Energy and Buildings 108 (2015) 463–469

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Comparison of survey and numerical sensitivity analysis results to assess the role of life cycle analyses from building designers' perspectives

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ARTICLE INFO

Article history:
Received 1 April 2015
Accepted 11 September 2015
Available online 12 September 2015

Keywords:
Building energy simulation
Life cycle cost assessment
Online survey
Sensitivity analysis

ABSTRACT

The objective of this study is to understand the role of life cycle analysis (LCA) in building system design process based on survey inputs from building system designers and a numerical sensitivity analysis. This paper first presents findings on the perceived importance of building life cycle assessment completed by 96 practicing designers from August 2012 to April 2013. The majority of respondents, approximately 70%, work as building system designers in the U.S. The building system designers are divided into three categories: (1) enclosure system designers, (2) mechanical system designers, and (3) designers working on both systems. One of the major survey findings is that life cycle assessments are much less used in building system design than energy simulations. The primary reason for performing a life cycle analysis for a building design project is a requirement from a building owner. Furthermore, Fisher's test shows that respondents' profession, company size, and work experience have significant correlations with the deployment of energy simulations and life cycle assessments in building design projects. ANOVA-based analyses demonstrate that there is no statically significant difference among the three categories of system designer responses on the importance of building components and design selection criteria. Interestingly, the sensitivity analyses performed for the medium size DOE (Department of Energy) reference building indicate that wall assemblies have a much larger impact on building life cycle costs than window properties. The comparison between sensitivity analysis and survey results indicates that the influence of window properties on life cycle cost is over estimated by most of the surveyed participants. Overall, this study revealed that LCA is still not widely used in the building industry even though it would help address design biases toward building systems that do not deliver the expected performance.

1. Introduction

Building energy simulations (BES) and life cycle analyses (LCA) enable the comparison of different building design solutions based on the predicted building performance. The utilization of BES and LCA supports decision making during the design process to optimize building performance from a range of design variants [1]. It is necessary to further study the role of BES and LCA from the designers' perspectives, and to define the significance of BES and LCA in the design processes. There have been studies to evaluate the influence of simulation tools and performance analyses on the building design. A study investigated a set of design projects and found that the presence of building performance analysis experts in the early stages of the design process can improve the building performance [2]. Another study demonstrated that LCA could enable better early stage decision-making by providing feedback about the embodied carbon footprint for different design choices [3]. Moreover, the concept of life cycle analysis is also useful when estimating the life cycle carbon dioxide in the planning phase [4]. However, there are very few studies which focus on the utilization of BES and LCA by building designers in the practical design processes.

A number of studies have been conducted worldwide in recent years to discover the role of building performance analyses in the design process by interviewing building designers. The results of a questionnaire administered in the UK suggested that building engineers/designers tend to use more detailed energy modeling than architects, while both groups believe their simulation errors

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http://dx.doi.org/10.1016/j.enbuild.2015.09.017
0378-7788/

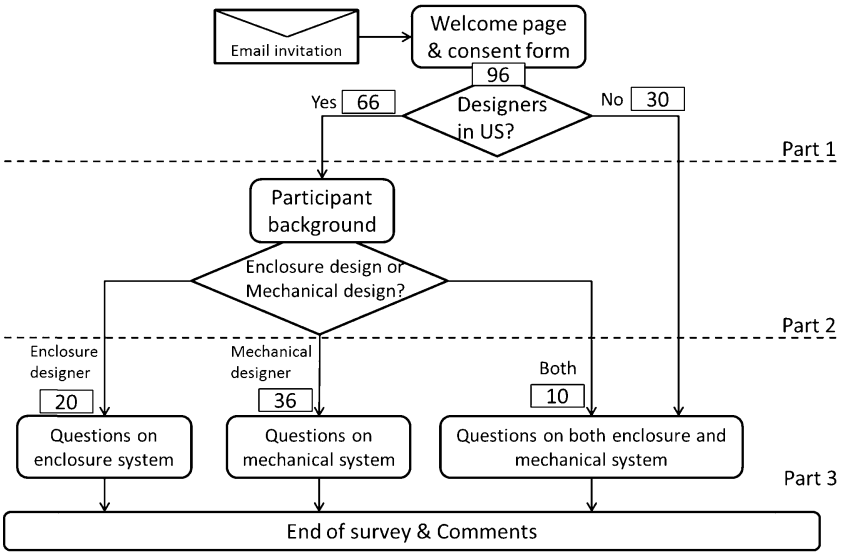

Fig. 1. The structure of survey. Depending on the responses, participants follow one of four main branches: enclosure system, mechanical system, both enclosure and mechanical systems, and non-designers. The numbers in the rectangular textboxes show the number of participants that went through that particular branch.

to be minor [5]. An interview of architects and building simulation consultants in the Netherland was conducted to capture the designers' viewpoint concerning building simulation. According to the results, energy simulation plays a very limited role in the average application of advanced energy saving technology. Instead, it is used more frequently for design optimization and verification [2]. A study in Singapore revealed that the usage of performance-based simulation tools for building design evaluation in Singapore is still very limited [6]. Another research study conducted in Hong Kong and Singapore indicated that it is very important to understand the building designers' viewpoint in order to analyze the obstacle of green building development and make recommendations [7]. A survey in Sweden indicated that there is a large interest in using LCA for the economic evaluation of investment decisions. However, difficulties in achieving relevant input data, lack of experience, and incentives for consultants and contractors became the major constraints of performing LCA [8]. The survey also showed that most of the participants consider LCA a useful tool during the design phase with the most possibilities for cost reductions related to operation and maintenance. The previous studies outside of the U.S. have shown that the utilization of building performance analysis in the design process could impact the design process, design results, and decision making. However, very few studies focus on the building system designers, and analyze their perspectives of building design process. Furthermore, no research has been conducted that studies the role of BES and LCA in the design process with the designers in the U.S. as the target participants. Therefore, it is necessary to further study the role of building performance analysis from the designers' perspectives in the U.S.

Previous surveys on the building performance were used to identify general trends in the design community. However, few studies considered the building system designers as the target participants. Furthermore, numerical performance simulation methodologies were rarely used to analyze the survey results. Therefore, this study aims to understand the importance of LCA from the perspectives of the building system designers in the U.S. Moreover, this study will include statistical and numerical sensitivity analyses as important analysis methodology to provide a deeper understanding of the survey results and the role of BES and LCA in building design as well.

2. Research methodology and survey design

The objective of this study is to identify the perspective of building designers in the U.S. on BES and LCA. The methodology of the questionnaire has been considered as an effective way to collect subjective opinions [9]. Therefore, this study conducted an on-line survey to collect the viewpoint of building system designers. The results of the survey were analyzed statistically to examine the correlation between participants' background and their responses. Furthermore, sensitivity analysis is employed to further understand the survey results and numerically test the significant factors for building life cycle cost.

The survey is web-based, so responses can be effectively gathered from a large number of design professionals. Participants were recruited through email invitations to selected mailing lists as well as through direct contact with different types of building designers. The questionnaire includes four question types: (a) multiple selections of specific categories, (b) a single selection of a specific category, (c) multiple selections of a specific category, and (d) free text. Multiple selection questions usually include a textbox where participants could provide information beyond the pre-defined options.

The whole survey has three parts, as shown in Fig. 1. A welcome web page explains the purpose of the survey, procedures to be followed, possible discomforts and risks, benefits, duration, statement of confidentiality, and rights to ask questions. The potential participants are also informed that their decision is voluntary, and they have the rights to end their participation at any time and for any reason. The incentive for individuals to participate in the survey is that "the participation will be crucial in the development of the building system optimization framework." Once individuals have consented to take part in the research, the questionnaire begins with the first question, which concerns the participants' profession. The first branching separated those participants who are currently working as a designer in the U.S. from those who are not. The former group follows the questions in part 2 of the survey. The latter group is guided toward the questions for both enclosure and mechanical system in part 3 of the survey.

In part 2, the questions are geared toward understanding the general participants' background, such as the size of their company, the energy code/standard they design to, the patch they follow