GREEN BUILDING CONSTRUCTION PROJECTS IN SINGAPORE: COST PREMIUMS AND COST PERFORMANCE

Ming Shan[1], Bon-Gang Hwang[1], Lei Zhu[2] and Xinyi Cheong[1]

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

[2]Department of Construction and Real Estate, Southeast University, 2 Sipailou, Nanjing, China

ABSTRACT

While there has been a wealth of research on the life cycle cost of green buildings, few of them addressed the cost management performance of green building construction projects. As a result, this study aims to investigate the cost premiums and the cost performance of such projects in Singapore, which is an active global leader for green buildings, and to come up with feasible solutions that can help reduce the cost premiums and improve the cost performance. To achieve these goals, an extensive literature review and a questionnaire survey were conducted. Data collected from 121 green building construction projects showed that the green cost premiums in Singapore ranged from 5% to 10%, with different project type and size being significant factors affecting the premiums. It also reported that the majority of green building construction projects exhibited poor cost performances, with cost overruns ranging from 4.5% to 7%. Lastly, six strategic solutions that can reduce the cost premiums and improve the cost performance were proposed. This study contributes to the body of knowledge by adding the literature and findings in the context of the cost premiums and cost performance of green building construction projects. Furthermore, it can provide the industry professionals with an in-depth understanding of green cost premiums and performance as well as the responding control solutions, helping them make better decisions on cost-related management approaches from the beginning of such projects.

Keywords: *Cost Management; Cost Performance; Cost Premiums; Green Building; Green Construction.*

1. INTRODUCTION

Over the past two decades, green buildings are becoming increasingly popular in a large number of countries around the world (Zuo & Zhao, 2014). According to Dodge Data & Analytics (2016), green buildings would continue to expand worldwide in the coming decades, particularly in developed countries like the United States, the United Kingdom, Canada, Germany and Singapore. Such a remarkable green expansion is mainly because green buildings can offer substantial environmental benefits. According to the United Nations Environment Programme (UNEP, 2009), a 30 to 80 percent cut in energy consumption of buildings is attainable if the right green technologies are used. Additionally, the World Green Building Council (WorldGBC, 2014) reported that the design of an office building could also impact the health, well-being, and productivity of its occupants.

In spite of the benefits of green buildings and the various efforts being made to promote a sustainable built environment, numerous practitioners in the construction industry are still somewhat sceptical about the financial benefits that green buildings can deliver. Particularly, many industry professionals have the perception that the design and construction costs of green buildings are 10 to 20 percent higher than those of traditional buildings (WorldGBC, 2013). The higher costs associated with "going green," namely the green cost premiums, are the one of the most common reasons hindering the widespread development of green buildings (Dodge Data & Analytics, 2016; Robichaud & Anantatmula, 2011).

*Corresponding Author: E-mail – bdgsm@nus.edu.sg

As a result, the objectives of this paper are: (1) to investigate the cost premiums of green building projects and the significant reasons for them; (2) to compare the cost performance between green and traditional building projects; and (3) to examine plausible solutions that can improve the cost performance of green building projects, eventually cutting off their cost premiums. This study will contribute to the green building body of knowledge by adding to discussions of cost premiums and the cost performance of green building projects. Furthermore, the findings from this study can assist industry practitioners in making better cost-related decisions right at the beginning of green building projects.

2. BACKGROUND

2.1. GREEN BUILDINGS AND THE RATIONALES

There are various definitions of the term 'green building' and many varied perspectives of what constitutes a green building. According to Glavinich (2008), the term green building is defined in The United States as a building that provides the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional and global ecosystems both during and after its construction and specified service life. In Singapore, a building is considered green if it has met the requirements under the Green Mark Scheme, which requires the building to be both energy and water efficient, be environmentally sustainable, have a minimum indoor environment quality and possess green features (BCA, 2009). Despite having multiple definitions, a green building essentially means a building that is energy and resource efficient and has minimal disruptions to the environment (Zuo & Zhao, 2014).

Green buildings have environmental, economic benefits. Green buildings first benefit the environment. Globally, buildings are responsible for 40 percent of annual energy consumption (UNEP, 2011). Moreover, buildings were responsible for about one-third of greenhouse gas (GHG) emissions in the world (WorldGBC, 2013). Therefore, the building sector could lead to a great and efficient reduction of GHG emission if appropriate green technologies, materials, and construction methods were used (Wu et al., 2014). Green buildings also bring economic benefits in terms of energy and water savings and lower operating costs. Fowler and Rauch (2007) reported that green buildings could consume 26 percent less energy and saved 13 percent of maintenance costs when compared to traditional commercial buildings. Green buildings not only lead to energy savings but also provide social benefits, such as the increase in occupants' satisfaction, and positive impacts on occupants' health and productivity. Singh et al. (2010) and Thatcher and Milner (2014) investigated the effects of a green office building on the perceived health and productivity of occupants and found that the green building significantly contributed to an increase in the self-reported productivity and physical well-being of employees. Barrett et al. (2013) carried out a questionnaire with 751 students from 34 various classrooms in seven different schools in the United Kingdom and found that 'green' classrooms have a significantly different impact on a student's study progress.

2.2. COST PREMIUMS OF GREEN BUILDING PROJECTS

The development of green buildings is often greatly discouraged by the perceived higher costs, commonly termed green cost premiums, compared with traditional non-green buildings (Dodge Data & Analytics, 2016; Chandramohan *et al.,* 2012). Currently, there is no standardized definition for green cost premiums and no clear methodology to describe the components and to estimate green cost premiums (Dwaikat & Ali, 2016; Nalewaik &Venters; 2010; Kubba, 2010). Kats (2010) defined green cost premiums as the differential cost between a green and traditional version of the same building. Houghton *et al.* (2009) defined green cost premiums as the additional design and construction costs associated with specific green components. In terms of the general costs of a typical building, which consist of capital costs, operation costs, as well as repair and maintenance costs (Hendrickson & Au, 1989), Furr *et al.* (2009) stated that the additional capital costs of green building features are commonly termed green premium by the industry. In light of the above review, this study defines green cost premiums as the additional capital costs caused by green building features.

Design and construction costs are perceived as contributing to the green cost premiums (Johnson, 2000; Chandramohan *et al.,* 2012). Green building projects generally have more complex designs as compared with traditional building projects. In order to achieve sustainability, green building projects generally require the use of special specifications, materials, construction methods, and building practices (Lam *et al.*, 2010;

Robichaud & Anantatmula, 2011). Moreover, the productivity of the design and construction of green building projects is currently lower than that of traditional projects because practitioners still need time to learn and become proficient in these technologies. Furthermore, unfamiliarity with green technologies and technical difficulties during the construction process can not only affect the project schedule, but can also lead to cost increases through rework (Hwang *et al.*, 2009; Hwang *et al.,* 2015; Tagaza &Wilson, 2004).

Researchers in several countries such as The United States, The United Kingdom and Australia have started investigating green cost premiums (Dwaikat & Ali, 2016). Kats (2010) conducted a large-scale study based on extensive financial and technical analyses of more than 150 green buildings in the United States and ten other countries. The results of the study showed that green buildings cost roughly 2 percent more to build than traditional buildings. Moreover, Kim *et al.* (2014) concluded that the green cost premiums for residential project development in Los Angeles were 10.77 percent. In addition, Houghton *et al.* (2009) found that the green cost premiums for healthcare buildings in the United States were around five percent. In the United Kingdom, Building Research Establishment (BRE) and Cyril Sweett (2005) asserted that the green cost premium were up to 7 percent. In Australia, Langdon (2007) reported that the impact on the construction cost ranged from 3 percent to 5 percent for a five-star rating. Dodge Data & Analytics (2016) also conducted a study on the challenges of green buildings and identified that higher perceived first costs were one of the top three challenges in nearly all the 13 surveyed countries.

The building industry of Singapore recognizes the importance of sustainable construction to create a high-quality living environment for all. The Building and Construction Authority of Singapore (BCA) has launched three editions of its Green Building Masterplan from 2006 to aid in the greening of Singapore's current and future buildings (BCA, 2014). Singapore is now in the midst of a robust increase in the level of green activity (Dodge Data & Analytics, 2016). Despite the rapid development, green buildings in Singapore encountered a series of significant obstacles. One of the major obstacles is the high premium cost associated with green building construction (Hwang & Tan, 2012). Furthermore, the costly green building practices were also recognized as a major obstacle to the green development in Singapore (Chan *et al.,* 2009). However, compared to other leading countries who has conducted extensive research on green cost premium (Houghton *et al.,* 2009; Langdon, 2007), Singapore lacks knowledge and data on green cost premiums. Therefore, this paper investigated the cost premium situation in green buildings in Singapore, aiming to bridge the knowledge gap.

2.3. COST PERFORMANCE OF GREEN BUILDING PROJECTS

Cost performance indicates how well costs are kept under control, namely over budget or under budget. A few studies have been conducted to examine the cost performance of green building construction projects. For instance, Chandramohan *et al.* (2012) assessed the cost overruns of green building projects; Son *et al.* (2015) identified important factors that may affect cost performance of green building projects; Kang *et al.* (2013) compared the impact of pre-project planning on cost performance between green and traditional building projects. Additionally, Robichaud and Anantatmula (2011) tried to improve the chances of delivering the project within acceptable costs by suggesting some construction management adjustments to traditional project management practices. Nevertheless, generally there is still a lack of studies investigating the actual cost performance of green building projects.

A few studies have been conducted on the cost performance of traditional building projects as compared with green building projects. Particularly, two indicators widely used for measuring the general project cost performance are project cost growth and project budget factor, which were proposed by the Construction Industry Institute, The University of Texas at Austin (Thomas *et al.,* 2002). Project cost growth was calculated by dividing the difference between 'actual total project cost' and 'initial predicted project cost' using 'initial predicted project cost.' Project budget factor was calculated by dividing the 'actual total project cost' using the sum of 'initial predicted project cost' and 'approved changes.' Using these two indicators, Thomas *et al.* (2002) conducted a survey on 617 U.S. domestic and international traditional construction projects to investigate the impacts of two delivery systems: design-build (DB) and design-bid-build (DBB), on project cost performance. The results showed that the project cost growths for DB and DBB projects were -0.041 and -0.030, respectively, from the owners' perspective; the project cost growths for DB and DBB projects were 0.038 and 0.056, respectively, from the contractors' perspective. The results indicated that the cost performance of the U.S. traditional construction projects was below or slightly above budget. The project budget factor for DB and DBB projects were 0.966 and 0.948, respectively, from the contractors' perspective, indicating that the changes generally contributed to a 3 to 5 percent cost increase. In light of the above, this study used the project cost growth to investigate the cost performance of green building projects in Singapore. This study did not use the project budget factor because valuing changes/variations is relatively challenging.

3. METHODOLOGY AND DATA PRESENTATION

This study first carried out an extensive literature review from multiple sources including government websites, reports from private institutions, and journal papers, to provide a better understanding of the current market situation of green building and the issues relating to cost premiums and cost performance of green building construction projects. Then a questionnaire was subsequently developed. The questionnaire was to: (1) capture the current perceptions of professionals on cost premiums and cost performance of green building projects, (2) identify the significant reasons for cost premiums, and (3) gauge the effectiveness of proposed solutions to reduce green cost premiums and improve cost performance. The collected data were analysed using the Statistic Package for Social Science (SPSS) statistical software.

The developed questionnaire consists of five sections. The first section provided a definition of green cost premiums. The second section included questions meant to profile the companies and respondents. In the third section of the questionnaire, the respondents were asked to indicate the cost premiums of green building projects by different project types and sizes. The fourth section of the questionnaire requested the respondents to rate the significance of the reasons for the difference in the cost premiums between green and traditional building projects using a five-point scale (i.e., 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). Lastly, the fifth section of the questionnaire asked respondents to rate the effectiveness of the solutions that may reduce the cost premiums of green buildings and improve their cost performance using another five-point scale (i.e., 1 = least efficient, 2 = somewhat efficient, 3 = neutral, 4 = efficient, and 5 = most efficient). Furthermore, post-survey interviews were carried out with two green building professionals who had at least three years of experience in the green building industry, especially in green building costs management, to validate the findings generated by the questionnaire.

The population of the questionnaire survey consisted of all the professionals who had BCA Green Mark certificate, members of the Singapore Institute of Surveyors and Valuers (SISV), and the BCA directory of registered contractors and licensed builders with at least three years of experience in the green building industry and specialized in green building cost performance. The questionnaires were randomly sent out to the professionals via emails. Thirty responses were received finally. Although the sample size was relatively small, statistical analysis could still be performed because the central limit theorem holds true when the sample size is no less than 30, which is a generally accepted rule (Ott & Longnecker, 2015). The profiles of the respondents, companies, and projects are provided in Table 1.

Table 1: Backgrounds of the Respondents and their Companies

Profile	Frequency	Percentage
Company (total = 30)		
Type		
Architecture	2	7
Quantity surveying	5	17
Contractor	23	76
Total	30	100
Respondent (total = 30)		
Job title		
Project Manager	8	27
Quantity Surveyor	5	17
Contractor	17	56
Total	30	100
Years of experience in green building construction		
Less than one year	9	30
1 to 2 years	0	0
2 to 3 years	5	17

Profile	Frequency	Percentage
3 to 4 years	6	20
More than four years	10	33
Total	30	100
Project		
Traditional		
Commercial	124	51
Offices	20	8
Residential	98	41
Total	242	100
Green		
Commercial	57	47
Offices	10	8
Residential	54	45
Total	121	100

As indicated in Table 1, the respondents consisted of project managers, quantity surveyors, and contractors from different types of companies such as architecture, quantity surveying, and contractor firms. Particularly, 70% of respondents had at least two years' experience in green building construction. Given the duration of a normal building project is around two years in Singapore, it can be inferred that most of the respondents have sufficient experiences regarding the problem of cost in green building projects and thus were able to provide reliable cost assessments and objective judgment. Additionally, as indicated in Table 1, a total of 242 and 121 traditional and green building projects were recorded from the questionnaire, respectively. The percentages of the three types of projects (i.e., office, commercial, and residential) in traditional and green building project were generally comparable, suggesting no bias would generate from the unequal distribution of projects.

A series of statistical tests were conducted to analyse the collected data. Specifically, one-way analysis of the variation (ANOVA) test was performed to test whether the project type and project size have significant effects on green cost premiums. Turkey post hoc (TPH) test was conducted subsequently further to analyse the proved differences. Furthermore, one sample t-test was conducted to check whether the identified reasons have significant effects on the premium differences between green and traditional projects, and to check whether the proposed solutions are effective.

4. RESULTS AND DISCUSSIONS

4.1. *OVERALL PERCEPTIONS ON GREEN COST PREMIUMS*

According to the results of the questionnaire, a total of 43% of the respondents perceived green cost premiums to be 5% ~ 10%, followed by 34% and 23% of the respondents who perceived green cost premiums to be 10% ~ 15% and 0% ~ 5%, respectively. None of the respondents perceived green cost premiums to be above 15%. This result was confirmed by the professionals attending post-survey interviews, and was also in line with the argument made by Houghton *et al.* (2009) that green cost premiums were getting lower as a result of decreasing capital cost over time. Furthermore, according to a report from WorldGBC (2013), building professionals - both with experience and without any experience in green projects - tended to perceive green cost premiums to be up to 13% and 18%, respectively, which was not significantly different from the analysis results of this study.

4.2. *ACTUAL COST PREMIUMS OF GREEN BUILDING PROJECTS*

The cost premiums for green projects by project size (i.e., less than S$5 million, S$5 million to less than S$50 million, S$50 million and above) and type (i.e., green commercial, office, and residential buildings) are summarized in Table 2. This result was derived from the respondents' inputs, which were based on green building projects in which they had been involved. As shown in Table 2, there were indeed cost premiums for going green, generally ranging from 0% to less than 15%, regardless of the project type and size. This result was consistent with the overall perception on the green cost premiums presented in the previous section.

Table 2: Cost Premiums of Green Building Projects by Project Type and Size

Project size (S$ · million)	Capital cost premiums (CCP)	No. of green commercial	No. of green office	No. of green residential
Less than 5 (small)	0% =< CCP < 5%	1	2	0
	5% =< CCP < 10%	9	1	1
	10% =< CCP < 15%	0	0	4
	15% =< CCP < 20%	0	0	0
	20%=< CCP	0	0	0
5 to 50 (medium)	0% =< CCP < 5%	12	0	0
	5% =< CCP < 10%	9	4	2
	10% =< CCP < 15%	9	0	3
	15% =< CCP < 20%	2	0	2
	20%=< CCP	0	0	0
50 and above (large)	0% =< CCP < 5%	11	3	32
	5% =< CCP < 10%	4	0	5
	10% =< CCP < 15%	0	0	5
	15% =< CCP < 20%	0	0	0
	20%=< CCP	0	0	0

4.3. ACTUAL COST PREMIUMS BY PROJECT TYPE

The mean cost premiums of green building projects by project size and type are shown in Table 3. The overall mean of green cost premiums ranged from 2.5% to 12.5%. This result was comparable with the conclusion drawn by Kansal and Kadambari (2010) that the initial costs of a green building were 7.5% more than those of the ordinary building. Additionally, it is obvious that green residential has the highest cost premiums, followed by green commercial and green offices for three different size classifications. To test whether the project type has a significant effect on green cost premiums, one-way analysis of the variation (ANOVA) test was performed. Because the one-way ANOVA test does not show which specific building types significantly differ, the Tukey post hoc (TPH) test was subsequently performed to further analyse the difference. Table 4 summarizes the results.

Table 3: Mean Cost Premiums of Green Building Projects by Project Size and Type

Project size (S$ · million)	Mean of green cost premiums		
	Commercial	Office	Residential
Less than 5 (small)	7.0%	4.2%	11.5%
5 to 50 (medium)	7.7%	7.5%	12.5%
50 and above (large)	3.8%	2.5%	4.3%

Table 4: ANOVA and TPH Results by Project Type

Project size (S$ · million)	p-value (ANOVA)	p-value (Tukey Post Hoc)	
Less than 5 (small)	0.000	C vs R	0.002
		R vs O	0.000
		C vs O	0.110
5 to 50 (medium)	0.045	C vs R	0.038
		R vs O	0.197
		C vs O	0.998
50 and above (large)	0.601	No difference	

The p-values from the ANOVA test for projects under S$50 million were smaller than 0.05, indicating the building type had a significant effect on the mean of green cost premiums when the project size was small or medium. When the project size was large, the building type did not have a statistically significant effect on the mean of green cost premiums. According to the results from the TPH test, the means of the cost premiums were statistically different between commercial and residential building projects, and between office and residential building projects when the project size was small. As for medium sized projects, only commercial and residential building projects had statistically different cost premiums.

4.4. Actual Cost Premiums by Project Size

From the perspective of project size, large-scale projects have the lowest means of green cost premiums for all three building types, followed by small- and medium-scale projects, as shown in Table 3. One possible explanation for this result is that respondents involved in large-scale projects were mainly professionals with a good deal of experience in green building projects and thus were able to efficiently utilize green products without increasing overall design and construction costs (Malin, 2000). Also, respondents with sufficient experience in green building were more likely to adopt the right strategies, lowering green cost premiums accordingly (Bordass, 2000). To test whether the project size has a significant effect on green cost premiums, ANOVA and TPH tests were performed again. As indicated in Table 5, the p-values from the ANOVA test for three building types were all smaller than 0.05, indicating the project size had a significant effect on the mean of green cost premiums regardless of the building type. Further analysis based on the p-value from the TPH test indicated that green cost premiums were statistically different for medium- and large-scale projects in all three building types, whereas cost premiums were statistically different for small- and large-scale projects only in residential projects.

Table 5: ANOVA and TPH Results by Project Size

Project Type	p-value (ANOVA)	p-value (Tukey Post Hoc)	
Commercial projects	0.010	Small vs Medium	0.888
		Medium vs Large	0.008
		Small vs Large	0.124
Office projects	0.010	Small vs Medium	0.059
		Medium vs Large	0.009
		Small vs Large	0.428
Residential projects	0.000	Small vs Medium	0.875
		Medium vs Large	0.000
		Small vs Large	0.000

4.5. Reasons for Different Cost Premiums Between Green and Traditional Building Projects

One-sample t-test was performed to check whether each of the reasons had a significant effect on the difference in cost premiums between green and traditional building projects. Because a five-point scale was used, the test value was set as 3 which is the middle value of the scale. Table 6 summarizes the test results as well as the ranking of the reasons. It can be found that except R1 and R6, all the rest reasons had significant effect on the difference as their means were statistically higher or equal to the test value 3. "High cost of green technologies and materials" was the top reason for the difference in cost premiums between green and traditional building projects. This is because green materials and technologies are normally more costly than traditional materials and technologies (Hwang et al., 2016). "High research and development costs for green building products and systems" was ranked second. This might be due to the fact that new green products and systems usually require more efforts in testing and code approvals, which leads to an increase in research and development costs (Malin, 2000). "Lack of required green expertise and information," which ranked third, could also lead to an unnecessary increase in cost premiums. This is because, without sufficient green building expertise, the professionals will inevitably have difficulty in using green construction method properly, which may cause reworks as a result and finally leading to an increase in the capital cost of the green building projects (Architecture Week, 2001).

Table 6: Ranking of the Reasons for the Difference in Cost Premiums

SN	Reasons	p-value	Mean	Rank
R1	Higher consultant and designer fees	0.022	2.60	6
R2	Lack of required green expertise and information	0.315	3.10	3
R3	Difficulty in getting green services from contractors and subcontractors	0.5000	3.00	5
R4	Difficulty in getting green resources e.g. materials, technologies etc.	0.444	3.03	4
R5	High cost of green technologies and materials	0.000	3.70	1
R6	Lack of Government incentives/subsidies for green building projects	0.034	2.57	7
R7	Higher research and development costs for green building products, systems, technologies etc.	0.221	3.13	2

4.6. COMPARISON OF COST PERFORMANCE BETWEEN TRADITIONAL AND GREEN BUILDING PROJECTS

Table 7 summarizes the cost performances of traditional and green building projects by project type. The negative and positive percentages indicate an "under budget" and "over budget" cost performance of projects, respectively. It can be found from Table 7 that, regardless of project types, green projects generally had a cost overrun, whereas traditional projects were generally under budget. One primary reason for such results might be professionals' unfamiliarity and insufficient expertise in green building projects compared with traditional projects (Hwang *et al.,* 2016). Another possible reason for the cost overrun of green building projects was that they were more likely to be delayed than traditional projects. Hwang and Leong (2013) found that 33.33% of green projects encountered a delay, as opposed to only 17.39% for traditional projects.

Table 7: Cost Performances of Traditional and Green Building Projects

Cost Growth (CG)	No. of Commercial Projects		No. of Offices Projects		No. of Residential Projects	
	Traditional	Green	Traditional	Green	Traditional	Green
-10% <= CG < -5%	10	0	7	0	30	0
-5% <= CG < 0%	60	6	4	0	42	0
0% <= CG < 5%	54	22	7	1	21	32
5% <= CG < 10%	0	29	2	9	5	22
Total	124	57	20	10	98	54

5. SOLUTIONS FOR COST PREMIUMS REDUCTION AND COST PERFORMANCE IMPROVEMENT

Table 8 presented the assessment results of the solutions that may reduce cost premiums and improve cost performance of green building projects. To determine the effectiveness of the solutions, one-sample t-test was performed. Because a five-point scale was used, the test value was set as 3, namely the middle value of the scale. It can be found from Table 8 that all the solutions were statistically effective as their assessments were statistically higher or equal to the test value 3. "Tax relief" was ranked as the most effective solution. It can bring economic benefits to businesses and individuals who have been using green products and systems and thereby make them stick to their choice of green (Bourgeois et al., 2010). "Availability of skilled and experienced project team" was ranked as the second most effective solution. Green building projects generally have a more complex design as compared with traditional building projects (Hwang et al., 2016). With a skilled and experienced project team, both lower cost premiums and better cost performance can be achieved because the right green design features and materials can be correctly and efficiently adopted during the design and construction period (Malin, 2000). Furthermore, if a project team has sufficient green building expertise, the cost performance of green buildings can be much improved because costs caused by unnecessary rework and changes can be avoided (Architecture Week, 2001). "Incentives/subsidies for green building projects" and "subsidies for green building professional and specialist courses from the government" were ranked third and fourth, respectively. From a practical standpoint, incentives from the government are extremely important for attracting and motivating hesitant building professionals to build green. Additionally, a good education on green products and systems can also be helpful as it can make industry practitioners more familiar with green products and systems (Nalewaik & Venters, 2010), thereby achieving cost premium reduction and cost performance improvement. These two solutions were also highly recommended by the professionals attending the post-survey interviews.

Table 8: Ranking of the Solutions to Reduce Cost Premiums of Green Buildings

Code	Solutions to reduce cost premiums	p-value	Mean	Rank
S1	Government to provide incentives/subsidies for green building projects	0.000	3.70	3
S2	Low interest loans	0.242	2.83	7
S3	Financial institutions to introduce lending schemes customized for green building projects	0.173	2.77	8
S4	Government to provide subsidies for research and development of green building products, systems and technologies	0.109	3.33	5
S5	Tax relief for developers and contractors for use of green building products, systems and technologies	0.000	3.83	1
S6	Availability of skilled and experienced project team and contractors	0.000	3.80	2
S7	Government to provide green building educational courses for key building players so as to flatten the learning curve of green construction	0.116	3.30	6
S8	Government to provide subsidies for green building professional and specialist courses	0.038	3.47	4

6. CONCLUSIONS AND RECOMMENDATIONS

Green buildings are becoming increasingly popular worldwide; however, the delivery of green buildings is still hindered by the higher cost associated with “going green.” As a result, this study aimed to investigate the current cost premiums of green building projects and identify the significant reasons for these cost premiums. In addition, the cost performance of green and traditional building projects was compared. Some plausible solutions that can reduce cost premiums and improve the cost performance were also proposed.

The first finding from this study was that the majority of the respondents perceived green cost premiums to be 5% ~ 10%, with green residential buildings having the highest cost premiums, followed by green commercial and green office buildings. Furthermore, it was proven that “project type” and “project size” were statistically significant variables affecting cost premiums. This study also identified that “high cost of green technologies and materials,” “higher research and development costs for green building products, systems, technologies, etc.,” and “lack of required green expertise and information” were the top three reasons for the cost premiums of green building projects. As for current cost performance, it was concluded that green building projects were generally over budget (4.5% ~ 7%), which was worse than traditional building projects. Finally, “tax relief” was identified as the most efficient solution that could have a significant impact on reducing cost premiums and improving the cost performance of green building projects.

Although the main objectives of this study were achieved, there are some limitations. First, caution should be given when the analysis results are interpreted and generalized because the sample size was relatively small. Second, the findings from this study were well interpreted in the context of Singapore, which may be different from the contexts of other countries. In spite of these limitations, the findings from this study are valuable. First, this study provides an exploratory investigation of cost premiums and cost performances of green building projects which can enhance practitioners and researchers’ understanding in this regard. Second, the reasons and solutions investigated in this study can help the policy makers to come up with some measures that are more effective in reducing cost premiums and improving cost performance in green building projects.

Further studies can investigate green building projects performed in other countries in the sense of cost premiums and cost performance, and provide the results from comparisons of projects. In addition, because this study was focused on new green building projects, other kinds of green building projects, such as green retrofit or maintenance projects, can be studied further.

7. REFERENCES

Architecture Week., 2001. *Barriers to Building Green* [Online]. USA: Architecture Week. Available: http://www.architectureweek.com/2001/0822/environment_1-2.html [Accessed 10.01 2015].

Barrett, P., Zhang, Y., Moffat, J. and Kobbacy, K., 2013. A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning. *Building and Environment, 59,* 678-689.

BCA., 2009. *2nd Green Building Masterplan* [Online]. Singapore: Building and Construction Authority. Available: http://www.bca.gov.sg/greenMark/others/gbmp2.pdf [Accessed 18.10 2014].

BCA., 2014. *3rd Green Building Masterplan* [Online]. Singapore: Building and Construction Authority. Available: http://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf [Accessed 18.10 2014].

Bordass, B., 2000. Cost and value: Fact and fiction. *Building Research and Information, 28(5-6)*, 338-352.

Bourgeois, M., Breaux, K., Chiasson, M. and Mauldin, S., 2010. Tax incentives of going green. *The CPA Journal, 80(11),* 19-24.

Building Research Establishment (Bre) & Cyril Sweett., 2005. *Putting a price on sustainability,* Bracknell, UK, BRE Electronic Publications.

Chan, E. H. W., Qian, Q. K. and Lam, P. T. I., 2009. The market for green building in developed Asian cities-the perspectives of building designers. *Energy Policy, 37(8)*, 3061-3070.

Chandramohan, A., Narayanan, S. L., Gaurav, A. and Krishna, N., 2012. Cost and time overrun analysis for green construction projects. *International Journal of Green Economics, 6(2)*, 167-177.

Dodge Data & Analytics., 2016. World Green Building Trends: Developing Markets Accelerate Global Green Growth SmartMarket Report. *Design and Construction Intelligence.* 34 Crosby Drive, Suite 201, Bedford, MA 01730: Dodge Data & Analytics, Research & Analytics.

Dwaikat, L. N. and Ali, K. N., 2016. Green buildings cost premium: A review of empirical evidence. *Energy and Buildings, 110,* 396-403.

Fowler, K. and Rauch, E., 2007. Using integrated design strategies and energy efficient technologies to enhance green buildings. *Strategic Planning for Energy and the Environment, 26(4)*, 43-54.

Furr, J. E., Kilbert, N. C., Mayer, J. T. and Sentman, S. D., 2009. *Green Building and Sustainable Development: The Practical Legal Guide,* Chicago, IL, American Bar Association, Section of Real Property and Trust and Estate Law.

Glavinich, T. E., 2008. Contractor's Guide to Green Building Construction: Management, Project Delivery, Hoboken, U.S.A, John Wiley and Sons, Inc.

Hendrickson, C. and Au, T., 1989. Project management for construction: Fundamental concepts for owners, engineers, architects, and builders, Chris Hendrickson.

Houghton, A., Vittori, G. and Guenther, R., 2009. Demystifying first-cost green building premiums in healthcare. *HERD, 2(4)*, 10-45.

Hwang, B., Shan, M. and Tan, E., 2016. Investigating Reworks in Green Building Construction Projects: Magnitude, Influential Factors, and Solutions. *International Journal of Environmental Research, 10(4)*, 499-510.

Hwang, B. G. and Leong, L. P., 2013. Comparison of schedule delay and causal factors between traditional and green construction projects. *Technological and Economic Development of Economy, 19(2)*, 310-330.

Hwang, B. G. and Tan, J. S., 2012. Green building project management: Obstacles and solutions for sustainable development. *Sustainable Development, 20(5)*, 335-349.

Hwang, B. G., Thomas, S. R., Haas, C. T. and Caldas, C. H., 2009. Measuring the impact of rework on construction cost performance. *Journal of Construction Engineering and Management, 135(3)*, 187-198.

Hwang, B. G., Zhao, X. and Tan, L. L. G., 2015. Green building projects: Schedule performance, influential factors and solutions. *Engineering, Construction and Architectural Management, 22(3)*, 327-346.

Johnson, S. D., 2000. The Economic Case for "High Performance Buildings". *Corporate Environmental Strategy, 7(4)*, 350-361.

Kang, Y., Kim, C., Son, H., Lee, S. and Limsawasd, C., 2013. Comparison of preproject planning for green and conventional buildings. *Journal of Construction Engineering and Management, 139(11),* 04013018.

Kansal, R. and Kadambari, G., 2010. Green Buildings: An Assessment of Life Cycle Cost. *The IUP Journal of Infrastructure, 8(4),* 50-57.

Kats, G., 2010. Greening our built world: costs, benefits, and strategies, Washington, DC, Island Press.

Kim, J. L., Greene, M. and Kim, S., 2014. Cost comparative analysis of a new green building code for residential project development. *Journal of Construction Engineering and Management, 140(5),* 05014002.

Kubba, S., 2010. Green construction project management and cost oversight, Butterworth-Heinemann.

Lam, P. T. I., Chan, E. H. W., Poon, C. S., Chau, C. K. and Chun, K. P., 2010. Factors affecting the implementation of green specifications in construction. *Journal of Environmental Management, 91(3)*, 654-661.

Langdon, D., 2007. The cost & benefit of achieving green buildings. Australia: Davis Langdon Management Consulting.

Malin, N., 2000. The cost of green materials. *Building Research and Information, 28(5-6)*, 408-412.

Nalewaik, A. and Venters, V., 2010. Cost benefits of building green. *IEEE Engineering Management Review, 38(2)*, 77-87.

Ott, R. L. and Longnecker, M. T., 2015. *An Introduction to Statistical Methods and Data Analysis*, Cengage Learning.

Robichaud, L. B. and Anantatmula, V. S., 2011. Greening project management practices for sustainable construction. *Journal of Management in Engineering, 27(1)*, 48-57.

Singh, A., Syal, M., Grady, S. C. and Korkmaz, S., 2010. Effects of green buildings on employee health and productivity. *American Journal of Public Health, 100(9)*, 1665-1668.

Son, H., Lee, S. and Kim, C., An Empirical Investigation of Key Pre-project Planning Practices Affecting the Cost Performance of Green Building Projects. *Procedia Engineering*, 2015. 37-41.

Tagaza, E. and Wilson, J., 2004. Green buildings: drivers and barriers e lessons learned from five Melbourne developments. *Report Prepared for Building Commission by University of Melbourne and Business Outlook and Evaluation*.

Thatcher, A. and Milner, K., 2014. Changes in productivity, psychological wellbeing and physical wellbeing from working in a 'green' building. *Work, 49(3)*, 381-393.

Thomas, S. R., Macken, C. L., Chung, T. H. and Kim, I., 2002. Measuring the Impacts of the Delivery System on Project Performance–Design-Build and Design-Bid-Build. *NIST GCR, 02-840.*

United Nations Environment Programme, 2009. *Buildings and Climate Change – Summary for Decision-Makers* [Online]. Available: http://www.unep.org/sbci/pdfs/sbci-bccsummary.pdf [Accessed 12.05 2014].

United Nations Environment Programme, 2011. *Sustainable Buildings and Climate Initiatives* [Online]. Paris: United Nations Environmental Programme. Available: http://www.unep.org/sbci/pdfs/sbci_2pager_eversion_Feb2011.pdf [Accessed 02.12 2015].

Worldgbc., 2013. *The Business Case for Green Building – A Review of the Costs and Benefits for Developers, Investors and Occupants* [Online]. Available: http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf [Accessed 22.12 2014].

Worldgbc., 2014. *Health, Wellbeing and Productivity in Offices - The Next Chapter for Green Building* [Online]. Available: http://www.worldgbc.org/files/6314/1152/0821/WorldGBC__Health_Wellbeing__productivity_Full_Report.pdf [Accessed 22.12 2014].

Wu, P., Xia, B., Pienaar, J. and Zhao, X., 2014. The past, present and future of carbon labelling for construction materials - A review. *Building and Environment, 77,* 160-168.

Zuo, J. and Zhao, Z. Y., 2014. Green building research-current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30,* 271-281.