Investigating Critical Safety Performance Factors in Green Building Construction Projects: The Case of Singapore

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ABSTRACT

Green building construction sector has achieved a rapid development over the past two decades owing to an increasing global recognition for its environmental benefits. However, very limited research effort was made to investigate the safety performance in green building construction projects. This study aims to identify and assess the critical safety performance factors in green building construction projects in Singapore. To achieve these objectives, a comprehensive literature review and three preliminary interviews were carried out, followed by a questionnaire survey conducted with 30 Singapore-based construction companies. The survey results showed that the top five critical safety performance factors are "safe operation of construction equipment," "proper and effective two ways communication between the management and workers," "management commitment towards safety," "provision of personal protective equipment," and "establishing a comprehensive companywide safety policy." This study contributes to the body of knowledge by exploring the critical safety performance factors in green building construction projects. The findings from this study can also help develop more effective strategies to improve the safety performance in green building construction projects.

Keywords: *critical safety performance factor, green building construction projects, Singapore*

1. INTRODUCTION

Based on a worldwide recognition for its efficacy of saving energy and resources consumption, green buildings have gained a remarkable momentum in numerous countries recently, and one typical representative is Singapore (Hwang et al., 2015). Singapore is a densely populated city-state with limited areas and resources, making green building a necessity rather than an option for this country (Agarwal et al., 2016). In 2005, the Singapore Government embarked on the green building movement by launching the Building and Construction Authority (BCA) Green Mark scheme. Since then, this country has advanced three rounds of Green Building Masterplans successively (i.e., Masterplans of 2006, 2009, and 2014) to promote the development of green buildings (BCA, 2014). Motivated by this comprehensive suite of schemes and plans, green buildings in Singapore have achieved a rapid development recently, and the number of green buildings in Singapore grew exponentially, from 17 in 2005 to over 2100 in 2014, which was equivalent to 25 percent of the total built-up area in the country (BCA, 2014).

According to the Workplace Safety Health Council (WSHC, 2014), construction, marine, and manufacturing, have been assessed as the top three unsafe industries in Singapore. The numbers of workplace minor, major, and fatal injuries in the Singaporean construction industry increased significantly from 1718, 133, and 22 in 2011 to 2686, 202, and 27 in 2014, respectively (WSHC, 2012, 2013, 2014). Moreover, the local construction industry has been accounting for the largest proportion of workplace fatalities in this country continuously since 2006 (WSHC, 2014). All these statistics show that construction safety remains a significant concern to Singapore.

Given the grave situation of construction safety in Singapore, and the fact that numerous green building projects are under construction in this country, it could be inferable that the safety situation in the green building construction industry of Singapore should be stressful. Nonetheless, current literature reveals that few studies have addressed the safety issues in green building construction projects. Therefore, this study attempted to bridge this knowledge gap by identifying and assessing the critical safety performance factors in green building construction projects in Singapore. This study contributes to the body of knowledge by exploring the critical safety performance factors in green building construction projects. This study is also beneficial to the industry as its findings can help the practitioners develop more effective strategies to improve their safety performances.

2. BACKGROUND

2.1 Green buildings

Green buildings are a particular type of building designed for optimum energy efficiency and constructed with a preference for natural, reclaimed and recycled materials (Hwang & Ng, 2013). These buildings provide healthier, more comfortable and productive indoor environments for occupants by maximizing the efficient usage of resources like energy, water and raw materials (Hwang & Leong, 2013). The American Society of Testing and Material (ASTM, 2009) maintained that green buildings provided the specified building performance requirements while minimizing disturbance and improving the function of local, regional, and global ecosystems throughout its entire building life cycle. Burnett (2007) described that the ideal green building should have five major features: integration with local ecosystems; closed-loop material systems; maximum use of passive design and renewable energy; optimization of building hydrologic cycles; and full implementation of indoor environmental quality measures.

2.2 Safety concerns in green building construction projects

Compared to traditional building construction projects, green building construction projects seemed to have imposed a higher safety risk to the workers. Walter (2011) stated that construction projects that were built to achieve Leadership in Energy and Environmental Design (LEED) certification accounted for a higher recorded injury rate than non-LEED buildings. Dewlaney et al. (2011) found that, compared to those on non-LEED projects, workers on LEED projects were subject to a 36 percent increase in laceration, strains, and sprains from recycling construction materials; a 24 percent increase in falls to lower level during roof work because of the installation of on-site renewable energy (e.g., photovoltaic panels); and a 14 percent increase in exposure to harmful substances when installing innovative wastewater technologies. Fortunato et al. (2011) expressed the similar concerns because their cases studies also showed that workers on LEED construction projects were exposed to work at height, with electrical current, near unstable soils, and near heavy equipment for a greater period of time than workers on traditional projects. The grave safety situation above implies that more efforts should be put in tackling safety issues in green building construction projects to improve their safety performances.

3. METHODOLOGY AND DATA COLLECTION

Despite the grave situation of safety in green building construction projects, few studies have examined the critical safety performance factors in such projects. Fortunately, studies that investigated safety performance factors in traditional building construction projects were abundant, which could provide solid support for this study. Based on a comprehensive literature review (e.g., Sawacha et al., 1999; Jannadi & Bu-Khamsin, 2002; Siu et al., 2003; Choudhry et al., 2008; Ulubeyli et al., 2014; Zhou et al., 2015), 39 factors that affect the safety performances in traditional building construction projects were identified. However, these traditional project related factors might have an issue of compatibility with the context of green building construction projects in Singapore. Thus, this study conducted interviews with three experienced industry experts to refine these 39 identified factors within the context of green building construction projects in Singapore. Finally, a total of 35 safety performance factors were finalized, as listed in Table 1.

Based on the results of the interviews, a questionnaire was developed and then disseminated to 102 BCA certified companies in October and November 2014. The questionnaire included the questions meant to profile the companies and respondents, and the questions meant to evaluate the significance of each safety performance factor using a five-point rating scale (i.e., 1 = least important, 2 = somewhat important, 3 = neutral, 4 = important, and 5 = most important). The survey received valid responses from 30 companies, yielding a response rate of 29 percent, which was consistent with the norm of 20 to 30 percent with most questionnaire surveys in the construction industry (Akintoye, 2000). The collected replies were from various construction-related organizations including 20 contractors, four consultant firms, three private developers, and three quantity surveyors. As for the respondents, 57 percent of them had at least three years of experience in undertaking green building construction projects, and 63 percent of them were holding top-level management positions like project director and project manager. Thus, obviously the respondents had sufficient knowledge and experience to address the research questions of this study. In addition, two statistical methods, namely, the Cronbach's alpha and one sample t-test, were used to analyse the data collected from the questionnaire survey. The Cronbach's alpha was employed to measure the internal

consistency or reliability of the data, while the one sample t-test was used to check whether each safety performance factor has significant impact on safety performance in green building construction projects.

4. RESULTS AND DISCUSSIONS

Data collected from the questionnaire were input SPSS Statistics 17.0 to perform the analysis, and the evaluation results as well as the relevant statistical analysis results were presented in Table 1. In this study, the Cronbach's alpha value of safety performance factors was 0.806, which was higher than the minimum threshold of 0.7 (Nunnally et al., 1967). Thus, the collected data were reliable. In addition, the mean values of all safety performance factors were statistically greater than 3, which was the test value of the one sample t-test. Thus, all the safety performance factors had significant influence on the safety performances in green building construction projects. It could be noted from Table 1 that the top five critical safety performance factors were "safe operation of construction equipment," "proper and effective two ways communication between the management and workers," "management commitment towards safety," "provision of personal protective equipment (PPE)," and "establishing a comprehensive companywide safety policy."

No.	Safety performance factors	Mean	Rank	Std. Dev.	p-value
1	Safety uncertainty	4.43	7	0.57	0.00*
2	Employee commitment/ participation towards safety	4.40	8	0.50	0.00*
3	Provision of safety training & seminar	4.30	15	0.60	0.00*
4	Reckless human behaviour / operations	4.37	11	0.49	0.00*
5	Knowledge of safety system	4.37	12	0.49	0.00*
6	Self-esteem	3.87	32	0.63	0.00*
7	Experience	4.47	6	0.57	0.00*
8	Fatigue in workers	4.03	24	0.61	0.00*
9	Incentives for increased productivity	4.07	22	0.83	0.00*
10	Safety obstacles (Interpersonal safety conflict/support)	4.10	21	0.55	0.00*
11	Proper and effective two ways safety communications between the management and workers	4.57	2	0.50	0.00*
12	Safety attitudes and behaviours of workers	3.90	30	0.66	0.00*
13	Safety attitudes and behaviours of supervisors	3.97	27	0.56	0.00*
14	Perceived level of risk / seriousness of accidents	3.83	34	0.59	0.00*
15	Supervisor's care for the workers	4.03	25	0.56	0.00*
16	Shortfall of safety regulation	4.30	16	0.53	0.00*
17	Performance pressure	4.40	9	0.56	0.00*
18	Overtaxing of workers	4.20	20	0.55	0.00*
19	Incorrect setting of safety screen	3.87	33	0.57	0.00*
20	Provision of proper tools and equipment	4.27	17	0.52	0.00*
21	Inadequate support for scaffolding	4.37	13	0.49	0.00*
22	Infeasible construction sequences	4.07	23	0.45	0.00*
23	Provision of personal protective equipment (PPE)	4.53	4	0.51	0.00*
24	Safe operation of construction equipment	4.60	1	0.50	0.00*
25	Toolbox check/brief	4.33	14	0.48	0.00*
26	Management commitment towards safety	4.57	3	0.50	0.00*
27	Management encouragement and support	3.97	28	0.41	0.00*
28	Safety awareness of management	4.27	18	0.45	0.00*
29	Regular safety talks	4.23	19	0.43	0.00*
30	Regular safety meetings	4.40	10	0.50	0.00*
31	Strong safety leadership role	3.97	29	0.56	0.00*
32	Promotional strategies	3.70	35	0.65	0.00*
33	Establishing a comprehensive companywide safety policy	4.50	5	0.51	0.00*
34	Housekeeping (proper storage of equipment)	4.00	26	0.59	0.00*
35	Tidy working environment	3.90	31	0.71	0.00*

Note: *The one sample *t*-test result is significant at the 0.05 significance level (two-tailed)

Table 1: Evaluation results of safety performance factors in green building construction projects

"Safe operation of construction equipment" was regarded as the top critical safety performance factor with the highest value of 4.60. Construction equipment are heavy machineries and vehicles that are used for executing construction operations. Construction equipment are also known as heavy machinery, which are used to perform construction tasks such as excavation, lifting, material handling, drilling, hauling, excavating, paving and grading. As for green building construction projects, there are numerous green featured construction tasks (e.g., constructing atria and installing green roofs, and photovoltaic panels) that must be completed with the assistance of construction equipment (Fortunato III et al. 2012). The improper operation of those construction equipment (e.g., cranes and loaders) can impose significant safety risks to the frontline workers and might incur serious injuries (e.g., caught-in injuries and struck-by or against injuries) to them. Thus, the respondents assessed the safe operation of construction equipment as the most critical safety performance factor in green building construction projects. Dewlaney et al. (2012) also emphasized that the proper operation of construction equipment was extremely important to improve the safety performance in those green building construction projects.

"Proper and effective two ways safety communications between the management and workers" was ranked second with a mean value of 4.57. Safety communication mainly refers to the extent, frequency, and effectiveness of the information exchanged on safety issues between the management and workers (Jiang et al., 2015), and effective and proper safety communication could increase the workers' safety awareness and knowledge and thus improve the project safety performance significantly. Safety communications are more crucial to green building construction projects than to traditional building construction projects. This is because green building construction projects always adopt innovative and complicated green construction methods that might bring in some special safety regulations. With the aid of the proper and effective two ways safety communications, the site supervisor can inform the workers all the special safety regulations that must be complied with; while the workers can also have proper channels to report to the management about those hazards omitted by the manuals but existing in reality.

"Management commitment towards safety" was assessed as the third most critical safety performance factor in green building construction projects. "Management commitment towards safety" mainly refers to a bunch of commitments made by the management, such as the promise of achieving a high standard of occupational safety and health management for the project implementation, providing adequate resources to implement the safety policies, and ensuring the understanding and execution of safety measures at all levels in the organization. Safety commitments play a vital role in improving safety performance of building construction projects (Demirkesen & Arditi, 2015; Shen et al., 2015), and they are even more crucial to green building construction projects than to traditional ones. This is because normally the management pay so much attention to the sustainability performance of green building construction projects that they may neglect the safety performance of in these projects, while the safety commitments from the management can increase the practitioners' awareness of construction safety, restrain them from conducting unsafe operations, and thus improve the safety performance in green building construction projects eventually.

"Provision of personal protective equipment (PPE)" was ranked fourth with a mean value of 4.53. Nowadays, the construction industry has developed an integrated set of PPE to protect the frontline workers from any potential safety hazard. These PPE includes wearing safety helmets, safety shoes, and safety gloves, wearing hearing protection in noisy environments, putting on goggles or eye protectors while doing welding, wearing respirators in dusty conditions, using breathing apparatus when working in confined spaces, putting on a safety harness when working at height, and wearing a reflective vest where good visibility was required (Choudhry, 2014). PPE is even more critical to workers those working on green building construction projects because they are exposed to the toxic substances, work at height, with electrical current, near unstable soils, and near heavy equipment for a greater period of time than those working on traditional projects (Fortunato et al., 2011). Currently, provision of proper PPE has been included into many green rating systems (e.g., Green Rating for Integrated Habitat Assessment, India)(Pearce & Kleiner, 2013), indicating that its importance has been widely recognized by the authority and the industry.

"Establishing a comprehensive companywide safety policy" was considered to be the fifth most critical safety performance factor in green building construction projects. A safety policy of a construction company is a recognized written statement that states the company's commitment to the protection of the health and safety of the employees. It shows the details of all occupational health and safety elements with the policy to protect the

employees' life and health, and the relevant forms include the safety standard, safety regulations, safety procedures, and even the safety incentive programs (Choudhry et al., 2008). Establishing a comprehensive companywide safety policy is extremely important to those organizations working on green building construction projects. This is because can only a comprehensive safety policy cover all those special, hidden, and unexpected safety hazards brought by the green building construction projects. In addition, a comprehensive safety policy can raise the employees' awareness of safety and health and provide information and instructions to them on the relevant safety regulations and good work practices. Park and Tae (2016) also reached the similar conclusion that an integrated safety policy was crucial to the safety performance in green building construction projects.

5. CONCLUSIONS AND RECOMMENDATIONS

Owing to an increasing recognition for the environmental benefits brought by the green buildings, there has been a significant growth in green building construction worldwide over the recent years. Nevertheless, minimal research effort has been devoted to examine the safety issues in green building construction projects. This study attempted to make a preliminary investigation of safety performance factors in green building construction projects. Facilitated by a series of qualitative and quantitative research methods such as literature review, structured interviews, and questionnaire survey, this study identified and evaluated 35 safety performance factors in green building construction projects. Results showed that the top five critical safety performance factors were "safe operation of construction equipment," "proper and effective two ways communication between the management and workers," "management commitment towards safety," "provision of personal protective equipment," and "establishing a comprehensive companywide safety policy." The findings from this study have presented a general view on the critical factors that affect safety performance in green building projects, which can also help develop more effective strategies to improve the safety performance in such projects. Future studies could be conducted to investigate the interrelationships among these critical safety performance factors in green building construction projects. Also, it would be interesting to compare the safety performance factors between the green and traditional building construction projects.

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