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QUANTIFYING UNCERTAINTY IN SENSITIVITY ANALYSIS OF BUILDING ENERGY SIMULATION MODEL

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ABSTRACT

Sensitivity analysis is important in rational decision making because it can identify meaningful design variables for energy-efficient design of new buildings or energy retrofit of existing buildings. However, it is often overlooked that sensitivity analysis itself is also influenced by uncertain parameters such as occupant behavior, infiltration, varying setpoint temperatures for cooling and heating, etc. With this in mind, this study investigates the degree of uncertainty in sensitivity analysis for a given office building. For energy analysis, EnergyPlus, a dynamic building energy simulation tool, developed by US DOE was employed. For uncertainty and sensitivity analyses, Latin Hypercube Sampling and Sobol were used. It is found that uncertainty in sensitivity analysis is significant and careful attention must be paid to selection of uncertain environmental factors, and corresponding engineering assumptions.

1 INTRODUCTION

Sensitivity analysis can play an important role to quantify the impact of architectural design variables on the building energy use. However, the aforementioned sensitivity analysis is strongly influenced by the five indoor environmental factors (e.g., occupancy density, equipment density, infiltration rate, heating/cooling setpoint temperature) that can't be quantified at the design stage, leading to *uncertainty in sensitivity*. In this regard, the authors aims to present a case study with regard to quantification of *uncertainty in sensitivity* as shown in Figure 1. For this purpose, an office building was selected and EnergyPlus, a dynamic simulation tool, was chosen. 1,000 simulation cases were populated using Latin hypercube sampling (Mckay et al. 2000) and then, Sobol method, a sensitivity analysis (Sobol 2001) was performed.

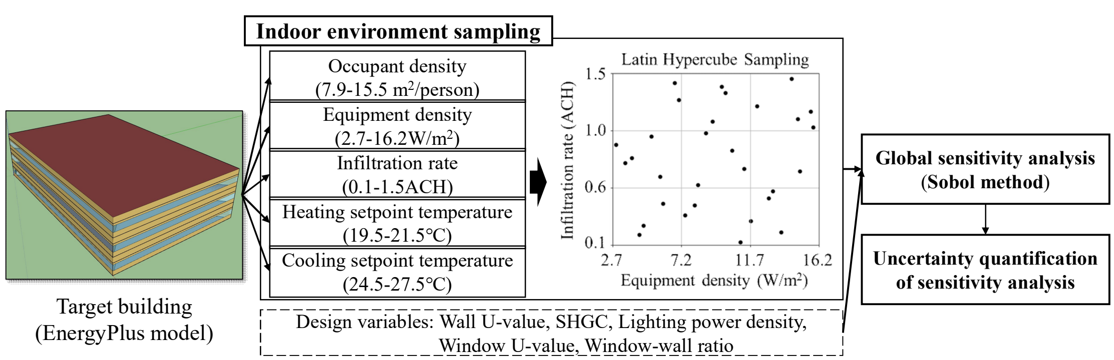
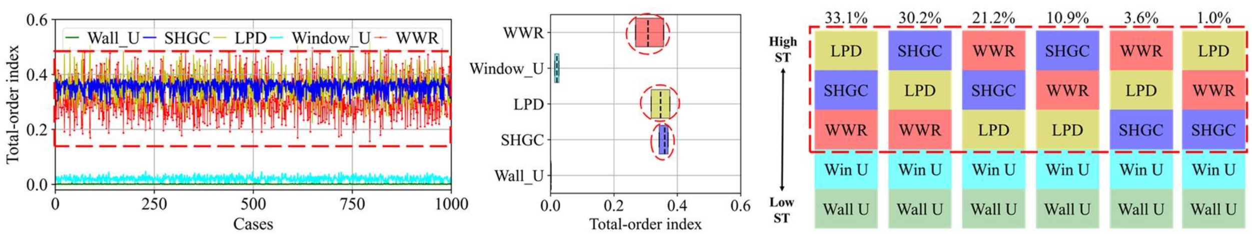


Figure 1: Quantification of uncertainty in sensitivity analysis.

2 CASE STUDY

The reference model for a medium-size office located in Atlanta developed by the US DOE was selected as the target building in this study. The model output is annual energy use (electricity + gas, unit: kWh). Wall U-value (0.30-0.80, W/m^{2}K), SHGC (0.3-0.7), lighting power density (8-20 W/m^2, hereinafter referred to as 'LPD'), Window U-value (1.5-3.5 W/m^{2}K) and Window-wall ratio (0.2-0.8, hereinafter referred to as 'WWR') were selected as the design variables. The ranges of the design variables and environmental factors (as shown in Figure 1) were referred to ASHRAE (2017) and Lee et al. (2015). In Sobol sensitivity analysis, a total-order index (the sum of effects by the variable itself and the interaction with other variables, hereinafter referred to as 'ST') were selected as the design variables' sensitivity.
It is observed that the impacts of SHGC (ST: 0.29-0.39), LPD (ST: 0.22-0.52), and WWR (ST: 0.16-0.50) on the building energy use are far greater than two U-values. It is noteworthy that uncertainties caused by SHGC, LPD and WWR are significant. Based on the interquartile range, the uncertainties of STs for the three variables increase in the order of WWR (0.09), LPD (0.06) and SHGC (0.03). As the environmental factors change, the sensitivity ranking of the three variables significantly vary (Figure 2).



<Sensitivity analysis> <Uncertainty quantification> <Combinations of sensitivity rank>

Figure 2: Uncertainty in sensitivity analysis of the building energy model.

3 CONCLUSION

In this study, the authors investigated the degree of *uncertainty in sensitivity analysis* of building energy models based on a given office building. EnergyPlus were used for the energy simulation tool, and Latin hypercube sampling and Sobol were performed for uncertainty and sensitivity analyses. It was found that *uncertainty in sensitivity* is significant, leading to the importance of a careful attention to selecting uncertain parameters for building energy retrofit. In future work, the authors will quantify the relationship between the uncertainty in sensitivity analysis and the uncertain variables.

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