GREEN RETROFIT PROJECTS: RISK ASSESSMENT AND MITIGATION

Xianbo Zhao[1], Bon-Gang Hwang[2] and Yi Lin See[3]

[1]*School of Engineering and Technology, Central Queensland University, Sydney, NSW 2000, Australia*
[2]*Department of Building, National University of Singapore, Singapore*
[3]*EC Harris, Singapore*

The Singapore building industry has been experiencing a trend of going green and the government has set up a target to have at least 80% of buildings being green by 2030. To achieve this target, initiatives have been steered towards retrofitting existing buildings to green buildings. This study aims to assess the risks associated with green retrofit projects in Singapore. To achieve the objective, 20 risks were identified from a literature review. In addition, a questionnaire survey was performed with 30 professionals experienced in green retrofits. In the risk assessment, this study adopted the index of risk criticality (RC), which is the product of likelihood of occurrence (LO) and magnitude of impact (MI). In terms of RC values, *"post-retrofit tenants' cooperation risk"*, *"regulatory risk"*, *"market risk"*, *"financial risk"*, and *"pre-retrofit tenants' cooperation risk"* were the top-five risks. Additionally, comparisons were made between traditional and green retrofit buildings. 17 and 19 risks received significantly higher LO and MI values in green retrofits than those in traditional retrofits, respectively, which contributed to the significant differences in RC values of 19 risks between the two groups of retrofits. These results also confirmed the necessity of risk management in green retrofit projects. Furthermore, 28 mitigation measures were collected and received agreement from the respondents. This study contributes to knowledge by providing an understanding of the risks in green retrofit projects in Singapore for both practitioners and researchers. Practitioners can customize their own list of critical risks in green retrofit projects based on the risk identification in this study.

Keywords: green building; retrofit; risk criticality; mitigation; Singapore.

INTRODUCTION

The building and construction industry greatly contributes to the increase in greenhouse gas (GHG) emissions, which leads to global climate change (Wu *et al*. 2014a; Wu *et al*. 2014b). In recent years, there has been an apparent shift towards green construction across the world (McGraw-Hill Construction 2013). Singapore has been viewed as a leader in advocating sustainability in the building and construction industry with its efficient green strategies and initiatives (WorldGBC 2013), and launched the Green Mark Scheme in 2005. Additionally, Singapore's government has set up a target to have at least 80% of buildings being green by 2030 (BCA 2009; Hwang and Tan 2012). To achieve this target, efforts should not only be directed to constructing new green buildings as existing buildings represent a bigger proportion. Initiatives have been steered towards retrofitting existing buildings to green buildings, and green retrofit had reduced operating costs by 14% over five years, with a payback time of approximately six years for green investment (McGraw-Hill Construction

[1] b.zhao@cqu.edu.au

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2013). Construction projects are inevitably plagued with risks (Zhao *et al*. 2014b), and in green retrofit projects, the risks are likely to be beyond those associated with traditional projects. Therefore, to ensure the achievement of the going green target set up by Singapore's government as well as the success and subsequent benefits of green retrofit projects, risks in the green retrofit projects should be well handled and managed. The objectives of this study are to (1) identify the potential risks in green retrofit projects in Singapore; (2) analyse their risk criticalities; (3) compare the risk criticalities between traditional and green retrofit projects; and (4) provide mitigation measures for the critical risks.

BACKGROUND

In order to reduce GHG emissions, and contribute to the global climate change mitigation efforts, the BCA launched the Green Mark Scheme in 2005. This scheme provides certification for building owners who have met the requirements set by the BCA. Hence, in Singapore, a building is considered as a green building if it has met the requirements of the Green Mark Scheme (Hwang and Ng 2013). In December 2006, the BCA formulated the 1st Green Building Masterplan to encourage, enable and engage industry stakeholders to increase their efforts in environmental sustainability. In 2009, the 2nd Green Building Masterplan were unveiled placed special emphasis on greening existing buildings because existing buildings represent a larger fraction and consume a third of Singapore's total end-use electricity (BCA 2010). Also, the Green Mark Incentive Scheme for Existing Buildings (GMIS-EB) is initiated to co-fund up to 35% of the retrofitting cost. Furthermore, in 2014, the BCA launched the 3rd Green Building Masterplan. In this Masterplan, a Green Mark Incentive Scheme for Existing Buildings and Premises (GMIS-EBP) is provided to incentivize existing small and medium enterprise (SME) tenants and building owners to adopt energy efficiency, and a Building Retrofit Energy Efficiency Financing (BREEF) Scheme is presented to help building owners overcome upfront costs of energy efficiency retrofits and adopt Green Mark standards for existing buildings (BCA 2014a).

Green retrofit projects are inevitably plagued with risks, including the risks common to all kinds of construction projects and those closely associated with green retrofit. These 20 risks are described in Table 1. In addition to the identification of the 20 risks above, this study also collected 37 risk mitigation measures from the literature review. The detailed description is presented in the section of results and discussions.

Table 1: Risks in green retrofit projects

Code	Risks	Description
R01	Financial risk	A higher certification is usually associated with a greater premium paid (WorldGE 2013). The additional upfront cost associated with green retrofit may threaten the achievement of the schedule and cost objectives of green retrofit projects.
R02	Return on investment (ROI) risk	A company's budget is usually not structured to track lifecycle cost due to the lack of appropriate financing model to estimate the benefits and costs, making it difficu to record long-term gains from retrofits. Also, the ROI can range widely dependin on the building's age, existing design, purpose, and the level of savings being targeted.
R03	Energy saving uncertainty	There are inconsistent energy savings throughout the building lifespan. One shoul be conscious that it is an unproven business case to accurately justify the energy saved.
R04	Accreditation of energy service companies (ESCOs)	An ESCO is a company dedicated to the provision of energy efficient technology and services including financing, design, implementation and management of projects. Risk resides where the ESCO selected is not accredited and lacks relevan experience and information to conduct benchmarking.

R05	Regulatory risk	The uncertainty about how the regulatory environment may evolve with regard to green buildings is a prime concern for developers as changes in regulations could lead to significant punitive damages if standards were not met.
R06	Legislative risk	Legislative risk refers to the risk that a change in the tax and incentives could affe a project. Incentives are not uniform and tend to change over time.
R07	Warranty risk	Warranty risk arises when a contract is not performed as promised. The current procurement contracts may lack the warranty in delivering the expected improvements.
R08	Market risk	Market risk occurs when developers are unable to articulate green building benefit to the prospective clients and fail to attain the anticipated market value.
R09	Industry risk	Green building knowledge may not be equally spread among project players withi the construction industry, leading to the lack of a consensus on the green building standards and knowledge.
R10	Delay in project completion	Delay is a common problem to all types of construction projects, including green retrofit projects. In retrofit, measures that minimize disturbance to occupants and disruption to existing building operations should be considered in the schedule planning.
R11	Productivity risk	Green retrofit projects require a peculiar set of knowledge and management skills that are different from traditional retrofits. The lack of such knowledge and management skills is likely to result in low project productivity.
R12	Manpower supply and availability	Green retrofit projects require skilled workers to handle specialized designs and features. However, there is a significant lack of competent and experienced workforce in the green construction industry. Also, Singapore's Ministry of Manpower (MOM) recently increased the foreigner worker levies and cut the fore worker quotas, which would aggravate the unavailability of competent manpower.
R13	Material supply and availability	In Singapore, the construction material supply, including green material, depends imports. Foreign governments' restrictions on material exports would aggravate th problems of material supply and availability.
R14	Team performance risk	Being a comparatively new industry, some owners have to approach green project with an inexperienced team. Others may encounter team members who are uncooperative, as they do not understand the rationale behind green buildings.
R15	Reliability and accuracy of benchmark	Many building owners had little information of their buildings' energy saving potentials and lacked energy performance indicators for measurement and verification of energy savings. Thus, the owners would not be able to benchmark themselves for improvement.
R16	Quality risk	Occasionally the green technology and product innovations were not properly fiel tested or untested and were of inferior quality, thus failing to meet the expectation
R17	Pre-retrofit tenants' cooperation risk	Pre-retrofit refers to the state prior to the completion of a retrofit project. Retrofit i usually performed while existing operations are running. Tenants may not apprehe the benefits and are uncooperative for fear of losing commercial profits during the retrofit process.
R18	Post-retrofit tenants' cooperation risk	Post-retrofit refers to the state after retrofit completion. One of the post-retrofit challenges faced by the owner is the whim of the tenants. To maintain the benefits after the retrofit, equipment has to operate at its best efficiency, requiring tenants' continuous cooperation.
R19	Different concerns of stakeholders	Because of the fragmentation nature of the construction industry, different stakeholders tend to have different concerns or conflicting objectives. The uncertainty in stakeholders' concerns represents a barrier to the adoption of green technology and may threaten objectives of green retrofit projects.
R20	Lack of streamlined tools and processes	There is a lack of streamlined tools and processes guideline set for companies to follow, which is also a challenge in the green building construction industry in Singapore. The risk could be magnified with the knowledge gap and lack of experience of design participants.

METHOD

Data collection and presentation

A questionnaire survey was performed to investigate the criticalities and mitigation measures of risks in green retrofit projects in Singapore. The literature review supported developing a preliminary questionnaire. A pilot study was conducted with three professionals through face-to-face interviews to solicit comments on the readability, comprehensiveness, and accuracy of the questionnaire. Based on their comments, new risk mitigation measures were added, revisions were made to improve the readability and accuracy of the statement of the risks and mitigation measures, and footnotes were added to explain the terminologies used. The finalized questionnaire included the questions meant to profile the firms and respondents. Additionally, the 20 risks were presented in the questionnaire, and the respondents were requested to assess the likelihood and impact of each risk in traditional and green retrofit projects, respectively. Moreover, the respondents were asked to answer whether they agreed or disagreed with the 37 risk mitigation measures for the 20 risks, using a five-point scale (1=very disagree; 3=medium; and 5=very agree). In addition, post-survey interviews were carried out with five of the respondents, in order to collect the rationale behind their ratings to support the survey results.

A list of professionals certified with the Green Mark Professional and Green Mark Manager Schemes was obtained from the BCA, and served as the sampling frame. A total of 145 questionnaires were randomly sent out, and 30 responses were received. The response rate was 21%, consistent with the norm of 20%-30% with most questionnaire surveys in construction research (Akintoye 2000). Although the sample size was not large, statistical analysis could still be performed because the central limit theorem holds true when the sample size is no less than 30 (Ott and Longnecker 2008). In addition, the sample size of this study was also comparable with previous studies relating to risk management or sustainable construction [e.g., 34 in Hwang *et al*. (2014); 33 in Zhao *et al*. (2013); and 17 in Wu and Low (2012)].

The 30 respondents had an average of 13.2 years' experience in retrofit projects and an average of 4.4 years in green retrofit projects. 53% of the respondents possessed over 10 years of experience in retrofits, whilst 63% had more than 4 years of experience in green retrofits, which was reasonable because the 2nd Green Building Masterplan focusing on green retrofits was launched in 2009. In addition, the respondents were from 10 consultancy firms (33%), six developers (20%), six facility management firms (20%), five ESCOs (17%), as well as three construction firms (10%).

Risk indices

The respondents were asked to rate the likelihood of occurrence (LO) and magnitude of impact (MI) of each risk. As the evaluation of risk criticality (RC) is complex and vague, qualitative linguistic terms are unavoidable (Wang *et al*. 2004). The LO was rated according to a five-point scale: 1 = rarely (LO < 20%); 2 = somewhat likely (20% ≤ LO < 40%); 3 = likely (40% ≤ LO < 60%); 4 = very likely (60% ≤ LO < 80%); and 5 = almost definite (LO > 80%). The MI was evaluated using another five-point scale: 1 = very small; 2 = small; 3 = medium; 4 = large; and 5 = very large. The LO and MI of each risk can be calculated using equation (1) and (2), respectively.

$$\mathrm{LO}^{i} = \frac{1}{n}\sum_{j=1}^{n} \mathrm{LO}_{j}^{i} \qquad (1)$$

$$\mathrm{MI}^{i} = \frac{1}{n}\sum_{j=1}^{n} \mathrm{MI}_{j}^{i} \qquad (2)$$

where n = the number of the respondents; LO^i = the likelihood of occurrence of risk i; LO^i_j = the likelihood of occurrence of risk i by respondent j; MI^i = the magnitude of impact of risk i; and MI^i_j = the magnitude of impact of risk i by respondent j. Thus, the

LO and MI of each risk are actually the mean scores assigned by the respondents. This study adopted a RC index to evaluate the criticality of each risk. RC has been widely recognized as the function of the LO and MI (Wu *et al*. 2013; Zhao *et al*. 2013). Hence, the RC of a risk can be computed as follows:

$$RC_j^i = LO_j^i \times MI_j^i \quad (3)$$

$$RC^i = \frac{1}{n}\sum_{j=1}^{n} RC_j^i \quad (4)$$

where n = the number of the respondents; RC^i_j = the risk criticality of the risk i by respondent j; and RC^i = the risk criticality of risk i. Thus, RC is on a full scale of 25.

RESULTS AND DISCUSSIONS

Risk ranking in green retrofit projects

Using Equations (1)-(4), this study calculated the LO, MI and RC values of each risk, as indicated in Table 2. According to the RC values, the risks were ranked. The top five critical risks are discussed as follows. In the risk ranking, *"post-retrofit tenants' cooperation risk"* occupied the top position, suggesting that tenants were likely to be uncooperative after the green retrofit completion. Without tenants' cooperation, the energy saving technology would not be used at the best efficiency and all the potential benefits would not be secured. Consequently, the owner would not have sufficient evidence to demonstrate the energy savings to the BCA, and may not be eligible for the financial incentives under the GMIS-EBP or BREEF Scheme. In addition, the BCA re-assess the certified Green Mark buildings every three years (BCA 2014b). The lack of tenants' cooperation would make the building fail in the Green Mark re-assessment.

"Regulatory risk" was ranked second. In Singapore, the regulatory environment relating to green building has been evolving in the past 10 years. The Green Mark Scheme became mandatory when the Building Control (Environmental Sustainability) Regulations were enacted in 2008. After December 2010, all new buildings had to comply with a higher Green Mark standard. This required an additional 10% in energy savings and the minimum standard was also 28% higher than that released in 2005.

"Market risk" received the third position. The rationale behind this high RC was collected from the post-survey interviews. In the property market, most practitioners lacked relevant knowledge on green technologies and may find it difficult to clearly express the possible benefits to the clients. Hence, the owner was not likely to ensure the expected market value. Also, many tenants tended not to relate green technologies with improved quality of life, and held an idea that the costs of green retrofits were transferred to their rent.

"Financial risk" was ranked fourth. Although Singapore's government provided various financial incentives schemes, such as the GMIS-EB, the GMIS-EBP and the BREEF Schemes, they would not significantly assist the building owners financially because of the uncertainty in receiving the cash incentives. In addition, the cash incentive in the GMIS-EB has expired with effect from 28 April 2014 because the funds for the cash incentives have been fully committed. Moreover, the S$50 million GMIS-EBP is only applicable to SME tenants and building owners, and building owners with at least 30% of its tenants who are SMEs.

"Pre-retrofit tenants' cooperation risk" was the fifth most critical risk. This risk was perceived impactful as the green retrofits are usually conducted with the tenants'

operation going on. The post-survey interviewees indicated that it was a challenge to obtain the tenants' cooperation because most of them believed that green retrofitting was not necessary and the works inevitably impacted their business. These findings echoed the viewpoint of Miller and Buys (2008) that tenants tended to view retrofitting works to be disruptive.

Table 2: Comparison between traditional and green retrofit projects in Singapore

Code	Traditional				Green				Paired t-test	
	LO	MI	RC	Rank	LO	MI	RC	Rank	Difference	p-value
R01	2.63	3.50	9.20	3	3.80	4.37	16.83	4	7.63	0.000*
R02	2.73	2.73	7.97	11	3.63	3.73	13.50	11	5.53	0.000*
R03	2.07	2.73	6.90	18	3.57	4.33	11.83	15	4.93	0.000*
R04	2.03	2.90	5.40	20	3.80	3.87	10.73	16	5.33	0.000*
R05	2.87	3.13	10.73	2	3.70	4.27	17.77	2	7.04	0.000*
R06	2.13	2.87	7.47	15	3.80	3.87	10.07	18	2.60	0.000*
R07	2.33	2.47	7.30	17	4.40	3.47	10.13	17	2.83	0.001*
R08	2.93	3.30	9.10	4	3.87	4.03	17.00	3	7.90	0.000*
R09	3.10	2.83	8.40	6	2.97	3.93	13.00	13	4.60	0.000*
R10	2.43	2.97	8.17	10	3.53	3.77	12.17	14	4.00	0.000*
R11	2.70	3.43	8.33	7	2.73	3.20	9.43	20	1.10	0.065
R12	2.73	2.50	7.60	14	2.73	3.67	13.30	12	5.70	0.000*
R13	2.27	3.73	6.03	19	4.13	3.90	15.30	7	9.27	0.000*
R14	2.57	3.50	7.40	16	2.57	4.03	14.40	10	7.00	0.000*
R15	2.90	3.20	9.00	5	2.97	3.80	14.47	9	5.47	0.000*
R16	2.60	3.13	8.23	8	4.17	4.10	15.20	8	6.97	0.000*
R17	2.70	2.70	7.90	12	3.30	4.17	15.90	5	8.00	0.000*
R18	3.00	3.33	7.77	13	3.30	4.30	18.97	1	11.20	0.000*
R19	3.20	3.03	11.00	1	2.87	3.97	15.37	6	4.37	0.000*
R20	2.83	2.57	8.23	9	3.97	3.30	9.93	19	1.70	0.008*

* The paired t-test result is significant at the 0.05 significance level.
The Spearman rank correlation coefficient is 0.408 (p-value=0.075)

Risk criticalities: Traditional vs. green retrofit projects

The respondents were also requested to rate the LO and MI of the 20 risks based on their experience in traditional retrofit projects in Singapore. Thus, the RC values were compared between traditional and green retrofit projects (Table 2). The paired t-test results showed that p-values of 19 risks were less than 0.05, indicating significant differences in RC values between traditional and green retrofit projects. The RC values of these 19 risks in green retrofit projects were significantly higher than those in traditional retrofit projects.

The differences in the RCs of *"pre-retrofit tenants' cooperation risk"* and *"post-retrofit tenants' cooperation risk"* between the two groups were great. It is an arduous task to manage tenants to main the benefits brought by the green retrofits, as a post-survey interviewee indicated. In traditional retrofit projects, the building owners do not have to demonstrate the evidence of energy savings, so the cooperation of tenants is not recognized as crucial.

"Material supply and availability" also received a low risk rank in the traditional group, and the second largest difference in RCs between the two groups. The post-survey interviewees expressed their struggles to search for green materials and were unaware of the available resources in the market, while the common materials are more widely available and known.

The difference in the RCs of *"market risk"* was the fourth largest. This was possibly because the real estate agents and investors were not clear about the green building benefits. The buildings with Green Mark Platinum usually experience a noticeable increase in the sale price premiums, compared to those at the Green Mark Certified level (WorldGBC 2013). The high price premiums tend to make green retrofit buildings unattractive to the potential investors (Durmus-Pedini and Ashuri 2010).

"Financial risk" received the fifth greatest difference in RCs, although it was ranked high in both groups. Compared with traditional retrofitting, green retrofitting involves investing in energy-saving equipment and technologies, thus having higher upfront costs. Also, the development of an accurate cash flow forecast relies on current knowledge and past experience. However, most practitioners are relatively inexperienced in cost estimation of green retrofitting.

"Regulatory risk" was ranked second in both groups, but the RC was much higher in the green retrofitting. This was because green retrofit projects should be in compliance with both the basic regulations and those specifically related to the Green Mark Scheme.

Furthermore, the Spearman rank correlation was used to check the agreement in the risk ranking between the two groups. The correlation coefficient of 0.408 with a p-value of 0.075 suggested that there was no significant agreement in the risk ranking between the two groups.

Risk mitigation measures

The respondents were asked to rate whether they agreed or disagreed on the 37 risk mitigation measures. As Table 3 shows, 28 risks obtained significant agreement. To obtain tenants' cooperation after the retrofits, building owners could increase tenants' awareness of the benefits and provide incentives and rebates to the tenants, such as rental rebates. This measure has been adopted by some commercial buildings in Singapore, such as the 313@Somerest building. This practice is also consistent with the concept of the green lease. In addition, as for the mitigation measures for the pre-retrofit tenants' cooperation risk, the respondents did not believe it was feasible to perform work outside standard working hours and arrange relocation for tenants because these two measures would increase the project cost and tenants may still be reluctant to cooperate. Thus, it is feasible to first get the tenants to understand the rationale behind the retrofit works.

To mitigate the regulatory risk, it is reasonable to hire consultants for advice, who have the experience and knowledge in managing green retrofit projects. These consultants should be registered under the Green Mark Professional Scheme.

As for the mitigation measures for the market risk, building owners could make the public aware of the possible benefits of green buildings through media, and use specific evidence to demonstrate these benefits. Previous studies have emphasized educating public through media (Durmus-Pedini and Ashuri 2010; WorldGBC 2013). However, collecting the evidence of building performance and energy saving received a higher score from the respondents, indicating that practitioners preferred real case studies to just education.

To handle the financial risk, practitioners could choose to retrofit in phases. By performing the green retrofit project in phases, the size and first cost would be noticeably lesser, and the impact on companies' cash flow would not be great. Also, Singapore's government has been very supportive of green retrofitting and provided several financial incentive schemes. Hence, these incentives schemes could be utilized to mitigate financial risk. These two measures received high scores from the respondents, indicating their applicability.

Table 3: Risk mitigation measures in green retrofit projects

Risk	Risk mitigation measures		Mean
R01	M1a	Retrofit in stages	4.23*
	M1b	Share the risk with other parties by contractual agreement	3.67*
	M1c	Tap on government and financial incentives (e.g. GMIS-EB, GMIS-EBP, and BREEF)	4.03*
R02	M2	Document building performance and savings to establish a proof of higher performance	3.60*
R03	M3	Establish a performance based contract with the consultants	3.97*
R04	M4a	Check ESCOs' credibility with reference to the list of ESCOs provided by the government	4.07*
	M4b	Seek background information on the type of past projects handled by the ESCOs	3.50*
R05	M5	Hire consultants for advice	3.73*
R06	M6a	Obtain legal advice (e.g. when drafting contract)	3.80*
	M6b	Clearly define the liability	3.63*
R07	M7	Transfer risk to a third party (e.g. purchase insurance)	3.83*
R08	M8a	Educate the public on green building through use of media	3.53*
	M8b	Document performance and savings earned as benefit evidence	3.77*
R09	M9a	Educate professionals' knowledge of green building	3.27*
	M9b	Government to sponsor more green building courses for professionals	3.30
R10	M10a	Adopt technologies (e.g. BIM) to manage projects	3.00
	M10b	Set attainable milestones and monitor them regularly. If necessary, expedite the project	3.80*
	M10c	Understand and set reasonable buffer time	3.73*
R11	M11	Implement good resource scheduling and planning to maximize productivity	3.80*
R12	M12a	Increase the usage of automation and machinery	2.90
	M12b	Change Singaporean mindsets and encourage them to take up the job	2.60
R13	M13a	Procure materials which are manufactured and available in either Singapore or the neighbouring countries	2.60
	M13b	Carefully schedule material supplies	3.73*
	M13c	Industry institutions and government to provide a portal or list of green materials available	3.93*
	M13d	Obtain government support and invest in green material and technology research and development	3.80*
R14	M14a	Improve team members communication and integration	3.43*
	M14b	Select the Design & Build delivery method	3.13
R15	M15	Prepare a “knowledge portal” for historical data and lesson learnt to be recorded	3.70*
R16	M16a	Use tested and certified green materials	3.50*
	M16b	Conduct routine checks to ensure the desired level of workmanship are met	3.37
R17	M17a	Perform retrofit work outside standard working hours	2.83
	M17b	Arrange relocation for the tenants	2.97
	M17c	Explain the rationale for retrofitting existing building to green building	3.57*
R18	M18a	Increase awareness of the benefits of retrofitting existing building to green building	3.50*
	M18b	Provide incentives and rebates to the tenants (e.g. rental rebate)	3.97*
R19	M19	Engage in the Design & Build delivery method	3.27*
R20	M20	Government to sponsor more green building research	3.33*

* The one-sample t-test result is significant at the 0.05 significance level.

To integrate various stakeholders, Design and Build (DB), as an integration delivery method, is a viable solution to improve communication and minimize alienating any stakeholder base (Kibert 2012). This is because DB allows early discipline integration (Xia and Chan 2011), and thus various stakeholders' concerns can be put across.

Moreover, to ensure the material supply and availability, a portal or list of green materials available can be helpful because post-survey interviewees revealed difficulties in searching for suitable green materials available in the market. A careful schedule of material supply is also reasonable to handle this risk. Another approach, with agreement from the respondents, is to develop green materials through research projects funded by the government, thus reducing Singapore's dependence on imports of green materials.

Furthermore, to ensure the quality of green retrofit projects, the tested and certified green materials should be used. However, it was not feasible to conduct routine check, as revealed by its non-significant score. This was not surprising as routine checks would not be able to reduce *"green washing"*.

CONCLUSIONS

The objectives of this study are to (1) identify the potential risks in green retrofit projects in Singapore; (2) analyse their risk criticalities; (3) compare the risk criticalities between traditional and green retrofit projects; and (4) provide mitigation measures for the critical risks. Quantitative and qualitative data were elicited from a questionnaire survey and interviews. The analysis results showed that the top five risks in the ranking were: *"post-retrofit tenants' cooperation risk"*, *"regulatory risk"*, *"market risk"*, *"financial risk"*, *"pre-retrofit tenants' cooperation risk"*. In addition, 19 risks received significantly higher RC scores in green retrofit projects than in traditional retrofit projects. Furthermore, 28 risk mitigation measures obtained significant agreement from the respondents.

Although the objectives were achieved, there were some limitations to the conclusions that may be drawn from the results. First, the RC index proposed in this study was subjective and could be influenced by the experience and risk attitude of the respondents. Nonetheless, many risk management studies indicated that most risk management practices in the construction industry depended on experience and subjective judgments (Thevendran and Mawdesley 2004; Zhao *et al*. 2014a). Second, as the sample size in this study was small, one should be cautious when the analysis results are interpreted and generalized. Also, the findings from this study were well interpreted in the context of Singapore, which may be different from the context of other countries. Nonetheless, this study still provides an in-depth understanding of the risk criticalities and the mitigation measures in green retrofit projects in Singapore for both practitioners and researchers. Practitioners can customize their own list of critical risks in green retrofit projects based on the risk identification in this study. In addition, because Singapore has been recognized as a leader in advocating sustainability in the building and construction industry with its up-to-date and efficient green strategies and initiatives (WorldGBC 2013), the implications of this study can also be helpful and useful to the practitioners in other countries, where green building or retrofit projects are advocated.

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