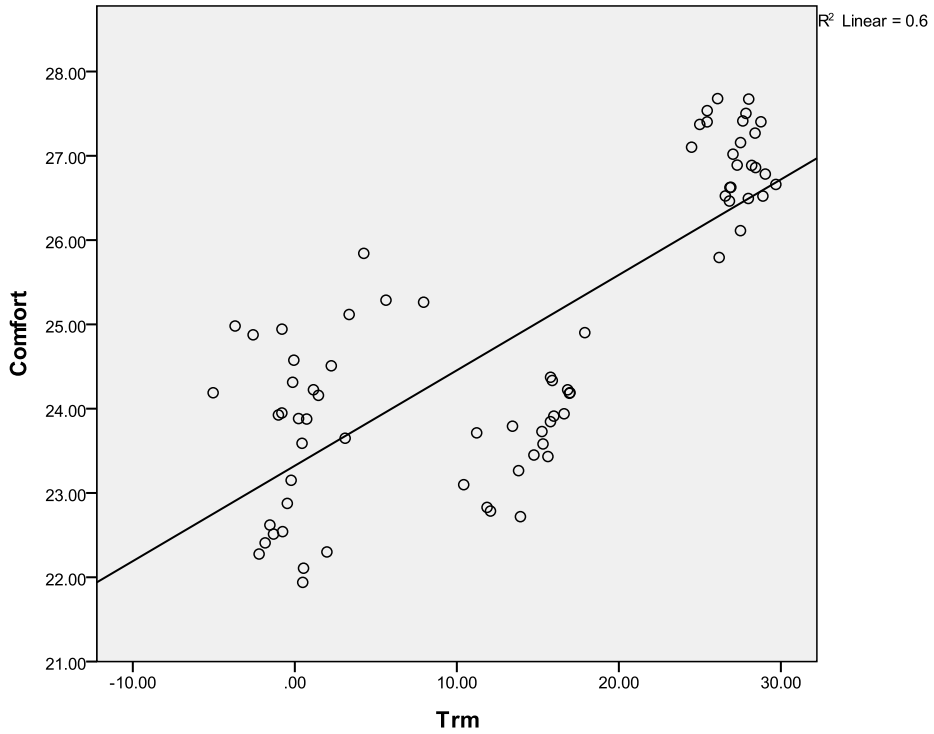


Fig. 4. Running mean temperatures and confort temperatures

### 3. Energy saving through the application of adaptive comfort models

In order to examine the energy saving potentials of a newly developed adaptive comfort model, energy simulation of the office buildings has been conducted using EnergyPlus.[ Fig. 5.] compares annual cooling energy consumption of the identical building but with different set point temperatures. A simulation indicates that the application of the adaptive comfort model has a high potential for reducing cooling energy use and shows that cooling energy use can be reduced by 34%, compared to a condition when a room temperature is maintained at 22 °C.

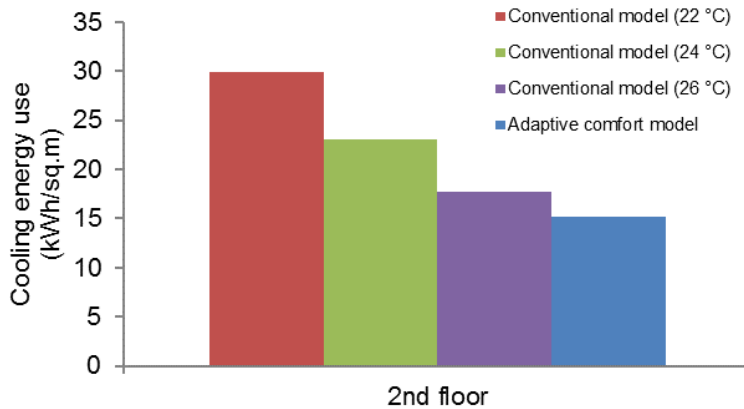


Fig. 5. Comparison of cooling energy consumption between conventional and adaptive confort models

#### 4. Increasing comfort levels through building design

Occupant surveys from 177 UK buildings indicate that green building are perceived as better by their occupants and green building occupants tend to be more tolerant of green building [13]. Thus, the level of thermal comfort perceived by green building occupants is higher thermal perception by conventional buildings. This implies that creating buildings sustainable is beneficial for improving their energy efficiency by enhancing thermal comfort.

Baker and Steemers [14] explore the roles of occupant controls in the environmental performance of buildings. It has been shown that provision of personal or local controls over the internal environment can extend the range of comfort. Thus, buildings should be designed in a way that provides building users with good adaptive opportunity, which refers to the scope for adaptive interventions to environmental conditions.

#### 5. Conclusions

This study shows that comfort and energy are critical factors of the design of sustainable buildings and there is a close relationship between user comfort and energy use in buildings. However, traditional comfort theories imply that improving comfort levels would result in increasing energy consumption in buildings.

This paper explores how new adaptive comfort model can contribute to reduction in building energy use, while satisfying occupant comfort in buildings, and illustrates how new comfort model based on the adaptive principle was developed from a series of field studies. The paper provides the evidence that the application of adaptive comfort model to the operation of buildings can lead to energy savings. This paper concludes with design considerations for sustainable buildings in order to realize energy saving potentials of the adaptive model in practice.

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