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

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Paper for

BUILDING AND ENVIRONMENT

**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.

31 **Stakeholder Impact Analysis during Post-occupancy**

32 **Evaluation of Green Buildings – A Chinese Context**

33

34 **Abstract**

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

54

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

57

58 **1. Introduction**

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

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

77 In response, this paper provides a means of analyzing GB operations stakeholders
78 thoroughly and comprehensively, to quantify their influence during POE. Through

79 this, various stakeholder groups are prioritized and hence overall stakeholder
80 satisfaction can be maximized by improving the efficiency and effectiveness of
81 participatory GB POE. A brief review of GB concepts and participatory POE theories
82 is presented, followed by an introduction to the research process/methods used. The
83 results of a survey are next described to reveal the different impact levels of various
84 stakeholder groups involved in GB POE. Subsequent validation interviews are then
85 discussed and more in-depth opinions concerning the development of GB in China are
86 examined. A proposed research agenda concludes the paper.

87

88 **2. The Definition of Green Building**

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

96

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

102

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

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

122

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

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

130

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

137

138 **3. Stakeholder Participation in the Post-occupancy Evaluation of** 139 **Green Buildings**

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

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

152 In China, this has created an anomaly of alarming proportions as, of the 1,446 projects
153 - equivalent to an overall area of 162,900,000 m² - passing assessments by January
154 2014 since the April 2008 introduction of its GB evaluation labeling policy, an
155 estimated 92% have not achieved the designed performance during their operation
156 stage (MOHURD, 2014). It seems that many proposals exaggerated their expected
157 energy performance when seeking their green labels, as they have later been found to
158 have an actual energy consumption far exceeding their designed levels, sometimes
159 with indoor air quality even worse than unlabeled buildings. Li *et al.* (2016a, 2017)
160 attribute this shortcoming to the lack of a participatory evaluation framework to assess
161 the life-cycle sustainability of GB.

162 According to André *et al.* (2006), a good participatory mechanism should involve
163 individuals and groups positively or negatively affected by a proposed intervention
164 (e.g., a project, program, plan or policy) throughout the decision/evaluation process.
165 Through this, stakeholders can influence and share control over development
166 initiatives as well as the decisions/evaluations that most affecting them (Amoatey and
167 Hayibor, 2017; Ng *et al.*, 2012; Li *et al.*, 2012a, b). Creighton *et al.* (1998) highlight
168 16 techniques for facilitating participatory decisions/evaluations, comprising
169 interviews, field offices, hotlines, displays or exhibits, newspaper inserts, information
170 bulletins, surveys, participatory television, brochures, contests, mediation and
171 charrettes, Delphi, simulation games, providing technical assistance to stakeholders
172 and training programs for stakeholders. No consensus has yet been reached in
173 formulating a universal and effective way of engaging stakeholders after comparing
174 the advantages and disadvantages of each technique. However, it is accepted by
175 researchers and practitioners that the advantages of participatory decision/evaluations
176 generally overshadow the disadvantages (Li *et al.*, 2013; Li *et al.*, 2016b, c). IAPP

177 (2007), for example, identifies the value of a participatory approach to
178 decisions/evaluations as: (i) the public have a say in the actions that could affect their
179 lives; (ii) there is a good chance that the public's contribution will influence the
180 decisions/evaluations; (iii) sustainable decisions/evaluations are promoted by
181 recognizing and communicating the needs and interests of all participants; (iv) it seeks
182 and facilitates the involvement of those potentially affected or interested; (v) it
183 promotes input from participants in designing how they should participate; (vi)
184 participants are provided with the information they need to participate in a meaningful
185 way; and (vii) it communicates to participants how their input affects the
186 decision/evaluations.

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

199 *Stakeholder theory* offers some insights into a solution. The theory began in the
200 1960s, with researchers at the Stanford Research Institute first proposing the
201 definition of stakeholders as groups without whose support an organization would

202 cease to exist (Olander, 2007). Freeman (1984, p. 46) later further interpreted this as
203 “any group or individual who can affect, or is affected by, the achievement of the
204 organization’s objectives”. Clarkson (1995), on the other hand, explains the
205 differences between *stakeholders* and *shareholders* – considering stakeholders’
206 satisfaction (instead of that of shareholders) as an indispensable criterion for
207 evaluating corporate success. The application of stakeholder theory has now far
208 extended from its original implementation in strategic management, to various fields
209 including construction project management (Atkin and Skitmore, 2008) where
210 stakeholders are defined as individuals and organizations who may affect, or be
211 affected, in a positive or negative manner throughout the project cycle (PMI, 2008).
212 Of relevance also is the classification of stakeholders in the construction industry by
213 Takim (2009) and Winch (2002) which comprises: (i) *internal* stakeholders, who have
214 a legal contact with the client and those clustered around the client on the demand
215 side (e.g. employees, customers, end-users and financiers) and the supply side (e.g.
216 architects, engineers, contractors, trade contractors and material suppliers); and (ii)
217 *external* stakeholders which include private actors (e.g. local residents, landowners,
218 environmentalists and archaeologists) and public actors (e.g. regulatory agencies, and
219 local and national governments).

220 For GB, the stakeholder groups are usually better defined, as schemes of this type
221 should have environmental, social and economic effects on the public in general
222 (Manowong and Ogunlana, 2008). Li *et al.* (2016a, 2017), for example, identify the
223 seven typical stakeholder groups of sustainable projects throughout the lifecycle as
224 government organizations, owners, designers, contractors, end-users (Liang *et al.*,
225 2016a, b, c), non-governmental organizations (NGOs), and other relevant groups
226 (material/technology providers, etc.) (Göçer *et al.*, 2015).

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

234

235 **4. Research Design**

236 *4.1 A quantitative method for prioritizing stakeholder impact*

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

244 Two elements are considered here, i.e. the *stakeholder attribute value*, A (Olander,
245 2007), and the *vested interest–impact index*, ViI (Olander, 2007). Olander (2007)
246 conceptualizes stakeholder attributes with three sub-components, namely: power (the
247 stakeholder’s power to influence, P), legitimacy (the legitimacy of stakeholder
248 relationships, L), and urgency (the urgency of the stakeholder’s claim, U). The
249 stakeholder attribute value (A) can be obtained by first determining the weight of each

250 attribute (P , L and U) and then summing the weighted attributes possessed by the
251 group (Olander, 2007).

252

$$253 \quad A = Weight_{(P)} + Weight_{(L)} + Weight_{(U)} \quad (1)$$

254

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

260

$$261 \quad ViII = \sqrt{\frac{v \times i}{5 \times 5}} \quad (2)$$

262

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

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

266

$$267 \quad FoSIL = A \times ViII = A \times \sqrt{\frac{v \times i}{25}} \quad (3)$$

268

269 4.2 Research stages and methods adopted

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

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

283 **Table 1**
 284 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

285

286 A structured questionnaire (both in English and Chinese) was then developed and
287 a survey conducted to elicit views on the probability of impact (v) and the level of
288 impact (i) of the major stakeholder groups during the POE of sustainable projects. To
289 do this, a 5-point Likert scale was incorporated with 1 representing “very low” and 5
290 denoting “very high”. The selection of respondents follows the purposive sampling
291 approach, requiring a minimum of three years’ practical or research experience in
292 sustainable construction-related industries, or in relevant disciplines, or having been a
293 user of green residential/public projects in China. This is in line with Akadiri and
294 Fadiya’s research, where a similar sampling technique was adopted to analyze the
295 determinants of environmentally sustainable practices in the UK construction industry.
296 According to Teddlie and Yu (2007), purposive sampling techniques are often used
297 when the researcher wants to select a purposive sample representing a broader group
298 of cases as closely as possible, or to set up comparisons between different types of
299 cases on a certain dimension of interest. It proves to be effective when only limited
300 numbers of people can serve as primary data sources due to the nature of the research
301 design and aims/objectives. This study focuses on GB POE – a relatively new concept
302 in China, leading to concerns over the value of the data if obtained by probability
303 sampling. As a non-probability sampling method, purposive sampling techniques
304 were considered more appropriate, given the lack of experienced
305 practitioners/researchers in the GB POE field in China. It was expected that
306 purposively selecting the research participants would improve the richness of the data
307 obtained. To ensure the efficiency of the purposive sampling process and the

308 effectiveness of the results, the selection criteria for the interview/questionnaire
 309 participants were carefully established. A consensus was reached based on the
 310 continuous discussions of the research group as well as the comments solicited from
 311 the experts in the pilot study.

312 Before undertaking the main survey, a pilot study was carried out with 14 experts
 313 from 7 relevant groups. This lead to some changes to the original version of the
 314 questionnaire, e.g. the original 7-point Likert scale was modified to a 5-point Likert
 315 scale to facilitate the participation of respondents with different educational
 316 backgrounds from the end-user and NGO groups. 847 updated questionnaires were
 317 then dispatched by mail, email, fax or street survey, and 198 were returned providing
 318 a total response rate 23.38% (Table 2) which is regarded as acceptable for research of
 319 this kind (Akintoye, 2000). The profiles of the respondents are summarized in Table 3,
 320 of which 32 (16.16%) are from academia, 30 (15.15%) from the end-user group, 29
 321 (14.65%) from the owner group, 28 (14.14%) from the contractor group and 27
 322 (13.64%) from the designer group. The least numbers of respondents are from
 323 government department (26) and NGOs (26). As Table 3 indicates, all the respondents
 324 fulfil the selection criteria, with 36 (18.18%) even equipped with more
 325 theoretical/practical experience in relevant fields.

326 **Table 2**
 327 Response rate.

Group	No. of questionnaires		Percentage return (%)
	<i>Sent</i>	<i>Returned</i>	
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

329
 330

331 **Table 3**
 332 Profile of respondents.
 333

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%)

334

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

348

349 **5. Results**

350 *5.1 Stakeholder attribute value (A)*

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

356

357 **Table 4**
 358 Superiority chart method
 359

	Power (<i>P</i>)	Legitimacy (<i>L</i>)	Urgency (<i>U</i>)	Rating
Power (<i>P</i>)	R _{PP}	R _{PL}	R _{PU}	Sum (R _{PP} , R _{PL} , R _{PU})
Legitimacy (<i>L</i>)	R _{LP}	R _{LL}	R _{LU}	Sum (R _{LP} , R _{LL} , R _{LU})
Urgency (<i>U</i>)	R _{UP}	R _{UL}	R _{UU}	Sum (R _{UP} , R _{UL} , R _{UU})

360

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

363

364 $R_{xy}=1$, if factor X is more important than factor Y (X, Y belong to *P*, *L* and *U*)

365 $R_{xy}=0.5$, if factor X and factor Y are equally important (X, Y belong to *P*, *L* and *U*)

366 $R_{xy}=0$, if factor X is less important than factor Y (X, Y belong to *P*, *L* and *U*) (4)

367

368 Consequently,

369

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

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

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

373

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

375

$$376 \text{ Weighting of } P = \frac{\text{Rating of } P}{\text{Rating of } P + \text{Rating of } L + \text{Rating of } U}$$

$$377 \text{ Weighting of } L = \frac{\text{Rating of } L}{\text{Rating of } P + \text{Rating of } L + \text{Rating of } U}$$

$$378 \text{ Weighting of } U = \frac{\text{Rating of } U}{\text{Rating of } P + \text{Rating of } L + \text{Rating of } U} \quad (6)$$

379

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

384

385 **Table 5**
 386 Weightings of *P*, *L* and *U* as revealed from first -stage interviews
 387

Group	Interviewee	Rating			Weighting		
		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
Owner	Anonymity	2.5	0.5	1.5	0.56	0.11	0.33
	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
Designer	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
	Anonymity	1.5	0.5	2.5	0.33	0.11	0.56
Contractor	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

	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

388

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

392

$$393 \quad CER_A(G_i) = \frac{O_A^+}{N} \quad (7)$$

394

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

400 The 15 resulting certainty indices are summarized in Table 6. $CER_A(G_i)$, with a
401 minimum value of 0.5, confirms the attachment of a particular attribute to group i . As

402 a result, the *stakeholder attribute value* (A) of each stakeholder group is obtained
 403 (Table 8).

404

405 **Table 6**

406 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

407

408 5.2 Vested interest–impact index ($ViII$)

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

414 5.3 Factor of stakeholder influencing level ($FoSIL$)

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

420

421 **Table 7**
 422 Respondents' rating of the vested-interest levels (*v*) and impact levels (*i*) of different stakeholder groups during post-occupancy of GB.
 423

<i>Group</i>	<i>Number of respondents</i>	Government organizations		Owners		Property management companies		End-users		NGOs	
		<i>v</i>	<i>i</i>	<i>v</i>	<i>i</i>	<i>v</i>	<i>i</i>	<i>v</i>	<i>i</i>	<i>v</i>	<i>i</i>
		<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>
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

424
 425 **Table 8**
 426 Influence of different stakeholder groups during green building post-occupancy
 427

<i>Stakeholder Groups</i>	<i>Attributes</i>			<i>Stakeholder influence</i>				
	<i>Power</i>	<i>Legitimacy</i>	<i>Urgency</i>	<i>Stakeholder attribute value</i>	<i>Mean value of the vested interest levels</i>	<i>Mean value of the influence impact levels</i>	<i>The vested interest–impact index (ViII)</i>	<i>The factor of stakeholder influencing levels (FoSIL)</i>
	<i>(P)</i>	<i>(L)</i>	<i>(U)</i>	<i>(a)</i>	<i>(v)</i>	<i>(i)</i>		
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

428

429 **6. Discussion**

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

452 as listed in Table 9 (Xu, 2016). These may serve as references for nearby regions
 453 lacking relevant subsidy measures.

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

Provinces/ Municipalities	Beijing	Shanghai	Shandong	Jiangsu	Guangdong	Shanxi
			15			10
Subsidy Policies (RMB/m²)	22.5	60	One-Star		25	One-Star
	Two-Star	Two-Star	30	15	Two-Star	15
	40	60	Two-Star	One-Star	45	Two-Star
	Three-Star	Two-Star	50		Three-Star	20
			Three-Star			Three-Star

456 Source: Xu, 2016

457
 458 Despite having a relatively high influence, the role of owners in maintaining
 459 expected GB performance during their operation phase is still controversial.
 460 Participants from the designer and contractor groups complained that the reason so
 461 many design innovations fail during post-occupancy could be ascribed to a lack of
 462 owner motivation. The owner representatives interviewed partly accepted these
 463 criticisms but pointed out that they are unfamiliar with the theory/practice of green
 464 operations due to their unrelated backgrounds. An NGO member also added that the
 465 relative high ratio of input/output of sustainable maintenance provides insufficient
 466 incentive for owners. Two interview participants from academia, on the other hand,
 467 proposed other factors to be considered, regarding the motivation of owners to apply
 468 sustainability concepts actively during post-occupancy. These are the partnership
 469 patterns of owners and property management companies, and the constituent
 470 relationships of the owners and end-users.

471 The end-users are another party contributing to GB POE scores (Liang *et al.*,
 472 2016a, b, c) and also play a vital role in project pre-occupancy evaluation (Shen *et al.*,
 473 2013). Shen *et al.* (2013) develop a User Pre-Occupancy Evaluation Method
 474 (UPOEM) to enhance the designer-client communication by applying building
 475 information modeling (BIM), user activity simulation and requirement management

476 techniques. As far as the GB POE is concerned, the two end-users of green
477 residential/public projects interviewed believed that they are increasingly aware of the
478 relationship between their daily behaviors and sustainable building operation. One
479 issue raised by them is that they want to have a say in the POE process instead of
480 merely being informed of the results. The government and academic representatives
481 all agreed with their comments and considered it important to improve the
482 transparency and legitimacy of the evaluation process/result through wider public
483 engagement. That the high level of influence of end-users during GB POE in China,
484 as revealed from this research, does not match the findings of Olander (2007), is
485 probably due to the growing tendency of end-users trying to influence the
486 implementation of projects of various types according to their individual concerns and
487 needs.

488 Property management companies and NGOs have relatively less influence over
489 GB post-occupancy. According to the government and owner groups, the majority of
490 property management companies consider that operating sustainable buildings is a
491 heavy burden due to the associated higher costs involved compared to their
492 conventional counterparts. As commented by two academic participants *“in the*
493 *current management mode of green projects during the operation stage, the property*
494 *management companies neither have responsibility to maintain sustainability nor any*
495 *gains from accomplishing this”*. Another academic suggested incorporating a
496 fluctuating fee contract based on the performance of the property management
497 companies in realizing sustainability aims during post-occupancy. As one government
498 participant pointed out, however, even when financial incentives are available, most
499 property management companies still fail to operate the buildings in a sustainable
500 manner since few have been authorized to do so, i.e., ISO 14001 (environmental

501 management systems), ISO 9001 (quality management systems), GB/T 23331 (energy
502 management systems), etc. Although the impact of NGOs on GB post-occupancy in
503 China is the least of the various groups, they still have a substantial interest in
504 delivering sustainability throughout the project lifecycle - especially during the
505 operation stage. According to two NGO participants, their lack of overt engagement is
506 because of the fear that the decision-maker(s) may misinterpret their contribution as
507 creating a confrontational atmosphere. Three academics, on the other hand, suggested
508 strengthening the supervisory role of NGOs to warrant a more transparent
509 decision/evaluation process and more reliable decision/evaluation results. The
510 government participants agreed, further suggesting that the NGOs would also benefit
511 from soliciting advice from technical experts before making their proposals.

512 **7. Conclusions**

513 Sustainability-related industries are booming in China, and particularly the green
514 AEC industry. To improve the effectiveness and efficiency of promoting sustainable
515 buildings in the country, it is suggested that project performance is monitored
516 throughout the lifecycle instead of the current practice of focusing solely on the
517 design stage. GB POE can therefore be turned into an indispensable element to
518 determine overall project success. Engaging relevant personnel has proven to be a
519 solution to the problem of lack of transparency/credibility during assessment. Some
520 participatory exercises can be unsatisfactory, however, because of the diverse
521 influences of different stakeholder groups. This study provides a quantitative analysis
522 of the impact of various stakeholder groups during GB POE, indicating that
523 government organizations have the most influence, followed by owners and end-users,
524 with property management companies and NGOs having the least influence. A series

525 of interviews provide a qualitative validation of survey findings. Naturally,
526 governments at various levels and owners should bear the most fundamental
527 responsibilities to further sustainable design/construction/operation from both macro
528 and micro perspectives. Property management companies and NGOs, on the other
529 hand, play their part too with significant roles as direct executor and supervisors;
530 different strategies could be applied to improve the current situation, such as material
531 incentives for property management companies and raising the awareness of NGOs.
532 The contribution of end-users needs to be viewed dialectically. On the one hand, they
533 have shifted their POE roles to some degree from previous passive executives to
534 currently active co-assessors. On the other hand, their influence on POE is still
535 relatively limited, as their input can hardly affects the results. Future research will be
536 directed at establishing an indexing system to assess GB post-occupancy performance
537 and proposing a participatory evaluation framework for the rational distribution of
538 participants from various stakeholder groups.

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543 **9. References**

544 Abidin ZN. Investigating the awareness and application of sustainable construction
545 concept by Malaysian developers. *Habitat International* 2010;34(4):421-26.
546 Akadiri PO, Fadiya OO. Empirical analysis of the determinants of environmentally
547 sustainable practices in the UK construction industry. *Construction Innovation*
548 2013;13(4):352-373(22).

549 Akintoye A. Analysis of factors influencing project cost estimating practice.
550 Construction Management and Economics 2000;18(1):77-89.

551 Amoatey C, Hayibor, MVK. Critical success factors for local government project
552 stakeholder management. Built Environment Project and Asset Management
553 2017;7(2):143-56.

554 André P, Enserink B, Connor D, Croal P. Public Participation International Best
555 Practice Principles. International Association for Impact Assessment, Fargo, USA;
556 2006.

557 Atkin B, Skitmore M. Editorial: stakeholder management in construction.
558 Construction Management and Economics 2008;26(6):549-52.

559 Bourne L, Walker DHT. Visualising and mapping stakeholder influence. Management
560 Decision 2005;43(5):649-60.

561 Bourne L, Walker DHT. Project relationship management and the stakeholder circle.
562 International Journal of Managing Projects in Business 2008;1(1):125-30.

563 Clarkson ME. A stakeholder framework for analyzing and evaluating corporate social
564 performance. Academy of Management Review 1995;20(1):92-117.

565 Creighton JL, Priscoli JD, Dunning CM. Public Involvement Techniques: A Reader of
566 Ten Years Experience at the Institute for Water Resources. Institute for Water
567 Resources, U.S. Corps of Engineers, VA, USA; 1998.

568 Deuble MP, Dear RJD. Green occupants for green buildings: the missing
569 link?. Building & Environment 2012;56(10):21-7.

570 Freeman RE. Strategic management: A stakeholder approach. Pitman, Boston, USA;
571 1984.

572 Göçer Ö, Hua Y, Göçer K. Completing the missing link in building design process:
573 enhancing post-occupancy evaluation method for effective feedback for building
574 performance. *Building & Environment* 2015;89:14-27.

575 IAPP. IAP2 Core Values for Public Participation. International Association for Public
576 Participation, Colorado, USA; 2007.

577 Johnson G, Scholes K. *Exploring corporate strategy*. London: Prentice Hall Europe;
578 1999.

579 Li HY, Ng ST, Dong YH. Stakeholder Analysis of Sustainable Construction in China.
580 Proceedings of 21st International Conference on “Advancement of Construction
581 Management and Real Estate”, 14–17, Dec. 2016, Hong Kong, China; 2016a

582 Li HY, Zhang XL, Ng ST, Skitmore M. Quantifying Stakeholder Influence in
583 Decision/Evaluations relating to Sustainable Construction in China – A Delphi
584 Approach. *Journal of Cleaner Production*, DOI: 10.1016/j.jclepro.2017.04.151.

585 Li THY, Ng ST, Skitmore M. Public participation in infrastructure and construction
586 projects in China: From an EIA-based to a whole-cycle process. *Habitat
587 International* 2012a;36(1):47-56.

588 Li THY, Ng ST, Skitmore M. Conflict or consensus: An investigation of stakeholder
589 concerns during the participation process of major infrastructure and construction
590 projects in Hong Kong. *Habitat International* 2012b;36(2):333-42.

591 Li THY, Ng ST, Skitmore M. Evaluating stakeholder satisfaction during public
592 participation in major infrastructure and construction projects: A fuzzy approach.
593 *Automation in Construction* 2013;29:123-35.

594 Li THY, Ng ST, Skitmore M. Modeling multi-stakeholder multi-objective decisions
595 during public participation in major infrastructure and construction projects: a

596 decision rule approach. *Journal of Construction Engineering and Management*
597 *ASCE* 2016b;142(3): 04015087-1-04015087-13.

598 Li THY, Ng ST, Skitmore M, Li Nan. Investigating Stakeholder Concerns during
599 Public Participation. *Proceedings of the Institution of Civil Engineers-Municipal*
600 *Engineer* 2016c;169(4):199-219.

601 Liang HH, Chen CP, Hwang RL, Shih WM, Lo SC, Liao HY. Satisfaction of
602 occupants toward indoor environment quality of certified green office buildings
603 in Taiwan. *Building & Environment* 2014;72(1):232-42.

604 Liang X, Hong T, Shen GQ. Occupancy data analytics and prediction: a case study.
605 *Building & Environment* 2016a;102:179-2.

606 Liang X, Hong T, Shen GQ. Improving the accuracy of energy baseline models for
607 commercial buildings with occupancy data. *Applied Energy* 2016b;179:247-60.

608 Liang X, Peng Y, Shen GQ. A game theory based analysis of decision making for
609 green retrofit under different occupancy types. *Journal of Cleaner Production*
610 2016c;137:1300-12.

611 Liu YX, Xu TS. Project manager professional credit evaluation model base on fuzzy
612 comprehensive evaluation method and superiority chart. *Economic Management*
613 *Journal* 2014;3(2):19-25 (in Chinese).

614 Manowong E, Ogunlana SO. Critical factors for successful public hearing in
615 infrastructure development projects: a case study of the On Nuch waste disposal
616 plant project. *International Journal of Construction Management* 2008;8(1):37-51.

617 Ministry of Housing and Urban-Rural Development of China. Methods and Practices
618 of Post-Occupancy Evaluation of Green Buildings in China. *Construction Science*
619 *and Technology* 2014;6:28-32 (in Chinese).

620 Mitchell RK, Agle BR, Wood DJ. Toward a theory of stakeholder identification and
621 salience: defining the principle of who and what really counts. *Academy of*
622 *Management Review* 1997;22(4):853-86.

623 Ng ST, Li THY, Wong JMW. Rethinking public participation in infrastructure
624 projects. *Proceedings of the Institution of Civil Engineers: Municipal Engineer*
625 *2012;165(2):101-13.*

626 Ogunbiyi O, Goulding JS, Oladapo A. An empirical study of the impact of lean
627 construction techniques on sustainable construction in the UK. *Construction*
628 *Innovation* 2014;14(1):88-107.

629 Olander S. Stakeholder impact analysis in construction project management.
630 *Construction Management and Economics* 2007;25(3):277-87.

631 Olubunmi OA, Xia B, Skitmore M. Green building incentives: A review. *Renewable*
632 *and Sustainable Energy Reviews* 2016;59:1611-21.

633 Parkin S, Sommer F, Uren S. Sustainable development: understanding the concept
634 and practical challenge. *Engineering Sustainability* 2003;156:169-71.

635 PMI A guide to the project management body of knowledge (4th edition). *Project*
636 *Management Institute, Pennsylvania, USA; 2008.*

637 Robichaud LB, Anantatmula VS. Greening project management practices for
638 sustainable construction. *Journal of Management in Engineering*
639 *2010;27(1):48-57.*

640 Shen W, Zhang X, Shen GQ, Fernando T. The user pre-occupancy evaluation method
641 in designer–client communication in early design stage: a case study. *Automation*
642 *in Construction* 2013;32(4):112-24.

643 Shi Q, Yan Y, Zuo J, Yu T. Objective conflicts in green buildings projects: a critical
644 analysis. *Building & Environment* 2016;96:107-17.

645 Takim R. The management of stakeholders' needs and expectations in the
646 development of construction project in Malaysia. *Modern Applied Science* 2009;
647 3(5):167-75.

648 Teddlie C, Yu F. Mixed methods sampling. *Journal of Mixed Methods Research* 2007;
649 1:77-100.

650 Wang L, Zhou XH, Wang YQ. A review on the research of project stakeholder impact
651 evaluation. *Project Management Technology* 2012;10(9):56-60.

652 Winch GM. *Managing construction projects: An information processing approach*.
653 Blackwell Science Ltd., Oxford, UK; 2002.

654 Xu ZQ. An analysis of green building incentive policies and recommendations for the
655 13th five-year plan. *Architecture* 2016;(07):8-17 (in Chinese).

656 Yu L, Ding R, Gao W, Wang H, Feng G. The practice research based on the POE
657 system of environmental performance of green residential building. *Procedia*
658 *Engineering* 2016;146:204-09.

659