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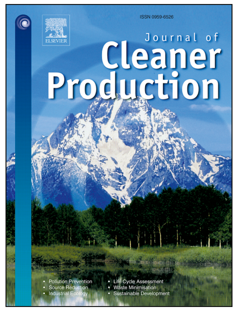

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Risk Perceptions of the Life-cycle of Green Buildings in China

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Abstract: While the numerous benefits of green construction have been widely recognized, the risks associated with green buildings have however not been addressed appropriately. In response to this knowledge gap, this study aims to assess the risk factors (including political risks, social risks, certification risks, financial/cost risks, quality/technological risks and managerial risks) of the life-cycle of green buildings in China and prioritize their importance based on probability of occurrence and degree of influence. Data were collected through a questionnaire distributed to experts in the construction industry. A Kendall's concordance test followed by a Spearman's rank correlation test was then used to test the consistency of risk ranked by experts from different groups. As a result, among 56 risk factors, 36 are perceived as key risk factors affecting the success construction of green buildings. In the ranking of risk importance, there are obvious differences between owners and contractors, owners and resident engineers, and designers and contractors. The findings present the differences of risk importance among stakeholders and provide a basis for different project participants to implement appropriate risk management strategies according to their perceptions of risk importance.

Keywords: green buildings; life-cycle; risk assessment; project participants; questionnaire survey.

Introduction

Green buildings have gained a remarkable momentum in the past few years due to the demand of more sustainable buildings around the world. This has been demonstrated by the rapidly increased green building space across the globe. Currently, more than 12.4 billion square feet of building space in over 150 countries and territories participate in some form or adaptation of the LEED (Leadership in Energy and Environmental Design) system and 1.85 million square feet of building space are certified by LEED per day around the world (Green Building Council, 2015). More than 425,000 buildings have been certified by BREEAM (Building Research Establishment Environmental Assessment Method) and over 2 million buildings have been registered for certification by BREEAM since it was first launched in 1990 (Building Research Establishment, 2015). Building green is deemed to be an effective way to resolve the conflicts between rapid development of the construction industry and the preservation of resources while having less impact on the environment and promoting renewable and clean energy. Green constructions have become a viable alternative in the construction building industry in many developed countries such as US, Canada, United Kingdom, etc. While such numerous potential benefits of green buildings as low energy comsumption, environmental friendliness, improvement of occupants' health and wellbeing and conservation of resources have been highlighted (Poveda and Young, 2015), the risks associated with green buildings have been undermined. The development of green buildings is not always smooth. Barriers such as greater complexity, lack of understanding of sustainability, and a greater possibility of cost overrun have hindered the dissemination of green buildings (Kang et al., 2013). Moreover, problems arouse from building green have also been gradually revealed. The United States Green Building Council (USGBC) has pointed out that a quarter of the new buildings that have been certified by LEED do not save as much energy as the designs have predicted (Holbrook, 2009). A panel discussion, conducted by the USGBC, has concluded that contemporary methods of constructing green buildings are relatively young, and the use of new technologies and approaches could lead to potential risks. As the green building industry matures, specific risks relating to expectations, regulations, and new technology should be addressed. Construction industry should therefore take up new challenges when dealing with risk management mechanisms (USGBC. 2009).

Green construction has proven to be one of the most important carriers for promoting the growth of new energies and new materials. The development of green buildings is in demand in both technical expertise and market needs (Chou, 2011). However, the inherent risks of green projects impact heavily on the development of green buildings. It is therefore important to investigate issues relating to the development of green buildings and explore the impact. Despite the concern of many scholars and practitioners in green building developed countries, little research has been undertaken within the construction domain in China where green building is immature regarding the risks involved in building green. In response to this knowledge gap, the current research uses the Green Building Risks Questionnaire developed by Qin et al (2013) to assess the 56 risk factors (including political risks, social risks, certification risks, financial/cost risks, quality/technological risks and managerial risks) that have been identified throughout the life-cycle of green buildings, and to prioritize their importance based on probability of occurrence and degree of influence.

Data were collected through an empirical questionnaire survey among the owners, contractors, resident engineers, and designers. This research helps different project participants to focus on the key risk factors throughout the life-cycle of green buildings and to implement effective risk mitigation measures in a proactive manner. This study is expected to benefit both academic researchers and industrial practitioners by presenting the differences of risk importance among stakeholders and establishing a sound foundation for further such research as an international comparison of risk assessment among green projects.

Literature Review

Green building (GB) refers to the life-cycle of a building that maximizes resources (energy, land, water, and materials), protects the environment, reduces pollution, provides people with healthy, comfortable and efficient use of space, and is constructed in harmony with nature (GB/T 503078-2014). Green buildings embody more complicated project objectives and inherent risks than conventional buildings.

Previous studies on risks relating to green buildings are mainly based on researchers' personal opinions with less support of empirical evidence. For example, Tulacz (2008) points out that the main risk for green buildings is the failure to obtain green certification. Other important risks involve those relating to new products and technologies, design failure, delays from lack of green-product availability, and unclear division of green certification responsibility. D'arelli and Vyas (2008) believe that the main factors affecting green buildings to obtain a LEED certification include the supply chain under the control of subcontractors and suppliers, inevitable change and substitutions in the construction, and project green certification is authenticated by a limited liability of a third party, etc. Glavinich (2008) in his book indicates that sustainable building design and construction can impact the contractor's material and equipment procurement, sequencing and scheduling of work, job-site productivity, and commissioning and closeout activities. Buckley (2009) points out that owners and developers are faced with more financial and regulatory risks. Failure to achieve green certification can result in onerous code violations or lead to the loss of significant tax credits. At the same time, project teams will encounter a lot of gray areas and access to limited coping approaches in green construction. Robichaud and Anantatmula (2011) indicate the barrier for green building to expand is the risk to deliver a green project within acceptable cost constraints. Although many researchers have demonstrated that high-performance sustainable buildings bring more safety to construction workers (Rajendran et al., 2009;

Fortunato et al., 2012), fewer people have paid attention to the risks of green buildings due to the rapid development of the industry (Frasier, 2012). Zou and his research team are the pioneers who study the risks of green buildings in Australia. They identify the 12 core risks that would influence the green design certification of commercial buildings (Rischmiller, 2009; Zou et al., 2010), and identify and manage the risks in green building development from a supply chain perspective (Zou and Couani, 2012). Their recent research work adopts a social network analysis (SNA) method to assess and analyse the risks and their interactions in complex green building projects (Yang and Zou, 2014) and identify the critical stakeholders and risks in green building development projects (Yang and Zou, 2016). Qin and her research team have been investigated the risks of green buildings in China construction industry since 2010 year (Qin and Wan, 2012; Wan and Qin, 2013; Qin and Jing, 2013; Qin et al., 2014a; Qin et al., 2014b). They have identified risk factors across the life-cycle of green buildings and have established a risk-list that affects the success of green buildings. The above researches have given us a great inspiration and guidance. Table 1 summarizes the research methods and the results of green building risks in China and other countries.

Table 1. Literature Review of risk identification methods and results of GB

Source	Author (year)	Research method	Results
Researches in other countries	Tulacz (2008)	Lawsuit case collection	The collection of lawsuit cases indicated that green buildings risks have gradually been exposed and the risk problems of green buildings have also been put forward.
	Marsh (2009)	Forums	The research team in the U.S. identified more than 50 risk factors which were consolidated into 10 categories, the top five risk categories were: financial, standards of care/legal, performance, consultants and subcontractors, and regulatory.
	Rischmiller (2009); Zou et al. (2010）	Case study + Expert discussion	This was a case study on green commercial buildings in Australia. Group discussion was adopted as a methodlogy for field work and 43 risk factors were identified from various perspectives of stakeholders.
	Zou and Couani. (2012）	Questionnaire survey	The study identified the risks in green building development from a supply chain perspective and 40 supply chain risk factors were identified and ranked by respondents according to their level of importance in green buildings.
	Yang et al. (2016）	group workshops+ face-to-face interviews+ desktop studies (SNA)	The research developed an interactive network model of the risks associated with different stakeholders in green building projects by using SNA method and evaluated the interaction between risk factors.
Researches in China	Xiao et al. (2008); Ding et al. (2009); Zhou et al. (2010);	Theoretical research	The study identified the risks of green buildings in the construction phase in China.
	Li et al(2011)	Case study (Expo Project)	In this study, three major categories of risk energy saving system of the Expo project were identified. They are the technological risks, economic and the managerial risks, and the social and environmental risks. The study was followed by an analysis of 12 sub-risks.
	Zhang et al. (2011)	Theoretical research	The study explored the risk factors of the development of green buildings in Chinese countryside
	Wan and Qin. (2013）	Expert interview + pre-survey Questionnaire survey	In this research, 52 internal risk factors and 10 external risk factors of green buildings were identified and a risk list consisted of 62 risk factors that affected the success of green buildings in China was established. A statistical analysis was used to evaluate the risk probability, risk impact, and risk significance.
	Qin et al. (2013)	Pre-survey +Expert interview	In this study, 56 risk factors were identified across the life-cycle of green buildings in China using an integrated approach
	Qin and Jing. (2013)	Questionnaire survey	Questionnaire survey was adopted to collect experts' opinions on the probability of risk occurrence and risk impact of GB. The data were analyzed by using the SPSS software with descriptive statistics and inferential statistics
	Qin et al. (2014)	Expert interview +Questionnaire survey(FA)	The research investigated the differentiation of green building projects risks between different climate，different regions and different cultural backgrounds. 43 risk factors were identified from green buildings in Haixi region and 8 common factors were extracted to form a risk

		evaluation function.
Qin et al. (2014)	Questionnaire survey(SEM)	This study established a risk measurement and evaluation hypothesis model based on the SEM in China. The impact factors and paths including the direct effect, indirect effect and total effect of 31 key risk factors, and five stages of the-life cycle of green buildings were analyzed.

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Based on the China Green Building Evaluation Criteria (GB/T 503078-2014) and the characteristics of green buildings, this study has divided the life-cycle of green buildings into five stages: namely, planning stage, design stage, construction stage, trial operation stage, and operation and maintenance stage. Compared with the major divisions of the life-cycle of green buildings in other developed countries, this study has expanded the trial operation stage, while the scrap demolishment and recycling stage has been abolished. The main reason is that green design certifications and green operation certifications are two independent certifications in China. A green design certification can be obtained in the design stage, but the operation certification can only be issued after a green building has passed the construction quality inspection, been put into use for more than a year, and been valid for three years. Thus, the duration between the building being put into use and eligible to be certified is known as the trial operation stage. Moreover, since green building practices in China are still in their infancy, and have not yet entered the scrap demolishment and recycling stage, this study has not considered the risks of that stage, which can be made up in future studies if necessary.

Research Method

A Green Building Risks Questionnaire developed by Qin et al (2013) is used in this study, in which 56 risk factors (including political risks, social risks, certification risks, financial/cost risks, quality/technological risks and managerial risks) have been identified vary and unequally distributed throughout the life-cycle of green buildings. There are more barriers in planning stage and construction stage than the other stages, including 13 risk factors at planning stage, 9 risk factors at design stage, 19 risk factors at construction stage, 9 risk factors at trial operation stage and 6 risk factors at operation and maintenance stage. The questionnaire was specially developed to identify and assess the risk factors of green buildings. A preliminary list of risk factors was established in accordance with the characteristics of China throughout the life-cycle of green buildings from a comprehensive literature review and this list was presented through interviews to the experts with hands-on experience of green buildings for their comments. These comments were then incorporated in the formulation of the final risk identification list, which lays out the foundation for current research. Therefore this research adopts the questionnaire developed by Qin et al (2013) and further assesses the risk importance across the life-cycle of green buildings based on probability of occurrence and degree of influence. Due to the word-limit requirement, the risk factor identification process is presented in detail in another paper.

The questionnaire included the following four parts: the first part deliberately introduced the research background and purpose; the second part was intended to gather information about the respondents' profile, including their education background, position, role and work experience with green buildings; the third part listed the risk factors identified in each stage of the green buildings life cycles with a detailed interpretation to ensure that all respondents have an accurate understanding of risk factors. For each risk factor, participants were asked to assess the risk probability of occurrence (P) and degree of influence (I) based on a 5-point Likert scale (1 = rare; 2 = unlikely; 3 = moderate; 4 = likely; 5 = almost certain) for risk probability of occurrence; and (1 = very low; 2 = low; 3 = average; 4 = high; 5 = very high) for degree of influence according to their own knowledge and work experience. The fourth part was comprised of open-ended questions for respondents who would like to put forward any comments on the questionnaire including suggestions for improvement. The questionnaires were distributed either directly to the subjects or through email.

To insure the validity of research, the survey respondents were selected based on two criteria,

1) experts and scholars who engaged in green buildings and risk management, and managers who held positions in either high or middle level in the company; 2) the practitioners in green buildings, including the owners, contractors, resident engineers, and designers. 125 questionnaires were sent to the experts, scholars, and practitioners associated with the construction industry. A total of 84 questionnaires have been received, 10 questionnaires were returned with half completed or ambiguous information thus excluded from the research. The remaining 74 respondents either had obtained hands-on experience in green projects or they declared to have well understanding of the green buildings even though without the direct exposure to green projects before. Therefore, only the data and perceptions obtained from these 74 responses were used for further data analysis, representing a response rate of 59.2%. The response rate has been considered adequate and representative when compared with other similar researches in construction management (Wang et al., 2004). From the profiles of respondents, it can be seen that the respondents covered all the known expert sources (Table 2). Most of the informants are of high level of education with certain understanding or hands-on experience of green buildings. Therefore, the data have been viewed as reliable and satisfactory for the purpose of this research.

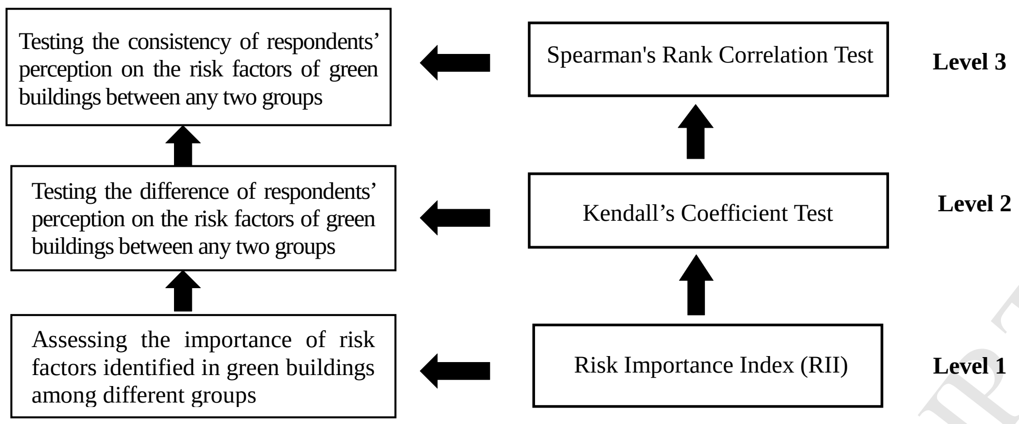
Table 2. Profiles of respondents

1) Education level	College	Bachelor	Master	Doctor		
	9.46%	52.71%	24.32%	13.51%		
3) Role	Researcher	Owner	Designer	Contractor	Resident engineer	
	22.97%	16.23%	29.74%	16.23%	14.83%	
3) Work experience on GB	0	1 year	2 years	3 years	4 years	5 years and above
	27.03%	22.97%	20.27%	10.81%	8.11%	10.81%
4) The number of participating in green projects	0	1	2	3	4	5
	29.7%	31.1%	20.3%	9.1%	1.4%	9.5%

The Cronbach's Alpha coefficient (α coefficient) has been used to verify the reliability of the current study. A coefficient ranges from 0 to 1. A higher value indicates a stronger internal consistency. In general, 0.7 <α <0.9 indicates a highly credibility. In this study, the Cronbach coefficient of the risk probability of occurrence and degree of ham were calculated to be 0.958 and 0.961, respectively, indicating that the research has shown a good credibility and the data are reliable and can be used for further analysis.

Data Analysis

Since there are numerous risks influencing the implementation of green goal in the life cycle of green buildings, trying to identify all the risks can be time-consuming and counter productive (ANDI, 2006). Attempts to consider every risk have also been proved to be a failure (Barkley, 2004). An effective method of risk management has therefore been used to identify the most significant risk in this study and Risk Importance Index (RII) is the most widely used method to find the key risks among other risks. Fang et al. (2004), Chan et al. (2011) and Zou et al. (2007) together used Risk Importance Index (RII) to measure the probability, impact, and rank of risks. In a research of ranking and analyzing risks in target cost contracts, Chan et al. (2011) used the Kendall collaborative coefficient to test the consistency of risks ranked by clients, contractors and consultants respectively. They further used the Spearman's rank correlation test to examine the strength of such consistency between clients and contractors, clients and consultants, and contractors and consultants. Tang et al. (2007) also adopted a similar approach in their research. As such, this study has used the Kendall coefficient test to measure the agreement of different surveyed respondents, including owners, contractors and resident engineers, on their ranks of risk factors based on probability and influence. Spearman’s rank correlation coefficient has also been applied to study the strength of ranking relationship between the three groups: owners and contractors, owners and resident engineers, contractors and resident engineers. A three-level data-analysis approach has been adopted as illustrated in Fig 1.



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210 Fig. 1. A three-level data analysis framework

Risk importance index

To calculate the identified risks importance, the literature tends to use *RII* (risk importance index) to rank the risk factor (Fang et al., 2004; Chan et al., 2011; Zou et al., 2007), the RII_j^i is calculated by formula (1).

$$RII_j^i = P_j^i I_j^i \quad (1)$$

RII_j^i = respondent j assesses the influence of risk i have on the achievement of green building goal; i = the serial number of risk, $i \in (1, 56)$; j = the serial number of respondent, $j \in (1, n)$, n= the total number of respondents; P_j^i = the score of respondent j assesses the probability of risk i; I_j^i = the score of respondent j assesses the influence of risk i. The average importance of each risk index can be calculated by formula (2).

$$RII^i = \frac{1}{n}\sum_{j=1}^{n} P_j^i I_j^i \quad (2)$$

RII^i = the average importance index of risk i. Then the RII^i is calculated for each risk based on the probability and influence, and these risks are then ranked according to their RII^i. This calculation method is simple, but the calculated value is larger and not convenient for data processing. Therefore, Xu et al. (2010) improved the RII^i formula (2) into formula (3) in a research on the evaluation of risks based on the PPP project.

$$RII^i = \sqrt{\frac{1}{n}\sum_{j=1}^{n} P_j^i I_j^i} \quad (3)$$

Formula (3) does not change the ranking results of risks, but reduces the data size and simplifies the data processing, thus providing a better data explanation. Hence, it has been used to calculate the risk importance index in this study. Table 3 presents the results of risk factors ranked according to their RII^i in the descending order, with the normalized values greater than 0.5 has been chosen as key risk factors for the subsequent factor analysis. This chosen criterion is similar to the research conducted by Xu et al. (2010). Therefore, 36 risk factors have been perceived as important risk factors (in grey), which should be given more attention and be managed better in practice (Table 3).

Table 3. Risk importance index of China's GB projects

ID	Risk factor	$RII=\sqrt{P\times I}$				
		R Mean	*I* Mean	*RII*	Rank	Normalization
8	Government bureaucracy and complicated approval procedures	3.58	3.34	3.458	1	1
52	Inadequate GB maintenance	3.35	3.39	3.370	2	0.881
14	Lack of GB design experience	3.47	3.27	3.369	3	0.879
42	Lack of experienced property management during trial operation stage	3.43	3.29	3.359	4	0.867
1	Inaccurate orientation of project's green-goal	3.22	3.45	3.333	5	0.831
32	High price of GB materials	3.45	3.19	3.317	6	0.810
38	Contractors / subcontractors lack knowledge of GB	3.39	3.23	3.309	7	0.799
35	Lack of experienced green construction workers	3.43	3.19	3.308	8	0.797
51	Lack of experienced property company	3.35	3.26	3.305	9	0.793
37	Resident engineer's poor supervision ability for GB	3.43	3.16	3.292	10	0.776
23	Lack of construction experience in new technologies / materials / equipments	3.27	3.3	3.285	11	0.766
15	Insufficient site investigation lead to the design is not tailored to local conditions	3.18	3.38	3.278	12	0.758
4	Lack of accurate estimate of GBs' long-term return on investment	3.39	3.16	3.273	13	0.7505
36	Lack of experienced resident engineers for GB	3.34	3.19	3.264	14	0.738
2	Inaccurate prediction of market demand for GB	3.2	3.32	3.259	15	0.732
34	Owners lack green construction management experience with GB	3.35	3.11	3.228	16	0.689
44	Lack of cooperation between parties involved in trial operation stage	3.28	3.14	3.209	17	0.664
28	Owner's unexpected cost increases	3.35	3.05	3.196	18	0.647
11	Lack of experienced consultants in GB	3.38	3.01	3.190	19	0.638
10	Incomplete regulations and laws for GB	3.24	3.14	3.190	20	0.638
22	Lack of participation of green project life cycle	3.21	3.16	3.185	21	0.631
53	Unclear responsibility in later upgrade	3.29	3.08	3.183	22	0.629
18	Inaccurate cost estimation of GB	3.15	3.18	3.165	23	0.604
17	Poor constructability of design innovation	3.11	3.22	3.164	24	0.604
45	Operation performance can not reach the goal of project requirement	3.17	3.15	3.160	25	0.598
29	Inaccurate quotation of contractors	3.2	3.11	3.155	26	0.591
5	Lack of consideration of the influence of green goal on project	3.19	3.1	3.145	27	0.577
49	Disputes due to unclear division of green certification responsibilities	3.24	3.03	3.133	28	0.562
6	Inaccurate investment estimate of GB	3.14	3.12	3.130	29	0.557
46	Project evaluation results did not reach the expected Green Star	3.15	3.1	3.125	30	0.550
3	Attitude to financial market is underestimated	3.12	3.12	3.12	31	0.544
30	Risks of project delay	3.24	2.99	3.112	32	0.534
47	Green certification cost increase	3.26	2.96	3.106	33	0.525
20	Unclear responsibility of green certification	3.26	2.95	3.101	34	0.518
55	Unstable operation performance for GB	3.13	3.06	3.095	35	0.510
16	Risks of green design innovation	3.18	3.01	3.094	36	0.508
48	Lack of standard test method for green certification evaluation	3.18	2.97	3.073	37	0.481
43	Incomplete commissioning record of GB	3.19	2.96	3.073	38	0.480
19	Lack of GB certification experience	3.21	2.9	3.051	39	0.451
24	Unstable performance of new green materials/equipments	3.04	3.03	3.035	40	0.429

40	Lack of corresponding contracts for GB	3.22	2.84	3.024	41	0.414
50	GB assessment results deviation	2.97	3	2.985	42	0.361
41	Lack of corresponding insurance products for GB (construction stage)	3.1	2.86	2.978	43	0.351
13	Lack of corresponding insurance products for GB (planning stage)	3.12	2.84	2.977	44	0.350
56	Green products upgrading	3.01	2.89	2.949	45	0.313
39	Lack of information/documents for GB evaluation	3.05	2.84	2.943	46	0.305
26	Lack of new products to meet the requirements of GB	3.01	2.86	2.934	47	0.293
27	High demand of environmental protection for construction site	2.97	2.84	2.904	48	0.252
7	Lack of consideration of the impact of life cycle inflation	2.93	2.85	2.890	49	0.233
12	Poor public acceptance of GB	2.85	2.91	2.890	50	0.219
33	Claims arising from green requirements	2.82	2.93	2.874	51	0.212
25	The use of unauthorized patent technologies in construction	2.74	2.96	2.848	52	0.176
31	Untimely supply of new materials/equipments	2.86	2.82	2.840	53	0.1669
9	GB policies change	2.84	2.81	2.825	54	0.145
54	GB evaluation standard changes	2.79	2.81	2.800	55	0.112
21	Poor communication ability of design team	2.6	2.84	2.717	56	0

Note：Normalized value =（RII actual value－RII minimum value）/（RII maximum value－RII minimum value）

Expert ranking of green building risks

During the life-cycle of green buildings, diverse groups of people, often with very different priorities and goals, had to work together for short-term periods of time. These groups include owners, designers, contractors, and resident engineers. Their perception of the importance of risks in each stage of the life-cycle of green buildings may be different. Therefore, it is necessary to analyze risk importance ranked by experts from different groups (as shown in Table 4). This research has adopted Kendall's concordance test and followed by a Spearman rank correlation test to analyze the differences in risk importance between any two expert groups.

Table 4. The risk importance ranked by experts of different groups

Stage	Risk category	ID	Risk factor	All respondents		Owners		Designers		Contractors		Resident engineers	
				Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Planning stage (13 risks)	Financial	1	Inaccurate orientation of project's green-goal	3.333	5	2.531	55	3.769	1	3.496	7	3.037	34
		2	Inaccurate prediction of market demand for GB	3.259	15	2.670	48	3.410	4	3.075	42	3.217	20
		3	Attitude to financial market is underestimated	3.120	31	2.664	49	3.132	30	3.334	24	3.222	17
		4	Lack of accurate estimate of GBs' long-term return on investment	3.273	13	2.875	32	3.339	12	3.502	6	3.132	28
		5	Lack of consideration of the influence of green goal on project	3.145	27	2.750	40	3.315	14	3.169	37	2.819	43
		6	Inaccurate investment estimate of GB	3.130	29	2.702	45	3.115	34	3.264	28	3.179	23
		7	Lack of consideration of the impact of life cycle inflation	2.890	49	2.694	46	2.929	46	3.300	26	2.450	56
	Political	8	Government bureaucracy and complicated approval procedures	3.458	1	2.999	20	3.685	2	3.421	11	2.988	40
		9	GB policies change	2.825	54	2.750	40	2.814	52	2.999	47	2.729	53
		10	Incomplete regulations and laws for GB	3.190	20	3.122	11	3.139	29	3.249	29	3.454	1
	Social	11	Lack of experienced consultants in GB	3.190	19	2.982	23	3.160	28	3.347	23	3.359	2
		12	Poor public acceptance of GB	2.880	50	2.644	50	3.115	34	2.670	56	3.312	7
		13	Lack of corresponding insurance product for GB (planning stage)	2.977	44	2.914	27	3.130	32	3.040	45	2.775	48
Design stage (9 risks)	Technical/ Quality	14	Lack of GB design experience	3.369	3	3.312	5	3.516	3	3.290	27	3.312	7
		15	Insufficient site investigation lead to the design is not tailored to local conditions	3.278	12	3.085	13	3.248	23	3.362	19	2.730	51
		16	Risks of green design innovation	3.094	36	3.225	8	2.883	49	3.420	12	3.336	6
		17	Poor constructability of design innovation	3.165	24	3.454	1	3.114	36	3.375	18	3.312	7
	Financial	18	Inaccurate cost estimation of GB	3.165	23	3.000	19	3.410	4	3.000	46	3.045	30
	Management	19	Lack of GB certification experience	3.051	39	2.861	33	3.249	21	3.042	43	2.995	38
			Unclear responsibility of green certification	3.101	34	2.814	37	3.127	33	3.249	29	2.730	51
		21	Poor communication ability of design team	2.717	56	2.938	26	2.432	56	2.914	54	2.814	45
		22	Lack of participation of green project life cycle	3.185	21	2.910	29	3.270	18	3.203	34	3.045	30
Construction stage (19 risks)	Technical/ Quality	23	Lack of construction experience in new technologies / materials / equipments	3.285	11	2.999	20	3.295	16	3.414	13	3.359	2
		24	Unstable performance of new green materials/equipments	3.035	40	2.749	42	2.953	45	3.460	8	3.180	21
		25	The use of unauthorized patent technologies in construction	2.848	52	2.540	54	2.955	44	2.946	52	2.766	50
		26	Lack of new products to meet the requirements of GB	2.934	47	2.834	34	2.819	51	3.125	39	3.042	33
		27	High demand of environmental protection in construction site	2.904	48	2.568	53	2.884	48	2.960	50	3.000	37
	Financial	28	Owner's unexpected cost increases	3.196	18	2.995	22	3.269	19	3.411	15	3.265	16

	/Cost	29	Inaccurate quotation of contractors	3.155	26	2.694	46	3.269	19	3.246	31	3.270	14
		30	Risks of project delay	3.112	32	3.122	11	2.920	47	3.164	38	3.269	15
		31	Untimely supply of new materials/equipments	2.840	53	2.744	43	2.839	50	2.875	55	2.772	49
		32	High price of GB materials	3.317	6	3.249	7	3.336	13	3.246	31	3.359	2
		33	Claims arising from green requirements	2.874	51	2.710	44	2.814	52	2.920	53	2.814	45
	Management	34	Owners lack green construction management experience with GB	3.228	16	2.830	35	3.244	24	3.203	33	3.312	11
		35	Lack of experienced green construction workers	3.308	8	2.914	27	3.379	8	3.414	13	3.312	11
		36	Lack of experienced resident engineers for GB	3.264	14	3.042	15	3.198	26	3.453	9	3.180	21
		37	Resident engineers poor supervision ability for GB	3.292	10	3.040	17	3.312	15	3.704	1	3.135	26
		38	Contractors / subcontractors lack knowledge of GB	3.309	7	3.330	2	3.108	38	3.619	3	3.222	17
		39	Lack of information/documents for GB evaluation	2.943	46	2.523	56	3.023	43	2.952	51	3.135	26
		40	Lack of corresponding contracts for GB	3.024	41	2.580	52	3.065	40	3.362	19	2.729	53
		41	Lack of corresponding insurance products for GB (construction stage)	2.978	43	2.625	51	3.215	25	3.111	40	2.909	41
Trial operation stage (9 risks)	Management	42	Lack of experienced property management during trial operation stage	3.359	4	3.132	10	3.359	9	3.583	4	3.222	17
		43	The commissioning record of green building is not complete	3.073	38	2.952	25	3.132	30	3.359	22	3.018	35
		44	Lack of cooperation between parties involved in trial operation stage	3.209	17	3.042	16	3.384	7	3.360	21	3.175	25
	Certification	45	Operation performance cannot reach the goal of project requirement	3.160	25	2.910	29	3.179	27	3.315	25	3.179	23
		46	Project evaluation results did not reach the expected Green Star	3.125	30	2.955	24	3.070	39	3.042	44	3.354	5
		47	Green certification cost increase	3.106	33	3.045	14	3.275	17	2.995	49	3.018	35
		48	Lack of standard test method for green certification evaluation	3.073	37	2.819	36	3.113	37	3.405	17	2.995	38
		49	Disputes due to unclear division of green certification responsibilities	3.133	28	3.263	6	3.340	10	3.089	41	2.807	47
		50	GB assessment results deviation	2.985	42	2.775	38	3.045	41	3.450	10	2.819	43
Operation and maintenance stage (6 risks)	Management	51	Lack of experienced property company	3.305	9	3.312	3	3.385	6	3.544	5	3.132	28
		52	Inadequate GB maintenance	3.370	2	3.312	3	3.339	11	3.639	2	3.312	7
		53	Unclear responsibility in later upgrade	3.183	22	3.037	18	3.025	42	3.180	35	3.305	13
	Political	54	GB evaluation standard changes	2.800	55	2.775	38	2.680	54	3.179	36	2.570	55
	Technical/ Quality	55	Unstable operation performance for GB	3.095	35	2.910	29	3.249	21	2.999	48	3.045	30
		56	Green products upgrading	2.949	45	3.135	9	2.640	55	3.407	16	2.897	42

Comparing the ranking results of risk importance arranged by different expert groups (Table 4), it is perceived that the designers of those different expert groups tended to show a bigger mean value than its counterpart in both planning and design stages of green buildings. This is reasonable because for those designers, the objectives were derived from the perspective of market needs for green buildings and the influence of green-goals to the design. As such it is not surprising for them to give higher rankings on the risk factors identified in the planning stage. Besides, contractors tended to provide high ratings of risk factors identified in the construction stage, trial operation stage, and operation and maintenance stage. The reason might have been that contractors are the most crucial participants in the construction stage, the key stage that makes green-building-design a reality. Thus, it is not surprising that the construction stage was given a higher evaluation on the ranking of risk importance.

In addition, it is interesting to find that resident engineers assigned medium ranking to the risk factors identified in the life-cycle of green buildings. One possible reason might have been that resident engineers are third parties when compared to other participants. Thus, they might have a relatively neutral attitude towards risk factors.

It should also be noted that owners generally gave low ratings to the risk factors identified in the life-cycle of green buildings. This reveals that currently owners have not paid enough attention to the risk factors identified in green buildings in China. To avoid failing to obtain green building certification, it is advisable for owners to equip themselves with the necessary knowledge of possible risks.

Kendall's concordance test

The Kendall’s coefficient of concordance (W) was used to measure the agreement of different respondents on their rankings of risk factors based on mean values within a particular survey group. First, null hypothesis H0，there is no statistically significant difference (rank) between the two populations, so they have the same median for the same risk. If the probability value is less than or equal to the significant level 0.05, the hypothesis H0 can be rejected, indicating that there is a statistically significant difference between the two groups regarding ranking, and vice versa.

The Kendall's concordance test was applied to test how consistent such different groups as the owners, designers, contractors, and resident engineers, agree on the ranks of the risk factors to green buildings, as shown in Table 5. The results showed that there were statistically significant differences (Sig. <0.05) between two paired expert groups on the risk ranking. However it did not clearly point out where the differences were. It is therefore a need to compare the difference between two expert groups. The comparison results are shown in Table 6.

Table 5. Kendall’s test on different groups of experts

N	4
Kendall's W[a]	.504
Chi-Square	110.842
df	55
Asymp. Sig.	.000

a. Kendall's Coefficient of Concordance

Table 6. Kendall's concordance test on the risk importance index between two expert groups

Kendall's concordance / Sig.		Owners	Designers	Contractors	Resident engineers
Owners	Kendall's concordance	——	0.644	0.705	0.699
	Sig.		0.073	0.024	0.027
Designers	Kendall's concordance	——	——	0.674	0.650
	Sig.			0.043	0.066
Contractors	Kendall's concordance	——	——	——	0.642
	Sig.				0.077

Table 6 shows that the Kendall's coefficients between owners and designers, designers and resident engineers, contractors and resident engineers were all under the significance level of 0.05, showing that there is no significant difference between the paired groups on the risk factor ranking in the life-cycle of green buildings. However, significant differences (in grey) have been found between owners and contractors, owners and resident engineers, designers and contractors on the risk factor ranking. In order to calculate the consistency of priorities among different groups regarding the risk probability and the level of influence, the Spearman rank correlation coefficient was used.

Spearman's rank correlation test

The Spearman's rank correlation coefficient is a statistical tool to test the strength of relationship between the rankings of two groups (El-Sayegh, 2008). It is especially designed for ranking exercise. The coefficient, rs, ranges between −1 and +1, where the greater the absolute value of coefficient, the stronger the correlation. Table 7 below shows the Spearman's rank correlation of risks ranked by experts from different groups.

It can be seen from Table 7, the correlation between owners and designers, designers and resident engineers, contractors and resident engineers was significant in the 95% confidence interval, and the correlation coefficients were 0.289, 0.301 and 0.284 respectively. Nevertheless, the correlation between owners and contractors, owners and resident engineers, and designers and contractors was significant only in the 99% confidence interval. The findings showed that there were statistically significant differences among experts from different groups regarding the risk factor ranking in the green buildings life-cycle (in grey). This indicates that different stakeholders have different concerns of green buildings risk management. It is therefore necessary to establish a tailored risk-management procedure based on specific needs.

315 **Table 7.** Spearman's rank correlation test

Spearman's rank correlation test			Owners	Designers	Contractors	Resident engineers
Spearman's rh0	Owners	correlation coefficient	1.000	.289*	.411**	.398**
		Sig. (2-tailed)	——.	.031	.002	.002
	Designers	correlation coefficient	.289*	1.000	.349**	.301*
		Sig. (2-tailed)	.031	.——	.008	.024
	Contractors	correlation coefficient	.411**	.349**	1.000	.284*
		Sig. (2-tailed)	.002	.008	.——	.034
	Resident engineers	correlation coefficient	.398**	.301*	.284*	1.000
		Sig. (2-tailed)	.002	.024	.034	.——

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

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Results and discussions

Overall ranking of the risk factors assessed by experts from five different groups are shown in Table 8. Only those risk factors perceived significantly different in such pairs as owners vs. contractors, owners vs. resident engineers, and designers vs. residents are reported in this paper in order to meet the word-limit requirement.

323 **Table 8.** The top 36 risk importance ranked by experts from different groups

Rank	Owners	Designers	Contractors	Resident engineers	Rank	Owners	Designers	Contractors	Resident engineers
1	risk17	risk 1	risk 37	risk 10	19	risk 18	risk 28	risk 15	risk 42
2	risk38	risk 8	risk 52	risk 11	20	risk 8	risk 29	risk 40	risk 2
3	risk 51	risk 14	risk 38	risk 23	21	risk 23	risk 19	risk 44	risk 24
4	risk 52	risk 2	risk 42	risk 32	22	risk 28	risk 55	risk 43	risk 36
5	risk 14	risk 18	risk 51	risk 46	23	risk 11	risk 15	risk 11	risk 6
6	risk 49	risk 51	risk 4	risk 16	24	risk 46	risk 34	risk 3	risk 45
7	risk 32	risk 44	risk 1	risk 12	25	risk 43	risk 41	risk 45	risk 44
8	risk 16	risk 35	risk 24	risk 14	26	risk 21	risk 36	risk 7	risk 37
9	risk 56	risk 42	risk 36	risk 17	27	risk 13	risk 45	risk 14	risk 39
10	risk 42	risk 49	risk 50	risk 52	28	risk 35	risk 11	risk 6	risk 4
11	risk 10	risk 52	risk 8	risk 34	29	risk 22	risk 10	risk 10	risk 51
12	risk 30	risk 4	risk 16	risk 35	30	risk 45	risk 3	risk 20	risk 18
13	risk 15	risk 32	risk 23	risk 53	31	risk 55	risk 43	risk 29	risk 22
14	risk 47	risk 5	risk 35	risk 29	32	risk 4	risk 13	risk 32	risk 55
15	risk 36	risk 37	risk 28	risk 30	33	risk 19	risk 20	risk 34	risk 26
16	risk 44	risk 23	risk 56	risk 28	34	risk 26	risk 6	risk 22	risk 1
17	risk 37	risk 47	risk 48	risk 3	35	risk 34	risk 12	risk 53	risk 43
18	risk 53	risk 22	risk 17	risk 38	36	risk 48	risk 17	risk 54	risk 47

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Analyses of the differences between owners and contractors

As seen in Table 8, the top five risk factors ranked by owners were "R17 poor constructability of design innovation", "R38 contractors / subcontractors lack knowledge of GB", "R51 lack of experienced property company", "R52 inadequate GB maintenance," and "R14 lack of GB design experience". Two of them were related to the design stage, one was related to the construction stage, and two were related to the operation and maintenance stage. For contractors, the most important risk factors were "R37 resident engineers poor supervision ability for GB", "R52 inadequate GB maintenance", "R38 contractors / subcontractors lack knowledge of GB", "R42 lack of experienced property management during trial operation stage", and "R51 lack of experienced property company". There were two located in the construction stage, two located in the operation and maintenance stage, and one was located in the trial operation stage. Despite the different perception on some risk factors, both owners and contractors had common views on the risk factors "R51 lack of experienced property company" and "R52 inadequate GB maintenance", both were related to the operation and maintenance stage. As regards "R38 contractors / subcontractors lack knowledge of GB", it was associated to the construction stage.

It is interesting to see that "R17 poor constructability of design innovation" and "R14 lack of GB design experience" were ranked 1st and 5th respectively by owners, whereas contractors ranked those two risk factors as 18th and 27th respectively (as seen in Table 4). However, contractors ranked "R4 lack of accurate estimate of GB's long-term return on investment" and "R1 inaccurate orientation of project's green-goal" as 6th and 7th, whereas owners ranked them as 32nd and 55th respectively. The findings reflect that owners believe that the two risk factors (R17 and R14) have important influence on the design, whereas contractors do not think those couple of risk factors will have any significant impact on green constructions. On the contrary, contractors believe the two risk factors (R4 and R1) have important impact on the planning stage, whereas owners hold different views.

It can be seen that the differences between owners and contractors are mainly concentrated in planning stage and design stage. This may be attributed to the fact that currently most of the green projects in China still adopt the traditional project management DBB (Design-Bid-Build) model where contractors are usually not involved in the design stage of the project and doing their work according to construction plans. Therefore contractors may be less sensitive to the risks at the design stage. In addition, Owners do not have sufficient experience of the development of green buildings, resulting in a lack of awareness of risks at planning stage. Furthermore, it is interesting to find that stakeholders generally give low ratings to the risk factors closely related to their behaviours and high ratings to the risk factors associated with other stakeholders' behaviours. This may reflects that stakeholders tend to show an optimistic attitude to the risks that can be controlled by themselves and a pessimistic attitude to the risks that can not be controlled by themselves.

Analyses of the differences between owners and resident engineers

The top five risk factors ranked by resident engineers were "R10 incomplete regulations and laws for GB", "R11 lack of experienced consultants in GB", "R23 lack of construction experience in new technologies / materials / equipments", "R32 high price of GB materials", and "R46 project evaluation results did not reach the expected Green Star". Two were located in the planning stage. Two were located in the construction stage, and one was located in the trial operation stage. However, these five risk factors were ranked 11th, 23rd, 20th, 7th and 24th by owners respectively. In addition to "R32 high price of GB materials", there were significant differences between resident engineers and owners in the ranking of the other four risk factors. There are also disparities between owners and resident engineers beyond the top five risk factors. For example, "R49 disputes due to unclear division of green certification responsibilities" was ranked 6th by owners while ranked 47th by resident engineers. This may be attributed to the fact that risk factor 49, mainly refers to the risks generated from an unclear division of the risk responsibility between owners and contractors in the costruction contract, is not closely related to resident engineers, As such it is not surprising for them to give it a lower ranking. Surprisingly, there is also disparity regarding “R12 poor public acceptance of GB”. This was ranked 7th by resident engineers, but owners only ranked it 50th. The result shows that owners generally provide a low rating on the importance of risks associated with the planning stage, while other participants believe that the planning stage is crucial to the project. It is perceived that owners should have a complete estimation and careful consideration before making a scientific decision in any project.

Both the owners and resident engineers had consistent views on the risks “R52 inadequate GB maintenance”, “R14 lack of GB design experience”, and “R16 risks of green design innovation”.

The risk rankings provided by resident engineers reflect their occupational characteristics. Resident engineers mainly provide a project with advice and management, therefore they are more concerned about the risks relevant to national policies, owner’s management experience and contractors’ construction experience that are closely related to the implementation of a project. Currently resident engineers usually join the project at the construction stage and have limited power to manage the project apart from the quality control in the field. Therefore most of these risks are also unable to effectively control by themselves.

Analyses of the differences between designers and contractors

The top five risk factors ranked by designers were “R1 inaccurate orientation of project’s green-goal”, “R8 government bureaucracy and complicated approval procedures”, “R14 lack of GB design experience”, “R2 inaccurate prediction of market demand for GB”, and “R18 inaccurate cost estimation for GB”. Three of which occur during the planning stage and two of which occur during the design stage. However, the contractors placed the five risk factors in the 7th, 11th, 27th, 42nd and 46th places respectively. Both the designers and contractors have similar views only on the two risk factors of "R1 inaccurate orientation of project's green-goal" and "R8 government bureaucracy and complicated approval procedures", whereas significant differences were found on the other risk factors, especially on the two risk factors of "R2 inaccurate prediction of market demand for GB" and "R18 inaccurate cost estimation for GB". Similar to the factors discussed before, this may be due to the fact that contractors usually join the project only at the construction stage and do not participate in the planning stage and design stage.

It is interesting to find that the risk factors "R24 unstable performance of new green materials / equipments", "R36 lack of experienced resident engineers in GB", and "R50 GB assessment results deviation" were ranked the 8th, 9th and 10th by contractors, while designers ranked them as 45th, 26th and 41st respectively. In addition to "R36", the other two risk factors were both ranked outside the order of 36 key risk factors. This shows that designers have not given adequate attention to green construction. One of the possible reasons is that, during the design stage, designers normally focus on the design aiming only at obtaining the green building certification. This has led to a phenomenon where currently very limited green building projects have been executed in China after the receipt of green design certifications. This is in consistent with the current situation of China. From 2008 to July 2015, 2619 projects have been officially certified as green buildings by the Ministry of Housing and Urban Rural Construction of China, of which 2443 projects receive green design certifications; only 175 projects receive operation certifications (Green Building Map， 2015). It is due to the fact that green design certifications and green operation certifications are two independent certifications in China. A building with the green design certification is not compulsorily required to obtain the operation certification. Moreover, a building with the green design certification is not necessarily able to obtain the operation certification.

However, contractors ranked "R44 lack of cooperation between parties involved in trial operation stage" and "R49 disputes due to unclear division of green certification responsibilities" as 21st and 41st, while designers ranked them as 7th and 10th respectively. It is perceived that contractors do not understand the trial operation stage correctly and fail to recognize the importance of the fair sharing of responsibilities regarding green building contracts. In addition, both the designers and contractors had common views on the risk factors of "R4 lack of accurate estimate of GBs' long-term return on investment", "R42 lack of experienced property management during trial operation stage" and "R51 lack of experienced property management companies"

The differences between designers and contractors are attributed to the traditional project management DBB model. Designers are more concerned about the risks in the planning stage and design stage, whereas contractors are more concerned about the risks in the construction stage and the operation and maintenance stage due to contractors are usually involved in the project at the construction stage. Both the designers and contractors believe that an experienced property management company is the key factor to influence the success of green buildings. However, contractors fail to recognize the increased responsibilities due to the special requirements for trial operation stage of green buildings.

Conclusion

An empirical questionnaire survey was conducted in China to assess the risk factors throughout the life-cycle of green buildings. The key risk factors have been identified according to their values of risk importance. The top five key risk factors ranked by all respondents have been found to be, (1) government bureaucracy and complicated approval procedures, (2) inadequate GB maintenance, (3) lack of GB design experience, (4) lack of experienced property management during trial operation stage, and (5) inaccurate orientation of project's green-goal. The Kendall's concordance analysis reveals that there are no significant differences between owners and designers, designers and resident engineers, and contractors and resident engineers in the ranking of risk importance in the life-cycle of green buildings, whereas obvious differences have been found between the ranks of risk importance identified by owners and contractors, owners and resident engineers, and designers and contractors. A further Spearman's rank correlation test has indicated that the owners and contractors, owners and resident engineers, designers and contractors only appeared significantly correlated and remarkably different within 99% confidence interval.

This study is imporant as it sheds lights on the risk perception of green buildings in China's construction industry and helps equipping different project participants with better knowledge and understanding of potential risk factors regarding green buildings. The findings present the differences of risk importance among stakeholders that would help them to implement appropriate risk management strategies according to their perceptions of risk importance. At the same time draws the attention of other participating units to focus on risk management. In doing so, it is hope that a concerted effort can be made to strengthen group cooperation, and, finally achieve a win-win situation for the project. Limitations of the research study lie in the conclusions drawn being indicative rather than conclusive as merely 74 completed survey questionnaires were received and analyzed and the scope of study was limited to China. It is recommended that further research should be launched to compare the research findings in China with those in such western countries as America and Australia, where the development of green buildings is mature and developed.

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Highlights

1. The risks of the life-cycle of green buildings are assessed.
2. The importance of risks are prioritized based on probability of occurrence and degree of influence.
3. Stakeholders hold obviously different views on some risks of green buildings.