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Sustainable Building Design Based on the Second Order Probability Approach

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Abstract

Sustainable building design needs to consider uncertainty due to various sources, including weather condition, design uncertainty, and inherent random parameters, in order to maintain high performance. These different types of uncertainty requires more advanced computational methods. Therefore, this paper implements a second order probability approach to take into account two types of uncertainty: aleatory (inherent randomness) and epistemic (incomplete information). A retail building located in Tianjin (China) is used to demonstrate the application of this second order probability approach. The results indicate that this second order probability can deal with these two types of uncertainty in sustainable building design. This method can also provide insight on the dominance of design uncertainty or inherent aleatory uncertainty. Moreover, the variable importance method based on a locally weighted regression model is applied to determine the key variables influencing both aleatory and epistemic uncertainty of energy use for this retail building.

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Keywords: Uncertainty analysis; Green design; Second order probability; Aleatory uncertainty; Epistemic uncertainty

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1. Introduction

Green buildings are influenced by a number of factors, including weather conditions, building envelope, internal heat gains, and HVAC systems. Among these factors, most of them cannot be treated as constants in the life cycle of buildings [1]. For instance, thermal properties of building envelope would vary as a function of building age, ambient temperature, humidity, and construction quality. Hence, it is necessary to implement uncertainty analysis for sustainable buildings by considering the variations of these factors in order to design robust green buildings.

A number of studies have been conducted to estimate building energy performance using uncertainty analysis. Tian and de Wilde [2] applied the Monte Carlo simulation to assess thermal performance of UK domestic buildings by taking into account probabilistic climate change projections. Evins et al. [3] analyzed variation of energy use between domestic buildings due to two type of factors: behavioral variables (stochastic characteristics of occupancy) and physical variations (building size, infiltration rate, and insulation levels). Tian et al. [4] carried out simulation using EnergyPlus program to compare energy use because of various built forms in Harbin, China. Kavgic et al. [5] quantified uncertainty in Belgrade's housing stock in order to determine the optimum energy saving strategies. Kim et al. [6] explored the decision making for HVAC systems by using Markov chain Monte Carlo method, instead of traditional deterministic approaches. The uncertainty of parameters influencing building thermal performance can be categorized into three types: design parameters, inherent uncertainty parameters, and scenario parameters [7]. However, the main limitation of these previous studies is that only one type of uncertainty is considered in assessing building energy performance.

Therefore, the aim of this paper is to implement a second order probability approach by considering both design and inherent uncertainty to provide robust analysis for green building design. A retail building located in Tianjin (China) is used as case study to demonstrate the application of the second order probability. The design uncertainty is also referred as epistemic uncertainty and the inherent uncertainty is also called aleatory uncertainty in second order probability analysis for this case study. Annual heating, cooling, and electricity use are used as energy performance indicators in this study to investigate how the variations of input factors affect thermal performance in the retail building.

2. Methods

This section will firstly describe the construction of building energy models. Then the second-order probability method will be presented in detail. The next section will discuss the variable importance approach to explain the results from the second order probability.

2.1. Building energy models

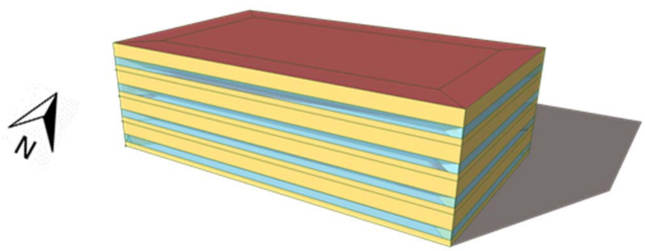

Fig. 1. A retail building used in this research.

Figure 1 illustrates a retail building used in this paper. This is a four-story rectangular building with the total floor area 1500m^2. The thermal parameters for this buildings are derived from the design standard for energy efficiency of Chinese buildings released in 2005 [8] and 2015 [9]. The typical hourly schedules for occupant, lighting and