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Comparison of Sensitivity Analysis Methods in Building Energy Assessment

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Abstract

Sensitivity analysis is an important tool in building energy assessment to determine the key factors influencing energy use or carbon emissions for buildings. This research is focused on comparing the characteristics of four global sensitivity analysis: SRC (standardized regression coefficient), Morris design, extended FAST (Fourier Amplitude Sensitivity Test) and TGP (treed Gaussian process) method. A retail building located at Harbin (China) is used as a case study to demonstrate the advantages and drawbacks for these four methods. The results indicate that the TGP method (one of meta-modelling approaches) is the best choice in terms of both accuracy and computationally cost. Note that the TGP method needs more time to calculate the sensitivity index although it needs only moderate time for running building energy models. At least two fundamentally different methods for sensitivity analysis are recommended to be performed to provide more robust results in building energy assessment.

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*Keywords:*Sensitivity analysis; Building performance; Global method; Energy simulation

1. Introduction

Sensitivity analysis has been widely used in building energy analysis because it can not only provide prioritization of energy saving measures, but also explore the patterns of energy use for model calibration and energy optimization [1-4]. The sensitivity methods used in the field of building performance analysis can be categorized into local and global sensitivity analysis approaches [2].

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More and more research has gradually implemented global methods because they can explore more thoroughly the relationship among inputs and outputs in the whole input space in order to provide more reliable energy saving measures. In contrast, the local sensitivity analysis can only study the relationship around the data points used in the analysis without considering the interactions among inputs [5]. The global sensitivity analysis can be further divided into four methods: regression-based, Morris design, variance-based, and meta-modelling [2]. Tian and Choudhary [6] used SRC (standardized regression coefficient) method to determine the key factors affecting energy use for London school buildings. Heo et al. [3] applied Morris design method to summarize the ranking of energy use intensity for office buildings located in the business district of Chicago. Spitz et al. [7] used the variance-based Sobol approach with 6669 simulation runs to determine the most influential parameters for an experimental house in France. Song et al. [8] implemented treed-based Bayesian Gaussian model (one of meta-modelling sensitivity analysis methods) for assessing the patterns of energy use of an office building located in London. However, there is lack of comparative study to demonstrate the advantages and disadvantages of various global sensitivity approaches in assessing building thermal performance.

Therefore, the aim of this study is to compare the suitability of four global sensitivity analysis methods (regression-based, Morris, variance-based, and meta-modelling) in assessing building energy performance. A retail building located in Harbin (China) is used as a case study for this purpose. More detailed information for the building used in this study will be described in the next section “Energy models”.

2. Energy models

A retail building considered in this study are assumed to be constructed after 2005. Hence, these buildings have construction standards commensurate with good practices based on the design standard for energy efficiency of public buildings in China [9]. The main parameters and detailed schedules are obtained from this energy efficiency standard [9].

Table 1.Variations of input parameters for sensitivity analysis of energy use in buildings

Variables	Short names	Range
Aspect ratio	X1	1,2,3,4 (building length/width)
Window-wall ratio	X2	0.2-0.8
Number of floor	X3	1-12
Orientation	X4	0~360o (0 denotes north)
Overall scale	X5	1000~5000 m^2 (main floor area)
Wall U-value	X6	0.1-0.5 W/m^{2}K
Roof U-value	X7	0.1-0.4 W/m^{2}K
Window U-value	X8	1.0-3.0 W/m^{2}K
Solar heat gain coefficient	X9	0.3-0.7
Lighting peak density	X10	12-19 W/m^2
Equipment peak density	X11	11-15 W/m^2

Table 1 shows the variations of input factors for sensitivity analysis in which the aspect ratio (X1) and number of floor (X3) are discrete variables and the remaining variables are continuous variables. The hourly schedules for all the internal heat gains (including occupants, lighting and equipment) are derived from the same standard [9]. A fan-coil system is used to provide heating, cooling, and ventilation. An electric screw chiller provides cooling and a gas-fried boiler provides hot water to maintain indoor thermal comfort. The operating time for this fan-coil system is from 8:00 to 21:00 [9]. The heating and cooling set-point temperatures are 18^{o}C and 25^{o}C, respectively [9]. The three output performance indicators are annual heating energy, cooling energy, and electricity per floor area (unit: kWh/m2). The buildings are located at Harbin in China [9]. The annual 99.6% dry bulb temperature for designing heating systems is -28.4^{o}C, while the 0.4% cooling dry bulb temperature is 31.1^{o}C [10].