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Quantitative description and simulation of human behavior in residential buildings

Chen Peng, Da Yan (✉), Ruhong Wu, Chuang Wang, Xin Zhou, Yi Jiang

Department of Building Science, School of Architecture, Tsinghua University, Beijing 100084, China

Abstract

An in-depth understanding of building energy use requires a thorough understanding of human behavior. This research gives a quantitative description of human behavior in residential buildings. This quantitative description method can be used to forecast the impact of the human behavior on the indoor building environment and energy use. Human behavior influences the energy use directly and indirectly by changing window openings, air-conditioner usage, lighting, etc. This quantitative description method describes these behavioral effects. Behavior can be divided into several types according to the usage with time related, environmentally related and random modes used to quantitatively describe the behavior. The method is then applied to describe a Beijing household with comparison to on-site observations of the resident's behavior and measurements of energy use to validate the method. The results show that the human behavior in the real world can be quantified by the quantitative description method. These simulation tools can greatly facilitate building energy conservation by describing the influence of human behavior on building performance and energy use.

Keywords

human behavior,
behavioral object,
energy use,
lifestyle model,
time related,
environmentally related,
random

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1 Introduction

Human behavior greatly influences building energy use by the way people move, use equipment, open or close windows, building system (e.g., air-conditioning systems and lighting systems) control by the property management personnel and automatic controls. These actions directly and indirectly affect energy use (e.g., electricity, gas, and water). Li et al. (2006) reported that there are significant differences in energy use among different apartments in the same residential building in Beijing. The human behavior such as air-conditioning operating times, temperature set points, and window opening/closing habits are quite different with these behavioral differences causing large differences in the electricity use by cooling systems in the same residential building, from 0 to 14.3 kWh/m^2 with average of 2.3 kWh/m^2.

Scientists began studying the relationship between human behavior and energy use around 1980s. Sociological models of human behavior were developed, showing that the social-cultural environment, the building and design requirements and the local climate affected both household lifestyles and energy use. Technical progress and social change also influence human behavior (van Raaij and Verhallen 1983; Hitchcock 1993). Further research established that usage times of some appliances, such as washing machines and bathroom heaters, change with the seasons. The average number of household members, their age, and their time spent at home are all factors closely related to energy use in residential buildings (Ouyang et al. 2007). An IEEA study showed that the average operating time of appliances in Europe varied in different countries, which is useful for energy use calculations, but does not describe the human behavior influence on energy use (IEEA 2008). There have also been studies of the interactions between human behavior and building energy use (Mahdavi 2007). The influence of human behavior on building energy use is now a hot issue at the Annex 53(2010).

As computer simulations have improved, these tools are being used more to analyze human behavior. Recent research (Hoes et al. 2009) has shown that human behavior

E-mail: yanda@tsinghua.edu.cn