Clean Technologies and Environmental Policy (2018) 20:2223–2237
https://doi.org/10.1007/s10098-018-1598-z

ORIGINAL PAPER

Adoption of sustainable construction for small contractors: major barriers and best solutions

Bon-Gang Hwang[1] · Ming Shan[2] · Jun-Ming Lye[3]

Received: 24 June 2018 / Accepted: 21 August 2018 / Published online: 24 August 2018

Abstract

There have been numerous studies on the adoption of sustainable construction; however, few have attempted to analyze the sustainable construction adoption from the perspective of small contractors. The objectives of this study are to investigate the major barriers that prevent small contractors from adopting sustainable construction and to propose a group of best solutions that can overcome these barriers. To achieve these goals, a comprehensive literature review was conducted first. Then, data from 30 Singapore-based small contractors were collected through a questionnaire for analysis. Results reported that "extra investment required," "slow recovery of investment," "lack of incentives," "limited knowledge on sustainable construction," "tendency to maintain current practices," and "lack of demands from clients" were the top six barriers that hinder small contractors from adopting sustainable construction. Results also revealed that three barrier categories, namely "financial barriers," "management barriers," and "knowledge barriers," were more critical to small contractors than to large contractors. Lastly, five best solutions that could help small contractors overcome the identified barriers were suggested. This study contributes to the body of knowledge by investigating the barriers and solutions for small contractors in adopting sustainable construction. The findings from this study are helpful to the industry practitioners as well, as they can enhance their understandings of the barriers and can also help policy makers to come up with more effective policies to tackle these barriers.

Keywords Small contractor · Sustainable construction · Barriers · Solutions · Singapore

Introduction

While the construction industry plays a vital role in supporting the development of national economy worldwide (Yu et al. 2017; Le et al. 2014), it is a major consumer of energy, water, and raw materials, which is in conflict with the concept of sustainability (Yeheyis et al. 2013). As a result, over the past two decades the global construction community has been encouraging sustainable construction actively worldwide (Serpell et al. 2013; Saleh and Alalouch 2015; Wu et al. 2014b; Maskil-Leitan and Reychav 2018). Sustainable construction was first mentioned in 1994 and defined as "a creation and responsible management of a healthy built environment based on resource efficient and ecological principles" (Du Plessis 2007; Kibert 2007). After that, considerable research efforts were devoted to this area (e.g., Bon and Hutchinson 2000; van Bueren and Priemus 2002; Hill and Bowen 1997; Zimmermann et al. 2005; Ofori 1998; Miyatake 1996; Manoliadis et al. 2006; Chong and Wang 2016; Reychav et al. 2017). Du Plessis (2007) made a concise summary of these research efforts and pointed out that sustainable construction has three essential features: embracing both technologies responses and non-technical aspects that contribute to social and economic sustainability, emphasizing both environmental protection and value addition to the quality of life of individuals and communities, and involving

✉ Ming Shan
ming.shan@csu.edu.cn

Bon-Gang Hwang
bdghbg@nus.edu.sg

Jun-Ming Lye
lyejunming@gmail.com

[1] Department of Building, National University of Singapore, 4 Architecture Drive, Singapore 117566, Singapore

[2] School of Civil Engineering, Central South University, 68 South Shaoshan Road, Changsha 410004, China

[3] Frasers Centrepoint Limited, 438 Alexandra Road, Alexandra Point, Singapore 119958, Singapore

many more role players than just those traditionally identified as making up the construction industry.

Being a major participant of the construction industry, contractors are crucial to the implementation of sustainable construction, as they are the team who construct and deliver sustainable built environment (Holloway and Parrish 2015; Tan et al. 2011). Although contractors vary considerably in size, it has been found that most of the contractors in the construction industry are small contractors. For instance, according to Department for Business, Enterprise and Regulatory Reform of UK, 99.8% of contractors in the construction industry of the country are small contractors (Lu et al. 2008). Likewise, the statistics released by the US Small Business Administration revealed that 96% of homebuilders and 97% of specialty trade contractors in America were small contractors (Siniavskaia 2015). Comparing to those large contractors, small contractors might have limitations in work scopes, experiences, and financial capability, as well as in the possessions of workforce and equipment (Luu et al. 2008). Such a difference has put more stress on small contractors and make them feel challenging to survive in the current construction market where the innovation-oriented sustainable construction is being actively promoted. It is necessary and imperative to conduct a comprehensive study to investigate the major barriers that hinder small contractors from adopting sustainable construction, and to come up with some solutions that can help small contractors tackle these barriers.

The research work described in this study was conducted within the context of Singapore. Singapore is a city-state with limited land area, natural resources, and small population, making sustainability a necessity rather than an option to the country. As a result, over the past two decades, Singapore has made a great deal of efforts in chasing sustainability in all its industries, and the construction industry is one of the country's primary emphases (Hwang et al. 2017a, Zhao et al. 2016). For instance, since 2005, the authority in charge of the local construction industry, namely the Building and Construction Authority (BCA 2014), has launched three rounds of Green Building Masterplans (i.e., Masterplans of 2006, 2009, and 2014) to encourage the local developers and contractors to have more involvement in sustainable construction. Additionally, according to the statistics released by BCA (2017b), 88.5% of the construction contractors in Singapore are small contractors, which imply that most of the contractors conducting the construction business in Singapore are small contractors. Therefore, Singapore is the right and suitable context for conducting the research.

Although there has been considerable research on sustainable construction in the existing literature (e.g., Hill and Bowen 1997; Bon and Hutchinson 2000; Manoliadis et al. 2006; Pitt et al. 2009; Ding and Forsythe 2013; Saleh and Alalouch 2015; Shan et al. 2017b), few of them look into the barriers and solutions for small contractors to adopt sustainable construction. Therefore, this study can contribute to the body of knowledge by adding the literature of sustainable construction. Additionally, this study offers multiple benefits to the industry. First, it provides small contractors with an in-depth understanding of the barriers they need to confront. Furthermore, it provides small contractors with validated recommendations for the elimination of the barriers.

Background

Sustainable construction in Singapore

Sustainable construction is critical to Singapore's national development, as Singapore has inherent limitations in population, land areas, and natural resources (Chew 2010). Therefore, the government of Singapore has been striving to promote the adoption of sustainable construction across the country over the past two decades. In 2005, the Singapore government kick-started the sustainable construction campaign by introducing the BCA Green Mark scheme, which is an extensive framework assessing the overall performance of sustainable construction projects from five aspects: energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green features and innovations (BCA 2017c; Low et al. 2014). In addition to that, Singapore has also released three rounds of national plans (i.e., Green Building Masterplans of 2006, 2009, and 2014) to promote the active use of sustainable construction in the country (BCA 2014). In the meantime, the Singapore government launched a series of incentive schemes (e.g., Green Mark Incentive Scheme for New Buildings in 2006 and Green Mark Incentive Scheme for Existing Buildings in 2009) to encourage the local developers, building owners, and contractors to adopt sustainable construction in their building projects (BCA 2015a, b). Stimulated by these comprehensive national initiatives, the sustainable construction in Singapore has achieved rapid development in the past few years, and Singapore has already become a world leading player in the area of sustainable construction (Hwang et al. 2015).

Small contractors in Singapore

As the criterion of "small" varies significantly in different countries, the standard definition for small contractors in the construction industry remains lacking. In the USA, the small business in the construction sector was categorized as those contractors who have average annual receipts less than USD 36.5 million (US Small Business Administration 2017). In the European Union, small contractors were defined as independent companies who have employees less than 250, sales less than EUR 50 million (approximately USD 59 million) or annual balance sheet less than EUR 43 million (approximately USD 50 million) (European Commission 2011). In Singapore, small contractors are yet to be clearly defined. However, there are clear criteria for small enterprises stipulated by the local government. According to the Ministry of Trade and Industry, small enterprises in Singapore are the companies that have at least 30% of local shareholding, group annual sales turnover less than SGD 100 million (approximately USD 74 million), or group employment size less than 200 employees (Singapore Business Review 2011). Although these criteria are not particularly established for companies in the construction industry, they are referential in defining small contractors in Singapore.

The BCA of Singapore is operating a Contractors Registration System for all the construction contractors who wish to participate in tenders or to conduct projects (as main or sub-contractors) in the public sector of Singapore (BCA 2017a). The system categorizes the registered contractors in different grades based on their paid-up capital and net worth, relevant technical personnel, management certifications, and track record (BCA 2017b, g), as shown in Table 1. Combining the definition of small enterprises provided by the Ministry of Trade and Industry and the grades of BCA Contractors Registration System, it can be inferred that small contractors in Singapore are those who are classified as B2 and below in the BCA Contractors Registration System. Furthermore, it could be observed from Table 1 that most of the BCA registered contractors are classified as B2 and below, suggesting they are small contractors. This indicates that Singapore is the right context for the research.

Table 1 Contractor grades of the BCA Contractors Registration System

Grade	Financial status (SGD*)	Track record (Past 3 years) (SGD)	Personnel	No. of registered contractors**
A1	15 million	150 million	24	91
A2	6.5 million	65 million	12	46
B1	3 million	30 million	6	79
B2	1 million	10 million	3	84
C1	300,000	3 million	1	329
C2	100,000	1 million	1	117
C3	25,000	100,000	1	1129
Total				1875

*1 SGD≈0.74 USD; **Data for December, 2017; "Financial "includes both minimum paid-up capital and minimum net worth must be met separately; "Track record" shows the completed projects in the past 3 years for all cases. "Personnel" means the technical personnel with qualification or recognized degree

Barriers to the adoption of sustainable construction

Despite its rapid growth, sustainable construction is confronted with various barriers, which have been investigated by a large number of studies (Darko and Chan 2017a). According to Bon and Hutchinson (2000), sustainable construction faces economic challenges at different levels including the macroeconomic level (i.e., the expansions of the construction industries in most developing countries are not in the best position to promote sustainable construction), meso-economic level (i.e., the supply chain of sustainable construction is not well established), and the microeconomic level (i.e., the finance for constructed facilities is increasingly adjusted to short and medium term which is in conflict with sustainable construction whose goals rely more on long-term outlooks). Robichaud and Anantatmula (2010) highlighted that higher initial cost was the greatest obstacle that hampered sustainable construction. Häkkinen and Belloni (2011) conducted literature review, interviews and case studies and tried to identify the major barriers for adopting sustainable construction. The results they obtained revealed that the lack of steering or the wrong type of steering for sustainable construction from the authorities, the fear of higher investment costs for sustainable construction, the lack of the understanding and knowledge of sustainable construction in the project team, various issues in sustainable construction implementation (e.g., procurement and tendering, schedule management, and stakeholder management) were major barriers. Similarly, Hwang and Tan (2012) carried out a questionnaire survey and interviews with 31 Singapore-based construction organizations to examine the common obstacles in managing sustainable construction projects. They found out that the top five obstacles were high cost premium of sustainable construction project, lack of communication, and interest among the project team members, sustainable construction practices are costly to implement, lack of credible research on the benefits of green buildings, and lack of expressed interest from client and market demand. Chan et al. (2017) and Darko et al. (2017) examined the main barriers affecting the adoption of green building technologies. They found that the main barriers were resistance of stakeholders to change, lack of knowledge and awareness, and higher cost. Furthermore, after reviewing the studies conducted in Canada (Ruparathna and Hewage 2015), Chile (Serpell et al. 2013), Ghana (Djokoto et al. 2014), and Vietnam (Nguyen et al. 2017), Darko and Chan (2017a) found that lack of demand for sustainable buildings, lack of strategy to promote sustainable construction, higher initial cost, lack of integrated design, lack of public awareness, and lack of government support were a group of barriers that were reported commonly by the literature.

It looks that numerous studies have investigated the barriers to the adoption of sustainable construction. However, most of them apply to generic contractors and very few of them are specific to small contractors. As a result, it is imperative to conduct a new research to identify the particular barriers that hinder small contractors from adopting sustainable construction. To achieve this goal, the research team went through all the barriers that were mentioned by prior studies. These barriers are valuable and helpful to this study, as they provide a solid foundation from where the particular barriers for small contractors could be identified. During the process of barrier identification, all the barriers that are highly associated with small contractors were kept. Finally, 19 specific barriers that may hinder small contractors from adopting sustainable construction were identified. As some barriers share the common nature, the 19 barriers were classified into five categories, which were financial barriers, political barriers, management barriers, physical barriers, and knowledge barriers. The barriers, together with their descriptions, categories, and sources are shown in Table 2.

Solutions to address the barriers in adopting sustainable construction

To address the barriers that hinder the adoption of sustainable construction or green buildings, a series of solutions have been proposed by several studies. For instance, to address the economic challenges facing sustainable construction, Bon and Hutchinson (2000) proposed three types of solutions, which are: governance through standards, legal and regulatory practices; market-oriented policies that influence the costs of sustainable construction methods. To tackle the obstacles that may be encountered by the project team during their management of sustainable construction projects, Hwang and Tan (2012) proposed three types of solutions: providing government incentives for sustainable construction projects; improving communication within the project team, and funding research on sustainable construction. Focusing on the barriers in the contexts of Ghana and Vietnam, Djokoto et al. (2014) and Nguyen et al. (2017) recommended several similar solutions, which are: trainings and short courses should be offered to frontline workers to improve their skills and knowledge on sustainable construction; expedited permit and tax exemptions for sustainable construction should be provided by government; and government should explore more ways to stimulate the demand on sustainable construction. After making a comprehensive review of the barriers that prevent the adoption of green buildings, Darko and Chan (2017a) listed up a series of solutions that can address those barriers. The recommended solutions include: establishing a strong collaborative system between policy makers, industry associations,

Table 2 Possible barriers hindering small contractors from adopting sustainable construction

Category	Code	Barrier	References										
			[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Financial barriers	B01	Extra investment required		√	√	√	√	√	√	√	√	√	√
	B02	Slow recovery of investment	√	√						√	√	√	√
	B03	Lack of incentives					√	√	√	√	√	√	√
Political barriers	B04	Lack of government support				√		√		√	√	√	√
	B05	Lack of sustainable building codes and regulations				√				√	√	√	√
Management barriers	B06	Lack of strategy to promote sustainable construction						√		√	√	√	√
	B07	Lack of coordination among stakeholders			√	√	√	√	√		√		√
	B08	Lack of measurement tool/framework			√				√		√		√
	B09	Lack of interest				√	√			√	√	√	√
	B10	Tendency to maintain current practices				√		√	√		√		√
	B11	Unequal distribution of benefits				√					√		√
Physical barriers	B12	Increased Schedule								√	√	√	√
	B13	Perceived risk and uncertainties			√					√	√	√	√
	B14	Lack of green materials and technology								√	√	√	√
	B15	Reduction of aesthetics									√		√
Knowledge barriers	B16	Lack of demands from clients				√	√	√		√	√	√	√
	B17	Lack of public awareness			√		√	√	√		√		√
	B18	Lack of training/education				√		√		√	√	√	√
	B19	Limited knowledge on sustainable construction			√	√	√	√		√	√	√	√

References: [1] = Bon and Hutchinson (2000), [2] = Robichaud and Anantatmula (2010), [3] = Häkkinen and Belloni (2011), [4] = Hwang and Tan (2012), [5] = Serpell et al. (2013), [6] = Djokoto et al. (2014), [7] = Ruparathna and Hewage (2015), [8] = Chan et al. (2017), [9] = Darko and Chan (2017a), [10] = Darko et al. (2017), [11] = Nguyen et al. (2017)

and developing companies; increasing the availability of information on the benefits of green buildings; changing the perception that the extra cost of green buildings would affect the competitive advantage of contractors; offering external incentives (e.g., financial assistance provided by government and institutional investors) and internal incentives (i.e., incentives from construction companies themselves); government to explore ways to stimulate the demand on green buildings; and government to issue clear policy packages at the national level to catalyze the adoption of green buildings.

Although very few of the prior studies paid particular attention to the solutions for small contractors, they are still informative and helpful, as they can serve as good references for customizing particular solutions suitable for small contractors. After going through all the solutions proposed by these prior studies, the research team identified 16 solutions that may be of particular help to small contractors and kept them for further research actions. The descriptions of these 16 solutions, together with their literature source and target barrier categories, are presented in Table 3.

Methods and data presentation

Research methods

Various methods, including qualitative and quantitative ones such as literature review, pilot interviews, questionnaire, and post-survey interviews, were adopted in this study.

Conducting literature review is an effective approach for researchers to learn about a given topic regarding its state of the art (Zhao 2017). To identify the barriers and solutions for small contractors in adopting sustainable construction, this study conducted a comprehensive literature review first. To ensure the comprehensiveness of the coverage of the literature review, a wide range of literature including books, journal articles, theses, documents from the relevant authorities, and information from internet websites, was systematically searched.

In the construction engineering and management research, conducting interviews with experienced industry experts is a widely adopted strategy to verify the information

Table 3 Possible solutions for small contractors to tackle barriers

Target barrier category	Code	Solution	Source						
			[1]	[2]	[3]	[4]	[5]	[6]	[7]
Financial barriers	S1	Government to provide higher subsidies to offset premiums	√	√	√	√	√	√	
	S2	Lower interest on loan for sustainable construction projects					√		
Political barriers	S3	Compulsory implementation of sustainable construction processes				√	√	√	
	S4	Creation of building codes and regulations	√			√	√		
	S5	Government to spur demand by adopting sustainable construction in public projects	√		√	√		√	
Management barriers	S6	Promote contractors with good sustainable construction practices track record			√				
	S7	Improvement on existing Green indicators					√		
	S8	Creation of easy-to-follow framework for sustainable construction					√		
	S9	Ensure effective communication between key players involved		√		√			
	S10*	Hire or engage a Green Mark Manager/Professional							√
	S11*	Costs savings from building operations to be shared with contractors							√
Physical barriers	S12	Government to promote R&D in education and private sectors to spur innovation	√	√	√		√		
	S13	Develop suitable risk management plans to prevent unexpected results from adopting new processes					√		
	S14	Inculcate green building aesthetics in education institutions					√		
Knowledge barriers	S15	Increase awareness of the benefits of sustainable construction				√	√		
	S16	Government to set up training funds for contractors to train workers on sustainable construction methods	√		√		√	√	
	S17	Government-funded educational program on improving built environment	√		√		√	√	
	S18	Education institution to prepare future workforce in sustainable construction			√		√	√	

References: [1] = Bon and Hutchinson (2000), [2] = Hwang and Tan (2012), [3] = Djokoto et al. (2014), [4] = Darko and Chan (2017a), [5] = Darko et al. (2017), [6] = Nguyen et al. (2017), [7] = Added by pilot interviews

*The solution was derived from the pilot interviews retrieved from literature review (Li et al. 2015). Thus, this study carried out pilot interviews with three experts to verify the barriers and solutions identified from the literature review, checking their relevance to the context of small contractors. The industry experts have at least 10 years of experience in conventional construction projects and at least 3 years of experience in sustainable construction projects. The results of the pilot interviews reported that the identified barriers and solutions were largely applicable and only minor amendment to the statements of the barriers and solutions were required. Additionally, the interviews supplemented two new solutions based on their experiences, which are "Hire or engage a Green Mark Manager/Professional" and "Costs savings from building operations to be shared with contractors." Thus, the number of the solutions that would be of help to small contractors came to 18.

Questionnaire is a widely used method to collect professional views of a certain topic in sustainable construction management research (Chan et al. 2018). As a result, this study used questionnaire as instrument to gather professionals' perceptions of barriers and solutions. Based on the results of the pilot interviews, a questionnaire was developed, which consisted of three sections. The first section was to record respondents' background information including their work scopes and years of experience in the construction industry and sustainable construction industry, as well as the sustainable construction projects they have conducted. The second section asked respondents to rate the significance of the identified barriers for two different types of contractors: small contractors and large contractors, using a five-point rating scale where 1 = least important and 5 = most significant. This is because this study would like to make a comparison of the barriers facing by small and large contractors. The third section requested respondents to pick and select the best solutions that could be used to overcome the identified barriers.

Lastly, post-survey interviews were conducted with four industry experts who had answered the questionnaire previously. In the post-survey interviews, the experts were provided with the analysis results obtained from the questionnaire and were requested to comment on the validity of the results. Furthermore, to gain an in-depth understanding of the analysis results, the experts were also asked to provide some explanations for the results wherever necessary.

Data collection and presentation

The sampling frame of the questionnaire is 1875 small contractors registered to the BCA Contractors Registration System, as indicated in Table 1. Referring to the common sampling frame of 10% (Turner 2003), 188 contractors were randomly selected from the registration system as the potential respondents of the questionnaire survey. After checking the work scopes of these contractors either by online search or by phone calls, 142 companies were found having experiences in sustainable construction and thus were selected as target respondents. Soft copies of the questionnaire were disseminated to those 142 companies in December 2016 via emails. As this study plans to compare the identified barriers in two contexts: small and large contractors. Thus, it was stated in the emailed questionnaire that the questionnaire can only be filled by a person who used to work in some large contractor. To ensure a high response rate, phone calls and email reminders were sent every week if the filled questionnaire was not returned. Finally, data from 30 companies were received, representing a norm response rate of 21% for surveys in the construction industry (Hwang et al. 2017b). The profiles of the respondents and the sustainable construction projects that they have conducted are shown in Table 4. It could be observed that the respondents were doing different jobs such as project manager, quantity surveyor, engineer, and site supervisor, and around 63% of them have at least 3 years of experiences in sustainable construction. Also, the sustainable construction projects that the respondents have conducted had a wide range in terms of project type, nature, and cost. Such a great diversity and heterogeneity in the respondent panel can ensure the quality of the collected data and can help yield research findings that are more convincing.

Data analysis methods

Statistical tests were conducted to analyze the data collected by the questionnaire. As a large number of statistical tests require the tested data to follow normal distribution (Kim 2015), Shapiro–Wilk test, recommended by Chou et al. (1998), was conducted first to check the data normality. The null hypothesis for Shapiro–Wilk test is that the tested data is normally distributed. If the *P* value obtained from the test is less than the chosen alpha level (e.g., 0.05), then the null hypothesis should be rejected, indicating that the tested data are not normally distributed (Villasenor Alva and Estrada, 2009). In this study, the common alpha level of 0.05 was selected, and the test was performed using the software IBM SPSS Statistics.

To check whether the identified barriers have statistical impact on small contractors, two statistical test methods, one sample *t* test and one sample Wilcoxon signed-rank test, were considered for adoption. One sample *t* test is widely used to check whether the mean of a sample is statistically equal to a hypothesized standard value. This method requires the sample data to be normally distributed (Norušis 2006). As for one sample Wilcoxon signed-rank test, it is an alternative to one sample *t* test when sample data are not normally distributed. The method checks whether the median of the sample is equal to a

Table 4 Respondent Profile

Variable	Category	Number	%
Job position	Project manager	13	43.33
	Quantity surveyor	3	10.00
	Engineer	12	40.00
	Site supervisor	2	6.67
Year of experience in conventional construction	Less than 3 years	5	16.67
	3–5 years	4	13.33
	6–10 years	11	36.67
	More than 10 years	10	33.33
Year of experience in sustainable construction	Less than 3 years	11	36.67
	3–5 years	8	26.67
	6–10 years	6	20.00
	More than 10 years	5	16.67
The types of the sustainable construction projects conducted	Building	169	76.81
	Infrastructure	43	19.55
	Industrial	8	3.64
The nature of the sustainable construction projects conducted	New construction	131	59.55
	Addition and alteration	89	40.45
The cost of the sustainable construction projects conducted (SGD*)	0.1–1 million	10	4.55
	1–5 million	102	46.36
	5–10 million	43	19.55
	> 10 million	65	29.55

*1 SGD ≈ 0.74 USD

hypothesized standard value (i.e., 3 for this study) (Thas et al. 2005). Therefore, the results of the data normality check obtained from the Shapiro–Wilk test will determine which method should be used. In this study, the hypothesized standard value was set as 3. Based on the rating scale applying to barriers, 3 represents that the given barrier has impact on small contractors.

As the respondents to the questionnaire can be categorized into different groups based on their job positions and experiences in sustainable construction, it is necessary to conduct inter-group comparison to check whether statistical difference exists because of the different backgrounds of the respondents. Two different statistical test methods were considered for the inter-group comparison, namely analysis of variance (ANOVA) and Kruskal–Wallis test. ANOVA is a widely used statistical test method checking the potential differences between the means of two or more independent groups (Xia et al. 2015). Kruskal–Wallis test is a rank-based statistical test method checking the potential differences between two or more different groups (Tixier et al. 2014). One of the major differences between these two methods is that ANOVA requires the tested data in normal distribution, while Kruskal–Wallis test is distribution free (Hwang et al. 2018). As a result, the results of data normality check provided by the Shapiro–Wilk test will determine which method should be used.

As the questionnaire solicited respondents' assessments of barriers in the contexts of small and large contractors respectively, statistical test is supposed to be conducted to check whether significant differences exist in the assessments between the two different contexts. Two statistical test methods, namely paired sample *t* test and Wilcoxon signed-rank test, were considered for the paired comparison. Paired sample *t* test is a statistical test method used to compare the means of a subject in different circumstances. It requires the tested data to fall in normal distribution (Shi et al. 2013). Wilcoxon signed-rank test is a method used to compare the ranks of a subject between two matched samples, and it is an alternative to the paired sample *t* test when the tested data are not normally distributed (Hwang et al. 2017a). Therefore, likewise, the Shapiro–Wilk test results determine which method will be used.

According to Roberts et al. (2016), conducting pairwise comparison of the matched variables is a good strategy to identify foremost variables (i.e., the core variables that have the highest priority in ranking or significance). As a result, this study conducted pairwise comparison of two matched barriers to identify the most significant barriers for small contractors in adopting sustainable construction. Wilcoxon signed-rank test was selected to carry out the comparison. The method has been widely used by prior studies for pairwise comparison (Wu et al. 2014a; Shan et al. 2017a; Darko and Chan 2017b). The specific comparison procedures are as follows. First, Wilcoxon signed-rank test was conducted between the top barrier and each of the rest of 18 barriers. After that, Wilcoxon signed-rank test was conducted between the second top barrier and each of the rest of 17 barriers. In a stepwise manner, the Wilcoxon signed-rank test was conducted all the way until all the 19 barriers are compared to each other. The final results of the pairwise comparison will be presented in a triangular matrix, which can clearly show the possible statistical difference between some barrier and the rest. Based on the information from the triangular matrix, it can clearly tell whether those top barriers are statistically different from the rest of the barriers. If the differences are found, conclusion can be made that those barriers are the most significant ones.

Results and discussion

Statistical test results

Tables 5 and 6 present respondents' assessments of barriers and the relevant statistical test results. The results of the Shapiro–Wilk test in Table 5 showed that all the barriers were significant at the significance level of 0.05, suggesting the collected data were not normally distributed. Therefore, one sample Wilcoxon test was used to check whether the barriers have statistical impact on small contractors, Kruskal–Wallis test was used for inter-group comparison, and Wilcoxon signed-rank test was used for the paired comparison of barriers between small and large contractors.

The results of the Kruskal–Wallis test in Table 5 revealed that none of the barriers were perceived differently by respondents in term of their designations, and except the barrier B09 none of the barriers were perceived differently by respondents in term of their experiences in sustainable construction. Such results imply that the assessments of the respondents were basically unanimous and could be treated as a whole for the further analysis. The results of one sample Wilcoxon signed-rank test in Table 5 showed that the assessments of all barriers were statistically equal to or greater than the test value of 3, indicating all the barriers have significant impacts on small contractors. Moreover, the pairwise comparison results in Table 6 showed that the assessments of B01, B02, B03, B19, B10, and B16 were statistically greater than most of the other barriers, suggesting that they are the most significant barriers for small contractors. Additionally, the results of Wilcoxon signed-rank test in Table 5 showed that respondents' assessments on B01, B02, B03, B19, B10, B16, B18, B06, and B09 were significant at the significance level of 0.05, implying that these barriers were perceived differently between the small and large contractors by respondents and that the relevant discussions should be initiated.

Significant barriers for small contractors to adopt sustainable construction

Receiving the highest assessment of 4.60, B01 "extra investment required" was assessed as the most significant barrier for small contractors to adopt sustainable construction. The adoption of sustainable construction may require some extra investment from contractors, which will be mainly used for the procurement of new equipment required by sustainable construction, and for the education of current workforce to enhance their skills and knowledge on sustainable construction (Ahn et al. 2013). However, according to the feedback collected from the post-survey interviews, most of small contractors are very sensitive about these investments, as these investments may result in the loss of their profit margin. This result is consistent with a lot of prior studies who also stated that extra investment cost is one of the major barriers that deters construction community from adopting sustainable construction (Serpell et al. 2013; Robichaud and Anantatmula 2010; Gan et al. 2015; Shi et al. 2013; Shen et al. 2016).

B02 "slow recovery of investment" was assessed as the second most significant barrier with an assessment of 4.57. Adopting sustainable construction requires contractors to pump in large investment into staff training and buying related equipment (Shan et al. 2017b; Chan et al. 2017). In most cases, such investment could not be fairly priced in contractors' tender, because it will lead to an increase to contractors' prices and make contractors lose the bid probably (Dobson et al. 2013). Therefore, contractors may have to disperse the investment into a large number of projects they are going to undertake in the future, waiting for their economic returns in a long-term manner. However, respondents who attended the post-survey interviews stated that this is unrealistic to small contractors in Singapore as most of them are in fragile financial conditions, which does not allow them to wait long for recouping their investment.

B03 "lack of incentives" was assessed as the third most significant barrier for small contractors to adopt sustainable construction, with an assessment of 4.50. The construction authority in Singapore has launched many incentives in the past few years to support the development of sustainable construction across the country (Shan et al. 2017b; Hwang et al. 2017b). However, the majority of these incentives target developers, owners, project architects, and tenants and very few of them look at contractors (BCA 2018a, b, e). Thus, small contractors in Singapore actually received very limited support from the local authorities. The post-survey interview confirmed this result, and the interviewees emphasized that lack of incentives has already become a significant

Table 5 Assessment results of the barriers in adopting sustainable construction

Code	Small contractors								Large contractors		Comparison	
	Mean	Z-score	Rank	*P* value of Shapiro–Wilk test	Median	*P* value of one sample Wilcoxon signed-rank test	*P* value of Kruskal–Wallis test (designation)	*P* value of Kruskal–Wallis test (experience in sustainable construction)	Mean	Rank	Difference	Wilcoxon signed-rank test (*P* value)
B01	4.60	1.71	1	0.000*	5.00	0.000**	0.560	0.346	4.07	1	0.53	0.006##
B02	4.57	1.64	2	0.000*	5.00	0.000**	0.759	0.518	3.93	2	0.63	0.001##
B03	4.50	1.47	3	0.000*	5.00	0.000**	0.286	0.476	3.80	3	0.70	0.005##
B19	4.40	1.24	4	0.000*	5.00	0.000**	0.766	0.626	3.70	5	0.70	0.001##
B10	4.37	1.17	5	0.000*	5.00	0.000**	0.299	0.069	3.73	4	0.63	0.001##
B16	4.17	0.71	6	0.000*	4.50	0.000**	0.925	0.084	3.53	8	0.63	0.006##
B11	3.83	−0.09	7	0.001*	4.00	0.000**	0.266	0.509	3.67	6	0.17	0.358
B13	3.80	−0.16	8	0.000*	3.00	0.001**	0.800	0.752	3.53	8	0.27	0.109
B18	3.73	−0.32	9	0.000*	4.00	0.004**	0.701	0.900	3.27	16	0.47	0.042##
B14	3.73	−0.32	9	0.001*	4.00	0.001**	0.697	0.090	3.43	10	0.30	0.053
B06	3.70	−0.39	11	0.000*	4.00	0.002**	0.488	0.501	3.20	17	0.50	0.021##
B09	3.67	−0.46	12	0.003*	4.00	0.004**	0.800	0.050#	3.30	14	0.37	0.022##
B12	3.67	−0.46	12	0.002*	4.00	0.009**	0.449	0.972	3.57	7	0.10	0.496
B04	3.63	−0.56	14	0.001*	3.50	0.002**	0.736	0.718	3.40	11	0.23	0.248
B07	3.53	−0.79	15	0.001*	3.00	0.006**	0.929	0.256	3.33	13	0.20	0.134
B17	3.53	−0.79	15	0.002*	3.00	0.007**	0.416	0.165	3.37	12	0.17	0.285
B05	3.43	−1.03	17	0.007*	3.00	0.031**	0.775	0.627	3.30	15	0.13	0.392
B08	3.37	−1.17	18	0.002*	3.00	0.057	0.674	0.805	3.10	19	0.27	0.142
B15	3.27	−1.40	19	0.000*	3.00	0.166	0.354	0.312	3.17	18	0.10	0.561

*The Shapiro–Wilk test was significant at the significance level of 0.05, suggesting the data were not normally distributed

**The one sample Wilcoxon signed-rank test was significant at the significance level of 0.05, suggesting the respondents' assessment was different from the test value of 3

#The Kruskal–Wallis test was significant at the significance level of 0.05, suggesting the respondents' assessments were different

##The Wilcoxon signed-rank test was significant at the significance level of 0.05, suggesting the barrier was assessed differently between small and large contractors

Table 6 Wilcoxon signed-rank test results for barriers

	B01	B02	B03	B19	B10	B16	B11	B13	B18	B14	B06	B09	B12	B04	B07	B17	B05	B08	B15
B01	–	0.803	0.386	0.001*	0.169	0.037*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.002*	0.001*	0.000*	0.000*	0.000*	0.000*	0.000*
B02		–	0.564	0.001*	0.204	0.033*	0.001*	0.000*	0.000*	0.001*	0.000*	0.000*	0.001*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
B03			–	0.003*	0.372	0.083	0.004*	0.003*	0.006*	0.001*	0.002*	0.001*	0.006*	0.000*	0.000*	0.001*	0.000*	0.000*	0.000*
B19				–	0.675	0.190	0.003*	0.008*	0.004*	0.002*	0.005*	0.001*	0.010*	0.005*	0.000*	0.001*	0.001*	0.001*	0.000*
B10					–	0.351	0.013*	0.010*	0.011*	0.004*	0.007*	0.002*	0.013*	0.003*	0.000*	0.001*	0.000*	0.000*	0.000*
B16						–	0.162	0.103	0.091	0.031*	0.044*	0.032*	0.054	0.021*	0.006*	0.002*	0.003*	0.010*	0.001*
B11							–	0.712	0.512	0.674	0.643	0.380	0.644	0.372	0.049*	0.117	0.155	0.014*	0.001*
B13								–	0.768	0.638	0.799	0.485	0.670	0.421	0.179	0.163	0.155	0.077	0.030*
B18									–	0.901	0.858	0.685	0.812	0.680	0.210	0.326	0.213	0.145	0.070
B14										–	0.890	0.642	0.950	0.587	0.238	0.210	0.321	0.160	0.028*
B06											–	0.909	0.858	0.691	0.236	0.211	0.115	0.093	0.063
B09												–	0.771	0.772	0.470	0.386	0.334	0.163	0.062
B12													–	0.911	0.435	0.619	0.449	0.140	0.127
B04														–	0.674	0.683	0.294	0.204	0.145
B07															–	1.000	0.787	0.320	0.123
B17																–	0.766	0.443	0.088
B05																	–	0.775	0.417
B08																		–	0.642
B15																			–

*The Wilcoxon signed-rank test was significant at the significance level of 0.05, suggesting the two compared barriers were statistically different from each other barrier that prevents small contractors from embracing sustainable construction.

B19 "limited knowledge on sustainable construction" received an assessment of 4.40 and was assessed as the fourth most significant barrier. It has been widely recognized that having sound knowledge of sustainable construction is critical to the successful implementation of sustainable construction (Banihashemi et al. 2017; Hwang et al. 2017c; Li et al. 2011; Low et al. 2014; Shen et al. 2017). However, the fact with small contractors in Singapore is that they still rely on low-skilled foreign labors who have very limited knowledge on sustainable construction mostly. Although some small contractors in Singapore have started adopting sustainable construction, they have yet to build a professional and specialized team for sustainable construction. This fact has been increasingly reported by the local media in Singapore over the recent years (Ng 2017).

B10 "tendency to maintain current practices" was assessed as the fifth most significant barrier receiving an assessment of 4.37. Currently, most of the small contractors in Singapore are still practicing in the old-fashioned way and they have demonstrated tendency to maintain the current practices (Ng 2017). There are several reasons could explain this. First, small contractors have been used to those conventional construction methods and they would like to stick to those methods they are more familiar with (Saleh and Alalouch 2015). Furthermore, small contractors are concerned with the high initial investment required by sustainable construction, which may put them under an additional risk of losing profit (Ng 2017). Lastly, most of small contractors are actually not ready for sustainable construction due to their limitations in human resources, financial and technical capabilities (Hwang et al. 2015; Hwang and Tan 2012).

B16 "lack of demands from clients" was assessed as the sixth most significant barrier for small contractors to adopt sustainable construction, receiving an assessment of 4.17. According to the post-survey interviews, in most cases, the projects awarded to small contractors in Singapore are of smaller scales. For these projects, the clients seldom require for the use of green or sustainable construction methods with the considerations of cost and schedule. As a result, small contractors have no motivation to adopt sustainable construction actively, as there are no demands from clients. Ahn et al. (2013) and Gan et al. (2015) obtained similar findings and pointed out that demands from the client are critical to the promotion and development of sustainable construction.

Barriers to adopt sustainable construction: small versus large contractors

Respondents' assessments of the identified barriers in the contexts of small and large contractors were compared in this study. The comparison results presented in Table 5 showed that all the identified barriers received higher assessments in small contractors than in large contractors, suggesting these barriers are more critical to small contractors than to large contractors in general. In particular, the Wilcoxon signed-rank test results in Table 5 showed that nine barriers (i.e., B01, B02, B03, B06, B09, B10, B16, B18, and B19) received statistically higher assessments in small contractors than in large contractors, suggesting these barriers are more critical to small contractors.

After going through all these nine barriers, it could be observed that they are mainly from three barrier categories: "financial barriers" (i.e., B01, B02, and B03), "management barriers" (i.e., B06, B09, and B10), and "knowledge barriers" (i.e., B16, B18 and B19). Comparing to large contractors, small contractors have lesser capital in their business (Gambo et al. 2016). Therefore, small contractors do not possess the same financial ability as large contractors do and thus, will face more financial difficulties when sustainable construction comes at a premium (Asante et al. 2018). As such, the respondents gave higher assessments of financial barriers for small contractors, signifying that the financial barriers were stronger for small contractors. "Management barriers" are another category of barriers more critical to small contractors, which mainly refers to the resistance to change in the current industry for sustainable construction. By nature, human being are resistant to change (Darko et al. 2017), and this can be especially true in the construction industry which is widely known for its conservative nature (Mulva 2017). In the current construction market of Singapore, the majority of the small contractors are still doing their business in the old-fashioned way (Ng 2017). One of the main reasons the small contractors refuse to go with sustainable construction is that, they have got used to the traditional construction methods which can bring them tangible profits. By contrast, they have low interest in shifting toward sustainable construction, as it would be a bit risky to them to a certain extent. "Knowledge barriers" are fairly common to small contractors in Singapore. Small contractors in Singapore mainly rely on foreign workers to do their construction business (Ng 2017). However, most of these foreign workers are from several undeveloped countries adjacent to Singapore (e.g., Bangladesh, Burma, Laos, India, and Cambodia) where sustainable construction is not that popular. Therefore, these workers might not be equipped with sound knowledge and skills regarding sustainable construction. Such an issue with foreign workers has been mentioned a lot by prior studies and has been widely recognized as a major obstacle hindering the adoption of sustainable construction in Singapore (Hwang et al. 2017b; Li et al. 2011; Low et al. 2014).

Best solutions for small contractors to overcome barriers

Based on a comprehensive literature review and pilot interviews, this study identified 18 solutions that can help small contractors to overcome the barriers investigated in this research. The questionnaire of this study solicited the respondents' endorsements on these identified solutions, and the relevant results are presented in Table 7. According to Table 7, S1, S5, S11, S3, and S10 were found to be the top five best solutions, who have received the most endorsement from the respondents. Due to the word and space limit, only these five solutions were discussed in detail in this section.

S1 "Government to provide subsidies to small contractors to offset premiums" was assessed as the best solution, receiving endorsement from 90% of respondents. This solution targeted the "financial barriers." As mentioned by Li et al. (2011) and Hwang and Tan (2012), engaging in sustainable construction may place extra premiums to contractors, particularly in sense of purchasing equipment that are required by implementing sustainable construction. This would bring additional financial stress to small contractors who often have limited financial capability. In such a case, it would be great if government could provide some subsidies to small contractors to offset their premiums. In Singapore, the local construction authorities have launched several schemes to provide financial assistance to small contractors. However, most of these schemes mainly look at the possible improvement of productivity and the application of advanced technologies like Building Information Modeling (e.g., the Construction Productivity and Capability Fund) (Wong and Ng 2017; BCA 2017d), very few of them encourage the adoption of sustainable construction. Thus, the local authority should broaden their scope and consider providing more special subsidies of sustainable construction to small contractors.

S5 "Government to spur demand by adopting sustainable construction in public projects" was recommended as the second best solution. This solution targeted the "political barriers" confronted by small contractors. This solution can help small contractors from two perspectives. On the one hand, it encourages small contractors to embrace sustainable construction actively, especially those who plan to conduct public projects. On the other hand, it creates more demands for sustainable construction, which would provide more opportunities for small contractors to adopt sustainable construction. Furthermore, this solution highlights the leading role of government in promoting sustainable construction among small contractors. This is in line with BCA's 3rd Green Building Masterplan (BCA 2014), where Continued Leadership is listed as the 1st strategic goal in the masterplan. Interviewees of the post-survey interview also agreed with this, and they emphasized that only the government can push forward the drive in the industry.

S11 "Costs savings from building operations to be shared with contractors" was ranked as the third best solution, receiving endorsement from 63.33% of respondents. This solution was about to tackle the "management barriers" confronted by small contractors. As claimed by a large number of studies (e.g., Shan and Hwang 2018; Darko and

Table 7 Respondents' endorsements on solutions proposed for barriers

Code	List of solutions	Frequency	%	Rank
S1	Government to provide higher subsidies to offset premiums	27	90.00	1
S5	Government to spur demand by adopting sustainable construction in public projects	22	73.33	2
S11	Costs savings from building operations to be shared with contractors	19	63.33	3
S3	Compulsory implementation of sustainable construction processes	19	63.33	3
S10	Hire or engage a Green Mark Manager/Professional	18	60.00	5
S2	Lower interest on loan for sustainable construction projects	16	53.33	6
S18	Education institution to prepare future workforce in sustainable construction	16	53.33	6
S12	Government to promote R&D in education and private sectors to spur innovation	15	50.00	8
S16	Government to set up training funds for contractors to train workers on sustainable construction methods	15	50.00	8
S17	Government-funded educational program on improving built environment	15	50.00	8
S7	Improvement on existing Green indicators	13	43.33	11
S8	Creation of easy-to-follow framework for sustainable construction	13	43.33	11
S15	Increase awareness of the benefits of sustainable construction	12	40.00	13
S4	Creation of building codes and regulations	11	36.67	14
S9	Ensure effective communication between key players involved	11	36.67	14
S6	Promote contractors with good sustainable construction practices track record	10	33.33	16
S14	Inculcate green building aesthetics in education institutions	8	26.67	17
S13	Develop suitable risk management plans to prevent unexpected results from adopting new processes	7	23.33	18

Chan 2017a; Häkkinen and Belloni 2011; Nguyen et al. 2017; Serpell et al. 2013), contractors in most cases cannot enjoy the financial benefits of sustainable construction, because these benefits mainly accrue in the operation of the building. As such, the respondents opined that there should be a partnership established between owners and contractors, which allow them to reap the benefits jointly in the long-term management of the building. However, the outcome of this option remains to be seen as it is often difficult to price in the actual savings in the initial stages of the procurement process.

Targeting the "political barriers," S3 "Compulsory implementation of sustainable construction processes" was also ranked as the third best solution, ting with S14. Such a high ranking indicated that the mandatory implementation of sustainable construction was widely supported by respondents. In Singapore, the BCA has enacted the Building Control Act which stipulated that sustainable construction is compulsory for all new buildings and existing buildings to be retrofitted after April, 2008 (BCA 2017f). However, small contractors may not have a lot of projects that involve large buildings or major retrofits. Therefore, the existing policy might need slight amendment. For example, projects of any size should be included under the umbrella of sustainable construction. It is believed that by doing this, the uptake of sustainable construction among small contractors would be increased significantly.

S10 "Hire or engage a Green Mark Manager/Professional" was ranked as the fifth best solution receiving endorsement from 60% of respondents. This solution was to tackle the "management barriers" confronted by small contractors. Implementing sustainable construction often requires some specialized knowledge and skills that vary from traditional construction methods and are rarely equipped by small contractors (Ametepey et al. 2015; Chan et al. 2017; Häkkinen and Belloni 2011). Therefore, it is necessary for small contractors to hire or engage a professional who has specialty in sustainable construction (e.g., Green Mark Manger or Professional). Using their experience and specialty, such a professional can set out the foundations that are necessary for small contractors to adopt sustainable construction, and ensure that sustainable practices are adopted to the maximum capacity for the project. This solution is extremely important to small contractors in Singapore as the majority of their existing employees lack the due capability in implementing sustainable construction (Ng 2017; Wong and Ng 2017). Although more magnitude of financial burden might be imposed on small contractors due to the adoption of this solution, it is worthwhile at it can significantly enhance the competitive advantage of small contractors in the green construction market.

Conclusions and recommendations

It is widely recognized that small contractors tend to face more challenges than large contractors in adopting sustainable construction. As a result, this study conducted a systematic investigation of the barriers that might hinder small contractors from adopting sustainable construction, and proposed a list of plausible solutions that could overcome those barriers, by analyzing the data from 30 small contractor firms in Singapore. According to the survey results, "extra investment required," "slow recovery of investment," "lack of incentives," "limited knowledge on sustainable construction," "tendency to maintain current practices," and "lack of demands from clients" were assessed as the top six significant barriers for small contractors to adopt sustainable construction. Moreover, the survey results found that the identified barriers, especially those under the categories of "financial barriers," "management barriers," and "knowledge barriers" were more critical to small contractors than to large contractors. Furthermore, the survey results reported five best solutions that can help small contractors in addressing the identified barriers. These solutions were "government to provide subsidies to small contractors to offset premiums," "government to spur demand by adopting sustainable construction in public projects," "costs savings from building operations to be shared with contractors," "compulsory implementation of sustainable construction processes," and "hire or engage a Green Mark Manager/Professional."

Although the objectives of this study have been achieved, some limitations still exist. First, the questionnaire of this study collected the data based on the respondents' perceptions, which might be biased upon their experiences. Second, the sample size was relatively small, and thus, caution should be warranted when the analysis results are interpreted. Lastly, the findings from this study were derived from the context of Singapore, which might vary in other countries. Nevertheless, the findings from this study are still valuable and useful in sense of being the first informative investigation of the barriers and solutions for small contractors to adopt sustainable construction. For small contractors, it summarizes and highlights the major barriers which they should pay special attention to, while for policy makers, it provides them with a list of feasible solutions that they may refer to for their policy development in the future.

For future research, it would be interesting to investigate the critical success factors of implementing sustainable construction by small contractors. It would be also imperative to identify the best practices for small contractors in implementing sustainable construction.

References

Ahn YH, Pearce AR, Wang Y, Wang G (2013) Drivers and barriers of sustainable design and construction: the perception of green building experience. Int J Sustain Build Technol Urban Dev 4:35–45

Ametepey O, Aigbavboa C, Ansah K (2015) Barriers to successful implementation of sustainable construction in the Ghanaian construction industry. Procedia Manufac 3:1682–1689

Asante J, Kissi E, Badu E (2018) Factorial analysis of capacity-building needs of small- and medium-scale building contractors in developing countries: Ghana as a case study. Benchmarking Int J 25:357–372

Banihashemi S, Hosseini MR, Golizadeh H, Sankaran S (2017) Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries. Int J Project Manag 35:1103–1119

Bca S (2014) 3rd green building masterplan. Building and Construction Authority, Singapore

BCA (2015a) Home-technology-BCA green mark scheme-enhanced SGD 20 million green mark incentive scheme for new buildings (GMIS-NB) [Online]. http://www.bca.gov.sg/greenmark/gmis.html. Accessed 5 Apr 2016

BCA (2015b) Home-technology-BCA green mark scheme-SGD 100 million green mark incentive scheme for existing buildings (BMIS-EB). Building and Construction Authority. https://www.bca.gov.sg/GreenMark/gmiseb.html. Accessed 5 Apr 2016

BCA (2017a) BCA Contractors Registration System (CRS) [Online]. https://www.bca.gov.sg/ContractorsRegistry/others/CRS_FAQ.pdf. Accessed 5 Dec 2017

BCA (2017b) BCA directory of registered contractors and licensed builders [Online]. https://www.bca.gov.sg/BCADirectory/Classification/Details/128. Accessed 17 Dec 2017

BCA (2017c) BCA green mark assessment criteria and online application [Online]. https://www.bca.gov.sg/GreenMark/green_mark_criteria.html. Accessed 18 Dec 2017

BCA (2017d) Construction productivity and capability fund [Online]. https://www.bca.gov.sg/CPCF/cpcf.html. Accessed 4 May 2018

BCA (2017e) Enhanced $20 million green mark incentive scheme for new buildings [Online]. Available: https://www.bca.gov.sg/GreenMark/gmis.html. Accessed 11 Apr 2018

BCA (2017f) Legislation on environmental sustainability for buildings [Online]. https://www.bca.gov.sg/EnvSusLegislation/Environmental_Sustainability_Legislation.html. Accessed 5 May 2018

BCA (2017g) Specific registration requirements for construction workhead [Online]. https://www.bca.gov.sg/ContractorsRegistry/others/Registration_CW.pdf. Accessed 5 Dec 2017

BCA (2018a) $100 million green mark incentive scheme for existing buildings [Online]. Available: https://www.bca.gov.sg/GreenMark/gmiseb.html [Accessed 11 April 2018]

BCA (2018b) Building retrofit energy efficiency financing (BREEF) scheme [Online]. https://www.bca.gov.sg/GreenMark/breef.html. Accessed 11 Apr 2018

Bon R, Hutchinson K (2000) Sustainable construction: some economic challenges. Build Res Inf 28:310–314

Chan APC, Darko A, Ameyaw EE, Owusu-Manu D-G (2017) Barriers affecting the adoption of green building technologies. J Manag Eng 33:04016057

Chan APC, Darko A, Olanipekun AO, Ameyaw EE (2018) Critical barriers to green building technologies adoption in developing countries: the case of Ghana. J Clean Prod 172:1067–1079

Chew K (2010) Singapore's strategies towards sustainable construction. IES J Part A Civ Struct Eng 3:196–202

Chong HY, Wang X (2016) The outlook of building information modeling for sustainable development. Clean Technol Environ Policy 18:1877–1887

Chou YM, Polansky AM, Mason RL (1998) Transforming non-normal data to normality in statistical process control. J Qual Technol 30:133–141

Darko A, Chan APC (2017a) Review of barriers to green building adoption. Sustain Dev 25:167–179

Darko A, Chan APC (2017b) Strategies to promote green building technologies adoption in developing countries: the case of Ghana. Build Environ 130:74–84

Darko A, Chan APC, Ameyaw EE, He B-J, Olanipekun AO (2017) Examining issues influencing green building technologies adoption: the United States green building experts' perspectives. Energy Build 144:320–332

Ding G, Forsythe PJ (2013) Sustainable construction: life cycle energy analysis of construction on sloping sites for residential buildings. Constr Manag Econ 31:254–265

Djokoto SD, Dadzie J, Ohemeng-Ababio E (2014) Barriers to sustainable construction in the Ghanaian construction industry: consultants perspectives. J Sustain Dev 7:134

Dobson DW, Sourani A, Sertyesilisik B, Tunstall A (2013) Sustainable construction: analysis of its costs and benefits. Am J Civ Eng Arch 1:32–38

du Plessis C (2007) A strategic framework for sustainable construction in developing countries. Constr Manag Econ 25:67–76

European Commission (2011) Key figures on European business with a special feature on SMEs [Online]. http://ec.europa.eu/eurostat/documents/3930297/5967534/KS-ET-11-001-EN.PDF/81dfdd85-c028-41f9-bbf0-a9d8ef5134c5. Accessed 19 Dec 2017

Gambo N, Said I, Ismail R (2016) Comparing the levels of performance of small scale local government contractors in Northern Nigeria with international practice. Eng Constr Arch Manag 23:588–609

Gan X, Zuo J, Ye K, Skitmore M, Xiong B (2015) Why sustainable construction? Why not? An owner's perspective. Habitat International 47:61–68

Häkkinen T, Belloni K (2011) Barriers and drivers for sustainable building. Build Res Inf 39:239–255

Hill RC, Bowen PA (1997) Sustainable construction: principles and a framework for attainment. Constr Manag Econ 15:223–239

Holloway S, Parrish K (2015) The contractor's role in the sustainable construction industry. Proc Inst Civ Eng Eng Sustain 168:53–60

Hwang B-G, Tan JS (2012) Green building project management: obstacles and solutions for sustainable development. Sustain Dev 20:335–349

Hwang BG, Zhao X, See YL, Zhong Y (2015) Addressing risks in green retrofit projects: the case of Singapore. Project Manag J 46:76–89

Hwang B-G, Shan M, Phua H, Chi S (2017a) An exploratory analysis of risks in green residential building construction projects: the case of Singapore. Sustainability 9:1116

Hwang B-G, Shan M, Phuah SL (2017b) Safety in green building construction projects in Singapore: performance, critical issues, and improvement solutions. KSCE J Civ Eng 22:447–458

Hwang B-G, Zhu L, Tan Joanne Siow H (2017c) Identifying critical success factors for green business parks: case study of Singapore. J Manag Eng 33:04017023

Hwang B-G, Shan M, Looi K-Y (2018) Key constraints and mitigation strategies for prefabricated prefinished volumetric construction. J Clean Prod 183:183–193

Kibert CJ (2007) The next generation of sustainable construction. Build Res Inf 35:595–601

Kim TK (2015) T test as a parametric statistic. Korean J Anesthesiol 68:540–546

Le Y, Shan M, Chan APC, Hu Y (2014) Overview of corruption research in construction. J Manag Eng 30:02514001

Li YY, Chen P-H, Chew DAS, Teo CC, Ding RG (2011) Critical project management factors of AEC firms for delivering green building projects in Singapore. J Constr Eng Manag 137:1153–1163

Li AS, Ling FYY, Low SP, Ofori G (2015) Strategies for foreign construction-related consultancy firms to improve performance in China. J Manag Eng 32:06015001
Low SP, Gao S, Tay WL (2014) Comparative study of project management and critical success factors of greening new and existing buildings in Singapore. Struct Surv 32:413–433
Lu S-L, Sexton MG, Abbot C (2008) Key characteristics of small construction firms: a United Kingdom perspective. In: Proceedings: CIBW065/055 joint international symposium: transformation through construction, 2008
Luu VT, Kim S-Y, Huynh T-A (2008) Improving project management performance of large contractors using benchmarking approach. Int J Proj Manag 26:758–769
Manoliadis O, Tsolas I, Nakou A (2006) Sustainable construction and drivers of change in Greece: a Delphi study. Constr Manag Econ 24:113–120
Maskil-Leitan R, Reychav I (2018) A sustainable sociocultural combination of building information modeling with integrated project delivery in a social network perspective. Clean Technol Environ Policy 20:1017–1032
Miyatake Y (1996) Technology development and sustainable construction. J Manag Eng 12:23–27
Mulva S (2017) JCEM and CII: advancing civilization. J Constr Eng Manag 143:02517012
Ng JS (2017) Small contractors still resistant to change [Online]. http://www.straitstimes.com/singapore/manpower/small-contractors-still-resistant-to-change. Accessed 11 Apr 2018
Nguyen H-T, Skitmore M, Gray M, Zhang X, Olanipekun AO (2017) Will green building development take off? An exploratory study of barriers to green building in Vietnam. Resour Conserv Recycl 127:8–20
Norušis MJ (2006) SPSS 14.0 guide to data analysis. Prentice Hall, Upper Saddle River
Ofori G (1998) Sustainable construction: principles and a framework for attainment-comment. Constr Manag Econ 16:141–145
Pitt M, Tucker M, Riley M, Longden J (2009) Towards sustainable construction: promotion and best practices. Constr Innov 9:201–224
Reychav I, Maskil Leitan R, Mchaney R (2017) Sociocultural sustainability in green building information modeling. Clean Technol Environ Policy 19:2245–2254
Roberts AC, Christopoulos GI, Car J, Soh C-K, Lu M (2016) Psychobiological factors associated with underground spaces: what can the new era of cognitive neuroscience offer to their study? Tunn Undergr Space Technol 55:118–134
Robichaud LB, Anantatmula VS (2010) Greening project management practices for sustainable construction. J Manag Eng 27:48–57
Ruparathna R, Hewage K (2015) Sustainable procurement in the Canadian construction industry: challenges and benefits. Can J Civ Eng 42:417–426
Saleh MS, Alalouch C (2015) Towards sustainable construction in Oman: challenges and opportunities. Procedia Eng 118:177–184
Serpell A, Kort J, Vera S (2013) Awareness, actions, drivers and barriers of sustainable construction in Chile. Technol Econ Dev Econ 19:272–288
Shan M, Hwang B-G (2018) Green building rating systems: global reviews of practices and research efforts. Sustain Cities Soc 39:172–180
Shan M, Hwang B-G, Wong KSN (2017a) A preliminary investigation of underground residential buildings: advantages, disadvantages, and critical risks. Tunn Undergr Space Technol 70:19–29
Shan M, Hwang B-G, Zhu L (2017b) A global review of sustainable construction project financing: policies, practices, and research efforts. Sustainability 9:2347
Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8:783
Shen W, Tang W, Siripanan A, Lei Z, Duffield CF, Wilson D, Hui FKP, Wei Y (2017) Critical success factors in Thailand's green building industry. J Asian Arch Build Eng 16:317–324
Shi Q, Zuo J, Huang R, Huang J, Pullen S (2013) Identifying the critical factors for green construction–an empirical study in China. Habitat Int 40:1–8
Singapore Business Review (2011) Govt sets new parameters to define SMEs [Online]. http://sbr.com.sg/retail/more-news/govt-sets-new-parameters-define-smes. Accessed 19 Dec 2017
Siniavskaia N (2015) Most homebuilders are small businesses [Online]. http://eyeonhousing.org/2015/12/most-homebuilders-are-small-businesses/. Accessed 21 June 2018
Tan Y, Shen L, Yao H (2011) Sustainable construction practice and contractors' competitiveness: a preliminary study. Habitat Int 35:225–230
Thas O, Rayner J, Best D (2005) Tests for symmetry based on the one-sample Wilcoxon signed rank statistic. Commun Stat Simul Comput 34:957–973
Tixier AJ-P, Hallowell MR, Albert A, van Boven L, Kleiner BM (2014) Psychological antecedents of risk-taking behavior in construction. J Constr Eng Manag 140:04014052
Turner AG (2003) Sampling strategies [Online]. https://unstats.un.org/unsd/demographic/meetings/egm/sampling_1203/docs/no_2.pdf. Accessed 12 May 2018
U.S. Small Business Administration, USA (2017) Summary of size standards by industry sector [Online]. https://www.sba.gov/contracting/getting-started-contractor/make-sure-you-meet-sba-size-standards/summary-size-standards-industry-sector. Accessed 19 Dec 2017
van Bueren EM, Priemus H (2002) Institutional barriers to sustainable construction. Environ Plan 29:75–86
Villasenor Alva JA, Estrada EG (2009) A generalization of Shapiro–Wilk's test for multivariate normality. Commun Stat Theory Methods 38:1870–1883
Wong SY, Ng JS (2017) Construction industry faces tough times [Online]. https://www.straitstimes.com/singapore/construction-industry-faces-tough-times. Accessed 4 May 2018
Wu P, Low SP, Liu JY, Pienaar J, Xia B (2014a) Critical success factors in distance learning construction programs at Central Queensland University: students' perspective. J Prof Issues Eng Educ Pract 141:05014003
Wu P, Xia B, Pienaar J, Zhao X (2014b) The past, present and future of carbon labelling for construction materials – A review. Build Environ 77:160–168
Xia B, Xiong B, Skitmore M, Wu P, Hu F (2015) Investigating the impact of project definition clarity on project performance: structural equation modeling study. J Manag Eng 32:04015022
Yeheyis M, Hewage K, Alam MS, Eskicioglu C, Sadiq R (2013) An overview of construction and demolition waste management in Canada: a lifecycle analysis approach to sustainability. Clean Technol Environ Policy 15:81–91
Yu T, Shi Q, Zuo J, Chen R (2017) Critical factors for implementing sustainable construction practice in HOPSCA projects: a case study in China. Sustain Cities Soc 37:93–103
Zhao X (2017) A scientometric review of global BIM research: analysis and visualization. Autom Constr 80:37–47
Zhao X, Hwang B-G, Gao Y (2016) A fuzzy synthetic evaluation approach for risk assessment: a case of Singapore's green projects. J Clean Prod 115:203–213
Zimmermann M, Althaus H-J, Haas A (2005) Benchmarks for sustainable construction: a contribution to develop a standard. Energy Build 37:1147–1157