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Li, Hongyang; Ng, S. Thomas; Skitmore, Martin

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# Stakeholder Impact Analysis during Post-occupancy Evaluation of Green Buildings – A Chinese Context

*Hongyang Li* [1,2*]
*S. Thomas Ng* [3]
*Martin Skitmore* [4]

Revised Version

[1] School of Civil Engineering and Transportation, South China University of Technology, Guangzhou 510641, China, E-mail: li.terryhy@yahoo.com

[2] State Key Laboratory of Subtropical Building Science, South China University of Technology, Guangzhou 510641, China

[3] Professor, Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, Email: tstng@hku.hk, Tel: Int+ (852) 2857 8556; Fax: Int+ (852) 2559 5337

[4] Professor, School of Civil Engineering and Built Environment, Queensland University of Technology (QUT), Garden Point Campus, GPO Box 2434, Brisbane, Q4001, Australia, Email: rm.skitmore@qut.edu.au; Visiting Professor, Faculty of Computing, Engineering and the Built Environment, Birmingham City University, Birmingham, UK.

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## Abstract

The high-energy consumption of the architectural, engineering and construction (AEC) industry and associated environmental pollution have become a global challenge, and governments at different levels in China have been dedicated to improving the industry's sustainability. However, although the concept of green building (GB) has been growing rapidly, the primarily emphasis has been on energy-saving design with little attention paid to sustainable post-occupancy operations, which is hindering further development. To address this fundamental issue it is necessary to evaluate the post-occupancy performance of GB and, given China's current circumstances, one that involves the participation of all stakeholders to avoid being dominated by construction professionals. However, such participatory evaluations are currently very limited and perfunctory in the country, usually involving simply informing or placating the stakeholders. In response, this paper develops a comprehensive quantitative method to analyze stakeholder impact during GB post-occupancy evaluation (POE). This enables the various stakeholder groups to be prioritized in terms of their influence levels and hence contributes to maximizing overall stakeholder satisfaction by improving the efficiency and effectiveness of the evaluation. The findings of the paper are expected to help clients and design teams improve their building designs by integrating the views of stakeholders through the POE in order to realize the true spirit of GB development.

*Keywords*: Sustainability, green building, post-occupancy evaluation, stakeholder participation, quantitative method.

## 1. Introduction

Concomitant with a growing awareness of the importance of sustainability in the architectural, engineering and construction (AEC) industry, the concept of green building (GB) has gained increasing popularity in different countries/regions. GB-related industries in China have also boomed rapidly over the last decade (Li *et al.*, 2017), primarily emphasizing energy-saving design. However, little regard is being paid to the efficiency of energy use by the building occupants, which is hindering the further development of GB in China. In order to better integrate GB design and use, it is first necessary to have a reliable understanding their post-occupancy performance. A starting point for this is to develop a suitable evaluation framework.

The operation of GB involves a number of stakeholders with diverse social, environmental and economic interests (Liang *et al.*, 2014; Liang *et al.*, 2016a, b, c; Shi *et al.*, 2016) and, given China's current circumstances, it is important that all are able to participate in the evaluation process to avoid being dominated by construction professionals. Although such participation offers a means of better addressing and meeting stakeholder concerns and expectations, the post-occupancy evaluation (POE) of contemporary GB is becoming ever more complicated, with an increasing number of stakeholders involved to reflect their own interests.

In response, this paper provides a means of analyzing GB operations stakeholders thoroughly and comprehensively, to quantify their influence during POE. Through this, various stakeholder groups are prioritized and hence overall stakeholder satisfaction can be maximized by improving the efficiency and effectiveness of participatory GB POE. A brief review of GB concepts and participatory POE theories is presented, followed by an introduction to the research process/methods used. The results of a survey are next described to reveal the different impact levels of various stakeholder groups involved in GB POE. Subsequent validation interviews are then discussed and more in-depth opinions concerning the development of GB in China are examined. A proposed research agenda concludes the paper.

## 2. The Definition of Green Building

Sustainable development has gradually become an overarching policy goal of various countries/regions since the 1992 Earth Summit (Parkin *et al.*, 2003). Robichaud and Anantatmula (2010) believe that the concept of sustainability in the construction industry is closely related to harmony with the surrounding environment, minimizing the use of resources and energy, greater adaptation of recyclable materials, less pollution, lower life cycle costs and a better living quality. Ogunbiyi *et al.* (2014, p. 89), on the other hand, consider sustainable construction as:

> *the set of processes by which a profitable and competitive industry delivers built assets (buildings, structures, supporting infrastructure, and their immediate surroundings), which: enhance the quality of life and offer customer satisfaction; offer flexibility and the potential to cater for user changes in the future; provide and support desirable natural and social environments, and maximize the efficient use of resources*.

Abidin (2010) postulate that sustainable construction should (i) be concerned about the people who use the facilities by ensuring that they are living in a healthy and safe built environment that is in harmony with nature; (ii) safeguard the interests of future generations while at the same time meeting today's needs; (iii) lead to the maximum benefits and lowest costs to the society and environment; (iv) minimize damage to the environment and its resources; (v) improve the quality of building facilities and their services so as to promote social cohesiveness; (vi) adopt technologies and expert knowledge to seek information to improve project efficiency and effectiveness; and (vii) comply with legislation and associated responsibilities.

Many terms have been proposed that are relevant to construction sustainability, e.g. "green project" and "high performance building". Olubunmi *et al.* (2016, p. 1612) define a green project as *"the practice of creating structures and using processes that are responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, and renovation"*. Projects of this type should reduce the use of resources (energy, land, water, materials, etc.) by adopting energy-efficient appliances and systems, while waste is expected to decrease by incorporating such long-lasting products as recycled steel, natural linoleum and bamboo flooring (Deuble and Dear, 2012). Meanwhile, high performance buildings are expected to:

*i.* *minimize or eliminate impacts on the environment, natural resources, and non-renewable energy sources to promote the sustainability of the built environment*
*ii.* *enhance the health, wellbeing and productivity of occupants and whole communities*
*iii.* *cultivate economic development and financial returns for developers and whole communities*

iv. *apply life cycle approaches to community planning and development* (Robichaud and Anantatmula, 2010, p. 49-50).

Although these terms are used almost synonymously, “green building” (GB) is more recognized in China (Li *et al.*, 2016a, 2017). In this paper, we refer to projects with minimal usage of various resources (e.g. energy, land, water, materials, etc.) throughout the project lifecycle, to imply an emphasis on environmental protection and pollution reduction as well as the provision of healthy, adaptive and efficient living space that is harmonious with the surroundings.

## 3. Stakeholder Participation in the Post-occupancy Evaluation of Green Buildings

In recent years, issues relating to energy consumption and environmental pollution in the architectural, engineering and construction (AEC) industry have attracted the attention of the Chinese government at various levels, attracting increasing attention from the mass media as well as the public towards the concept of sustainable construction (Liang *et al.*, 2016a, c). Despite the boom in the GB-related industry in China, barriers still exist which hinder its further development.

The greatest hindrance lies with the quantitative imbalance between the GB design and operation phases (Yu *et al.*, 2016). While more than 80% of energy consumption occurs during the actual occupancy operation stage rather than during the construction stage (Liang *et al.*, 2016a, b, c), which indicates that the post-occupancy performance of GB largely determines the overall sustainability level, GB labelling relies instead on the information available at the preconstruction stage.

In China, this has created an anomaly of alarming proportions as, of the 1,446 projects - equivalent to an overall area of 162,900,000 $m^2$ - passing assessments by January 2014 since the April 2008 introduction of its GB evaluation labeling policy, an estimated 92% have not achieved the designed performance during their operation stage (MOHURD, 2014). It seems that many proposals exaggerated their expected energy performance when seeking their green labels, as they have later been found to have an actual energy consumption far exceeding their designed levels, sometimes with indoor air quality even worse than unlabeled buildings. Li *et al.* (2016a, 2017) attribute this shortcoming to the lack of a participatory evaluation framework to assess the life-cycle sustainability of GB.

According to André *et al.* (2006), a good participatory mechanism should involve individuals and groups positively or negatively affected by a proposed intervention (e.g., a project, program, plan or policy) throughout the decision/evaluation process. Through this, stakeholders can influence and share control over development initiatives as well as the decisions/evaluations that most affecting them (Amoatey and Hayibor, 2017; Ng *et al.*, 2012; Li *et al.*, 2012a, b). Creighton *et al.* (1998) highlight 16 techniques for facilitating participatory decisions/evaluations, comprising interviews, field offices, hotlines, displays or exhibits, newspaper inserts, information bulletins, surveys, participatory television, brochures, contests, mediation and charrettes, Delphi, simulation games, providing technical assistance to stakeholders and training programs for stakeholders. No consensus has yet been reached in formulating a universal and effective way of engaging stakeholders after comparing the advantages and disadvantaged of each technique. However, it is accepted by researchers and practitioners that the advantages of participatory decision/evaluations generally overshadow the disadvantages (Li *et al.*, 2013; Li *et al.*, 2016b, c). IAPP

(2007), for example, identifies the value of a participatory approach to decisions/evaluations as: (i) the public have a say in the actions that could affect their lives; (ii) there is a good chance that the public's contribution will influence the decisions/evaluations; (iii) sustainable decisions/evaluations are promoted by recognizing and communicating the needs and interests of all participants; (iv) it seeks and facilitates the involvement of those potentially affected or interested; (v) it promotes input from participants in designing how they should participate; (vi) participants are provided with the information they need to participate in a meaningful way; and (vii) it communicates to participants how their input affects the decision/evaluations.

While GB is expected to achieve environmental, social and economic sustainability, a participatory approach to assess GB post-occupancy performance should play a vital role during the process (Li *et al.*, 2016a, 2017). Stakeholder participation is beneficial in enhancing the transparency of the evaluation process as well as improving the credibility of the evaluation outcome. As a result, less controversy is expected throughout the project lifecycle (especially during the operation stage) so as to help realize China’s governing philosophy of maintaining societal harmony. However, the current participatory evaluations of GB post-occupancy performance are rather limited and perfunctory in China, and usually take form of informing or placating stakeholders. This can be partly attributed to the diversity of the stakeholder groups involved and difficulty in reaching, not to mention about satisfying, all those concerned participants during the evaluation.

*Stakeholder theory* offers some insights into a solution. The theory began in the 1960s, with researchers at the Stanford Research Institute first proposing the definition of stakeholders as groups without whose support an organization would cease to exist (Olander, 2007). Freeman (1984, p. 46) later further interpreted this as *"any group or individual who can affect, or is affected by, the achievement of the organization's objectives"*. Clarkson (1995), on the other hand, explains the differences between *stakeholders* and *shareholders* – considering stakeholders' satisfaction (instead of that of shareholders) as an indispensable criterion for evaluating corporate success. The application of stakeholder theory has now far extended from its original implementation in strategic management, to various fields including construction project management (Atkin and Skitmore, 2008) where stakeholders are defined as individuals and organizations who may affect, or be affected, in a positive or negative manner throughout the project cycle (PMI, 2008). Of relevance also is the classification of stakeholders in the construction industry by Takim (2009) and Winch (2002) which comprises: (i) *internal* stakeholders, who have a legal contact with the client and those clustered around the client on the demand side (e.g. employees, customers, end-users and financiers) and the supply side (e.g. architects, engineers, contractors, trade contractors and material suppliers); and (ii) *external* stakeholders which include private actors (e.g. local residents, landowners, environmentalists and archaeologists) and public actors (e.g. regulatory agencies, and local and national governments).

For GB, the stakeholder groups are usually better defined, as schemes of this type should have environmental, social and economic effects on the public in general (Manowong and Ogunlana, 2008). Li *et al.* (2016a, 2017), for example, identify the seven typical stakeholder groups of sustainable projects throughout the lifecycle as government organizations, owners, designers, contractors, end-users (Liang *et al.*, 2016a, b, c), non-governmental organizations (NGOs), and other relevant groups (material/technology providers, etc.) (Göçer *et al.*, 2015).

In this paper, we develop a quantitative method to identify the various stakeholder groups involved in GB post-occupancy evaluation (POE) in China and for a comprehensive analysis of their relative individual impact. This provides a basis for prioritizing the stakeholder groups in terms of their influence during the operation stage of sustainable projects to provide a means of improving the efficiency and effectiveness of participatory evaluation towards the eventual goal of maximizing overall stakeholder satisfaction.

# 4. Research Design

## *4.1 A quantitative method for prioritizing stakeholder impact*

Various techniques have been proposed to assess stakeholder influence levels, including the score-based approach (Mitchell *et al.*, 1997), power/interest matrix (Johnson and Scholes, 1999) and stakeholder circle (Bourne and Walker, 2008). These have been criticized by Wang *et al*. (2012), however, as being overly qualitative and subjective. Correcting this necessitates a quantitative and objective method of prioritizing stakeholder-impact. A factor of *stakeholder influencing level* (FoSIL) is, therefore, defined and incorporated in what follows.

Two elements are considered here, i.e. the *stakeholder attribute value, A* (Olander, 2007), and the *vested interest–impact index, ViII* (Olander, 2007). Olander (2007) conceptualizes stakeholder attributes with three sub-components, namely: power (the stakeholder's power to influence, $P'$), legitimacy (the legitimacy of stakeholder relationships, $L$), and urgency (the urgency of the stakeholder's claim, $U$). The stakeholder attribute value ($A$) can be obtained by first determining the weight of each attribute (*P*, *L* and *U*) and then summing the weighted attributes possessed by the group (Olander, 2007).

$$A = Weight_{(P)} + Weight_{(L)} + Weight_{(U)} \tag{1}$$

It is, however, insufficient to measure only the attribute(s) of a stakeholder group - evaluating the probability and level of the stakeholder impacts involved is also necessary (Olander, 2007). These two sub-factors, the vested interest level (probability of impact, *v*) and the influence impact level (level of impact, *i*), are combined into a vested interest–impact index (*ViII*) given by

$$ViII = \sqrt{\frac{v \times i}{5 \times 5}} \tag{2}$$

with both *v* and *i* rated on a Likert scale ranging from 1 (“very low”) to 5 (“very high”)

The factor of *stakeholder influencing level* (FoSIL) is given by (Olander, 2007)

$$FoSIL = A \times ViII = A \times \sqrt{\frac{v \times i}{25}} \tag{3}$$

### *4.2 Research stages and methods adopted*

The overall research was carried out in three phases, and adopted various methods (including interviews and a questionnaire survey). In the first stage, 28 semi-structured interviews were conducted during the period from November to

December 2016 in Beijing and Shenzhen, with representatives of the government, owners, designers, contractors, end-users, academia and NGOs. Their input helped identify the major stakeholder groups during GB post-occupancy operation and the weightings of three stakeholder attributes of power ($P$), legitimacy ($L$) and urgency ($U$). All participants were purposively selected as having a minimum of five years' practical or research experience in sustainable construction-related industries, or in relevant disciplines, or having been a user of green residential/public projects. Table 1 provides the profiles of the first stage interview participants. All are at senior management level or with ample hands-on GB experience, indicating the authenticity of their views.

**Table 1**
Profiles of the first stage interview participants.

| Group | No. | Position | Organization |
|---|---|---|---|
| Government department | 1 | Deputy director | Municipal department |
| | 2 | Director | Municipal commission |
| | 3 | Deputy secretary-general | Provincial bureau |
| | 4 | Policy advisor | Provincial bureau |
| Owner | 5 | Development manager | Real estate corporation |
| | 6 | Deputy project manager | Real estate corporation |
| | 7 | General manager | Real estate corporation |
| | 8 | Deputy engineering manager | District infrastructure construction office |
| Designer | 9 | Deputy Director | Design institute |
| | 10 | Architect | Design institute |
| | 11 | Structural Engineers | Design institute |
| | 12 | Principal Architect | Design consultants |
| Contractor | 13 | Senior Technician | Construction company |
| | 14 | Deputy Engineering Manager | Construction company |
| | 15 | Project Manager | Construction company |
| | 16 | Engineer | Construction company |
| End-user | 17 | End-user of green residential projects | N.a. |
| | 18 | End-user of green residential projects | N.a. |
| | 19 | End-user of green public projects | N.a. |
| | 20 | End-user of green public projects | N.a. |
| Academia | 21 | Professor | University |
| | 22 | Professor | University |
| | 23 | Senior Research Associate | University |
| | 24 | Research Associate | Provincial research institution |

| | | | |
|---|---|---|---|
| | 25 | Director | Municipal research institution |
| NGOs | 26 | Director | Environmental group |
| | 27 | Member | NGO |
| | 28 | Member | NGO |

A structured questionnaire (both in English and Chinese) was then developed and a survey conducted to elicit views on the probability of impact ($v$) and the level of impact ($i$) of the major stakeholder groups during the POE of sustainable projects. To do this, a 5-point Likert scale was incorporated with 1 representing "very low" and 5 denoting "very high". The selection of respondents follows the purposive sampling approach, requiring a minimum of three years' practical or research experience in sustainable construction-related industries, or in relevant disciplines, or having been a user of green residential/public projects in China. This is in line with Akadiri and Fadiya's research, where a similar sampling technique was adopted to analyze the determinants of environmentally sustainable practices in the UK construction industry. According to Teddlie and Yu (2007), purposive sampling techniques are often used when the researcher wants to select a purposive sample representing a broader group of cases as closely as possible, or to set up comparisons between different types of cases on a certain dimension of interest. It proves to be effective when only limited numbers of people can serve as primary data sources due to the nature of the research design and aims/objectives. This study focuses on GB POE – a relatively new concept in China, leading to concerns over the value of the data if obtained by probability sampling. As a non-probability sampling method, purposive sampling techniques were considered more appropriate, given the lack of experienced practitioners/researchers in the GB POE field in China. It was expected that purposively selecting the research participants would improve the richness of the data obtained. To ensure the efficiency of the purposive sampling process and the effectiveness of the results, the selection criteria for the interview/questionnaire participants were carefully established. A consensus was reached based on the continuous discussions of the research group as well as the comments solicited from the experts in the pilot study.

Before undertaking the main survey, a pilot study was carried out with 14 experts from 7 relevant groups. This lead to some changes to the original version of the questionnaire, e.g. the original 7-point Likert scale was modified to a 5-point Likert scale to facilitate the participation of respondents with different educational backgrounds from the end-user and NGO groups. 847 updated questionnaires were then dispatched by mail, email, fax or street survey, and 198 were returned providing a total response rate 23.38% (Table 2) which is regarded as acceptable for research of this kind (Akintoye, 2000). The profiles of the respondents are summarized in Table 3, of which 32 (16.16%) are from academia, 30 (15.15%) from the end-user group, 29 (14.65%) from the owner group, 28 (14.14%) from the contractor group and 27 (13.64%) from the designer group. The least numbers of respondents are from government department (26) and NGOs (26). As Table 3 indicates, all the respondents fulfil the selection criteria, with 36 (18.18%) even equipped with more theoretical/practical experience in relevant fields.

**Table 2**
Response rate.

| **Group** | **No. of questionnaires** | | **Percentage return (%)** |
|---|---|---|---|
| | *Sent* | *Returned* | |
| Government department | 118 | 26 | 22.03 |
| Owner | 120 | 29 | 24.17 |
| Designer | 115 | 27 | 23.48 |
| Contractor | 122 | 28 | 22.95 |
| End-user | 124 | 30 | 24.19 |
| Academia | 131 | 32 | 24.43 |
| NGO | 117 | 26 | 22.22 |
| **Total** | **847** | **198** | **23.38** |

**Table 3**
Profile of respondents.

| Group | No. of respondents (%) | No. with 3-5 years working or research experience or have been users of 1 green residential/public project (%) | No. with more than 5 years working or research experience or have been users of more than 1 green residential/public project (%) |
|---|---|---|---|
| Government Department | 26 (13.13%) | 21 (80.77%) | 5 (19.23%) |
| Owner | 29 (14.65%) | 20 (68.97%) | 9 (31.03%) |
| Designer | 27 (13.64%) | 23 (85.19%) | 4 (14.81%) |
| Contractor | 28 (14.14%) | 22 (78.57%) | 6 (21.43%) |
| End-user | 30 (15.15%) | 27 (90.00%) | 3 (10.00%) |
| Academia | 32 (16.16%) | 25 (78.13%) | 7 (21.87%) |
| NGO | 26 (13.13%) | 24 (92.31%) | 2 (7.69%) |
| **Total** | **198 (100%)** | **162 (81.82%)** | **36 (18.18%)** |

A series of semi-structured interviews was conducted in the final stage of the research (in April 2017) to verify the results of the previous stages and therefore improve the effectiveness of the outcome. This involved 15 experts from Shanghai and Guangzhou, with 2 from each group of government, owners, designers, contractors, end-users and NGOs, and 3 from academia. Their positions and organizations are not listed to preserve anonymity. They were chosen according to the same criteria as in the first phase interviews, again to confirm the value of their input. In order to improve the validity of the research findings, the interview participants involved in this stage had not been involved in the first round of interviews. To facilitate and expedite the interview process, all the participants were sent an advance package of information that included the research aim, background information and survey findings. For the sake of effectiveness and efficiency, each interview was controlled to last within an hour and a half.

## 5. Results

### *5.1 Stakeholder attribute value (A)*

Five major stakeholder groups involved in GB post-occupancy operation were identified based on the findings of the first-stage of interviews. These comprise government organizations, owners, property management companies, end-users and NGOs. The superiority chart method (Table 4) was then applied to determine the weightings of the three stakeholder attributes (*P*, *L* and *U*) (Liu and Xu, 2014).

**Table 4**
Superiority chart method

| | Power (*P*) | Legitimacy (*L*) | Urgency (*U*) | Rating |
|---|---|---|---|---|
| Power (*P*) | $R_{PP}$ | $R_{PL}$ | $R_{PU}$ | Sum ($R_{PP}$, $R_{PL}$, $R_{PU}$) |
| Legitimacy (*L*) | $R_{LP}$ | $R_{LL}$ | $R_{LU}$ | Sum ($R_{LP}$, $R_{LL}$, $R_{LU}$) |
| Urgency (*U*) | $R_{UP}$ | $R_{UL}$ | $R_{UU}$ | Sum ($R_{UP}$, $R_{UL}$, $R_{UU}$) |

This involved each of the 28 interview participants comparing the importance of *P*, *L* and *U* in a pairwise manner according to the rule that:

$R_{xy}$=1, if factor X is more important than factor Y (X, Y belong to *P*, *L* and *U*)

$R_{xy}$=0.5, if factor X and factor Y are equally important (X, Y belong to *P*, *L* and *U*)

$R_{xy}$=0, if factor X is less important than factor Y (X, Y belong to *P*, *L* and *U*) (4)

Consequently,

Rating of *P*= Sum ($R_{PP}$, $R_{PL}$, $R_{PU}$)

Rating of *L*= Sum ($R_{LP}$, $R_{LL}$, $R_{LU}$)

Rating of *U*= Sum ($R_{UP}$, $R_{UL}$, $R_{UU}$) (5)

The weightings of *P*, *L* and *U* can be obtained from

$$Weighting\ of\ P = \frac{Rating\ of\ P}{Rating\ of\ P + Rating\ of\ L + Rating\ of\ U}$$

$$Weighting\ of\ L = \frac{Rating\ of\ L}{Rating\ of\ P + Rating\ of\ L + Rating\ of\ U}$$

$$Weighting\ of\ U = \frac{Rating\ of\ U}{Rating\ of\ P + Rating\ of\ L + Rating\ of\ U} \quad (6)$$

From this, we determine the average weightings of *P*, *L* and *U*, as rated by the 28 interview participants to be 0.37, 0.30 and 0.33 respectively (Table 5). As required by the participants, their positions and organizations are not linked to their ratings to preserve anonymity.

**Table 5**
Weightings of *P*, *L* and *U* as revealed from first -stage interviews

| | | **Rating** | | | **Weighting** | | |
|---|---|---|---|---|---|---|---|
| **Group** | **Interviewee** | **P** | **L** | **U** | **P** | **L** | **U** |
| Government department | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| | Anonymity | 1.5 | 0.5 | 2.5 | 0.33 | 0.11 | 0.56 |
| | Anonymity | 1.5 | 2.5 | 0.5 | 0.33 | 0.56 | 0.11 |
| | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| Owner | Anonymity | 1.5 | 2.5 | 0.5 | 0.33 | 0.56 | 0.11 |
| | Anonymity | 2.5 | 1.5 | 0.5 | 0.56 | 0.33 | 0.11 |
| | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| | Anonymity | 0.5 | 1.5 | 2.5 | 0.11 | 0.33 | 0.56 |
| Designer | Anonymity | 1.5 | 0.5 | 2.5 | 0.33 | 0.11 | 0.56 |
| | Anonymity | 2.5 | 1.5 | 0.5 | 0.56 | 0.33 | 0.11 |
| | Anonymity | 0.5 | 1.5 | 2.5 | 0.11 | 0.33 | 0.56 |
| | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| Contractor | Anonymity | 2.5 | 1.5 | 0.5 | 0.56 | 0.33 | 0.11 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Anonymity | 1.5 | 0.5 | 2.5 | 0.33 | 0.11 | 0.56 |
| | Anonymity | 0.5 | 2.5 | 1.5 | 0.11 | 0.56 | 0.33 |
| | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| End-user | Anonymity | 0.5 | 2.5 | 1.5 | 0.11 | 0.56 | 0.33 |
| | Anonymity | 0.5 | 2.5 | 1.5 | 0.11 | 0.56 | 0.33 |
| | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| | Anonymity | 0.5 | 2.5 | 1.5 | 0.11 | 0.56 | 0.33 |
| Academia | Anonymity | 1.5 | 0.5 | 2.5 | 0.33 | 0.11 | 0.56 |
| | Anonymity | 1.5 | 2.5 | 0.5 | 0.33 | 0.56 | 0.11 |
| | Anonymity | 2.5 | 1.5 | 0.5 | 0.56 | 0.33 | 0.11 |
| | Anonymity | 1.5 | 2.5 | 0.5 | 0.33 | 0.56 | 0.11 |
| | Anonymity | 0.5 | 1.5 | 2.5 | 0.11 | 0.33 | 0.56 |
| NGOs | Anonymity | 1.5 | 0.5 | 2.5 | 0.33 | 0.11 | 0.56 |
| | Anonymity | 2.5 | 1.5 | 0.5 | 0.56 | 0.33 | 0.11 |
| | Anonymity | 2.5 | 0.5 | 1.5 | 0.56 | 0.11 | 0.33 |
| | Average | 1.68 | 1.36 | 1.46 | 0.37 | 0.3 | 0.33 |

During the interviews, each participant was invited to comment on the attribute(s) of the five groups considered. From this, we calculate a certainty index (CER) defined as:

$$CER_A(G_i) = \frac{O_A^+}{N} \tag{7}$$

where $CER_A(G_i)$ denotes the certainty index of group *i* (government organizations, owners, property management companies, end-users or NGOs) regarding each attribute (*P*, *L* or *U*); $O_A^+(G_i)$ refers to the number of participants holding the opinion that group *i* possesses the attribute considered; and $N$ is the overall number of participants.

The 15 resulting certainty indices are summarized in Table 6. $CER_A(G_i)$, with a minimum value of 0.5, confirms the attachment of a particular attribute to group *i*. As a result, the *stakeholder attribute value* ($A$) of each stakeholder group is obtained (Table 8).

**Table 6**
Certainty indices of various stakeholder groups regarding $P$, $L$ and $U$

| Group \ Attribute | Power ($P$) | Legitimacy ($L$) | Urgency ($U$) |
|---|---|---|---|
| Government organizations | 1.00 (√) | 0.75 (√) | 0.93 (√) |
| Owners | 0.61 (√) | 0.89 (√) | 0.82 (√) |
| Property management companies | 0.36 | 0.50 (√) | 0.43 |
| End-users | 0.29 | 0.57 (√) | 0.54 (√) |
| NGOs | 0.21 | 0.50 (√) | 0.14 |

### *5.2 Vested interest–impact index (ViII)*

In the next stage of the questionnaire survey, 198 respondents assessed each stakeholder group based on its probability of impact ($v$) and level of impact ($i$) during GB post-occupancy on a 5-point Likert scale. Table 7 summarizes the results. The vested interest–impact index (*ViII*) of each stakeholder group is then obtained through Eq. (2) as shown in Table 8.

### *5.3 Factor of stakeholder influencing level (FoSIL)*

Based on the previous results, the factor of *stakeholder influencing level* (FoSIL) is calculated by Eq. (3), as detailed in Table 8. Government organizations have the highest influencing level (*FoSIL*=0.93), followed by owners (*FoSIL*=0.89), end-users (*FoSIL*=0.51) and property management companies (*FoSIL*=0.24), with NGOs having the least influence (*FoSIL*=0.19).

**Table 7**
Respondents' rating of the vested-interest levels (*v*) and impact levels (*i*) of different stakeholder groups during post-occupancy of GB.

| *Group* | *Number of respondents* | Government organizations | | Owners | | Property management companies | | End-users | | NGOs | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *v* *Mean* | *i* *Mean* | *v* *Mean* | *i* *Mean* | *v* *Mean* | *i* *Mean* | *v* *Mean* | *i* *Mean* | *v* *Mean* | *i* *Mean* |
| Government department | 26 | 4.42 | 4.88 | 4.19 | 4.65 | 3.85 | 4.42 | 4.31 | 3.69 | 4.50 | 3.42 |
| Owner | 29 | 4.45 | 4.93 | 4.31 | 4.59 | 3.79 | 4.45 | 4.38 | 3.83 | 4.03 | 2.52 |
| Designer | 27 | 4.26 | 4.89 | 4.41 | 4.67 | 3.89 | 4.44 | 4.19 | 3.70 | 4.22 | 2.30 |
| Contractor | 28 | 4.36 | 4.96 | 4.29 | 4.71 | 3.82 | 4.39 | 4.14 | 3.93 | 3.79 | 2.18 |
| End-user | 30 | 4.60 | 4.83 | 4.50 | 4.60 | 3.80 | 4.23 | 4.63 | 3.63 | 3.80 | 2.47 |
| Academia | 32 | 4.38 | 4.75 | 4.25 | 4.63 | 4.13 | 4.00 | 4.41 | 3.78 | 3.94 | 2.88 |
| NGO | 26 | 4.46 | 4.81 | 4.27 | 4.38 | 3.92 | 4.00 | 4.31 | 3.54 | 4.62 | 1.88 |
| Overall | 198 | 4.42 | 4.86 | 4.32 | 4.61 | 3.89 | 4.27 | 4.34 | 3.73 | 4.11 | 2.53 |

**Table 8**
Influence of different stakeholder groups during green building post-occupancy

| ***Stakeholder Groups*** | ***Attributes*** | | | ***Stakeholder influence*** | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Power (P)* | *Legitimacy (L)* | *Urgency (U)* | *Stakeholder attribute value (a)* | *Mean value of the vested interest levels (v)* | *Mean value of the influence impact levels (i)* | *The vested interest–impact index (ViII)* | *The factor of stakeholder influencing levels (FoSIL)* |
| Government organizations | 0.37 | 0.30 | 0.33 | 1 | 4.42 | 4.86 | 0.93 | 0.93 |
| Owners | 0.37 | 0.30 | 0.33 | 1 | 4.32 | 4.61 | 0.89 | 0.89 |
| Property management companies | | 0.30 | | 0.30 | 3.89 | 4.27 | 0.82 | 0.24 |
| End-users | | 0.30 | 0.33 | 0.63 | 4.34 | 3.73 | 0.80 | 0.51 |
| NGOs | | 0.30 | | 0.30 | 4.11 | 2.53 | 0.64 | 0.19 |

## 6. Discussion

It is accepted by all the interview participants involved in the validation that government organizations are the most influential in GB POE. The results correspond with Li *et al*.'s (2017) research on stakeholder analysis in sustainable construction. Two government representatives believe that the current huge contrast in the number of green-design-labeled buildings and green-operation-labeled buildings has attracted attention from governments at various levels. The government sectors emphasize the performance of green projects during their operation stage as part of their responsibility to build and maintain a resource-saving and environmental friendly community. Two interviewees from academia later added that ensuring GB effectiveness and efficiency throughout their lifecycle can help the government achieve macro benefits environmentally, socially and economically, and a comprehensive POE framework is particularly important during the process. A government representative, on the other hand, suggested that GB POE should consider such aspects as the management system (educating and disseminating the green concept, management of operational staff, etc.), and technology and environment (information management, waste management, etc.). For the interviewee participants from other groups (i.e. owners, designers, contractors, end-users and NGOs), a consensus was reached that, given the current environmental-social-economical contexts in China, the influencing role of government may outmatch that of the market for promoting the concept of sustainability in the AEC industry. During the process, government financial subsidies are indispensable. Various provinces/municipalities have issued subsidy policies to stimulate GB development, as listed in Table 9 (Xu, 2016). These may serve as references for nearby regions lacking relevant subsidy measures.

**Table 9**
Subsidy policies of various provinces/municipalities

| **Provinces/ Municipalities** | Beijing | Shanghai | Shandong | Jiangsu | Guangdong | Shanxi |
|---|---|---|---|---|---|---|
| **Subsidy Policies ($RMB/m^2$)** | 22.5<br>Two-Star<br>40<br>Three-Star | 60<br>Two-Star<br>60<br>Two-Star | 15<br>One-Star<br>30<br>Two-Star<br>50<br>Three-Star | 15<br>One-Star | 25<br>Two-Star<br>45<br>Three-Star | 10<br>One-Star<br>15<br>Two-Star<br>20<br>Three-Star |

Source: Xu, 2016

Despite having a relatively high influence, the role of owners in maintaining expected GB performance during their operation phase is still controversial. Participants from the designer and contractor groups complained that the reason so many design innovations fail during post-occupancy could be ascribed to a lack of owner motivation. The owner representatives interviewed partly accepted these criticisms but pointed out that they are unfamiliar with the theory/practice of green operations due to their unrelated backgrounds. An NGO member also added that the relative high ratio of input/output of sustainable maintenance provides insufficient incentive for owners. Two interview participants from academia, on the other hand, proposed other factors to be considered, regarding the motivation of owners to apply sustainability concepts actively during post-occupancy. These are the partnership patterns of owners and property management companies, and the constituent relationships of the owners and end-users.

The end-users are another party contributing to GB POE scores (Liang *et al.*, 2016a, b, c) and also play a vital role in project pre-occupancy evaluation (Shen *et al.*, 2013). Shen *et al.* (2013) develop a User Pre-Occupancy Evaluation Method (UPOEM) to enhance the designer-client communication by applying building information modeling (BIM), user activity simulation and requirement management techniques. As far as the GB POE is concerned, the two end-users of green residential/public projects interviewed believed that they are increasingly aware of the relationship between their daily behaviors and sustainable building operation. One issue raised by them is that they want to have a say in the POE process instead of merely being informed of the results. The government and academic representatives all agreed with their comments and considered it important to improve the transparency and legitimacy of the evaluation process/result through wider public engagement. That the high level of influence of end-users during GB POE in China, as revealed from this research, does not match the findings of Olander (2007), is probably due to the growing tendency of end-users trying to influence the implementation of projects of various types according to their individual concerns and needs.

Property management companies and NGOs have relatively less influence over GB post-occupancy. According to the government and owner groups, the majority of property management companies consider that operating sustainable buildings is a heavy burden due to the associated higher costs involved compared to their conventional counterparts. As commented by two academic participants *"in the current management mode of green projects during the operation stage, the property management companies neither have responsibility to maintain sustainability nor any gains from accomplishing this"*. Another academic suggested incorporating a fluctuating fee contract based on the performance of the property management companies in realizing sustainability aims during post-occupancy. As one government participant pointed out, however, even when financial incentives are available, most property management companies still fail to operate the buildings in a sustainable manner since few have been authorized to do so, i.e., ISO 14001 (environmental management systems), ISO 9001 (quality management systems), GB/T 23331 (energy management systems), etc. Although the impact of NGOs on GB post-occupancy in China is the least of the various groups, they still have a substantial interest in delivering sustainability throughout the project lifecycle - especially during the operation stage. According to two NGO participants, their lack of overt engagement is because of the fear that the decision-maker(s) may misinterpret their contribution as creating a confrontational atmosphere. Three academics, on the other hand, suggested strengthening the supervisory role of NGOs to warrant a more transparent decision/evaluation process and more reliable decision/evaluation results. The government participants agreed, further suggesting that the NGOs would also benefit from soliciting advice from technical experts before making their proposals.

## 7. Conclusions

Sustainability-related industries are booming in China, and particularly the green AEC industry. To improve the effectiveness and efficiency of promoting sustainable buildings in the country, it is suggested that project performance is monitored throughout the lifecycle instead of the current practice of focusing solely on the design stage. GB POE can therefore be turned into an indispensable element to determine overall project success. Engaging relevant personnel has proven to be a solution to the problem of lack of transparency/credibility during assessment. Some participatory exercises can be unsatisfactory, however, because of the diverse influences of different stakeholder groups. This study provides a quantitative analysis of the impact of various stakeholder groups during GB POE, indicating that government organizations have the most influence, followed by owners and end-users, with property management companies and NGOs having the least influence. A series of interviews provide a qualitative validation of survey findings. Naturally, governments at various levels and owners should bear the most fundamental responsibilities to further sustainable design/construction/operation from both macro and micro perspectives. Property management companies and NGOs, on the other hand, play their part too with significant roles as direct executor and supervisors; different strategies could be applied to improve the current situation, such as material incentives for property management companies and raising the awareness of NGOs. The contribution of end-users needs to be viewed dialectically. On the one hand, they have shifted their POE roles to some degree from previous passive executives to currently active co-assessors. On the other hand, their influence on POE is still relatively limited, as their input can hardly affects the results. Future research will be directed at establishing an indexing system to assess GB post-occupancy performance and proposing a participatory evaluation framework for the rational distribution of participants from various stakeholder groups.

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