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RETRACTION

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ABSTRACT

Architects are facing increasing risks that result from heightened expectations of benefits and performance when designing green buildings compared to traditional buildings. This study aims to identify the possible risk factors for architects developing green building projects in South Korea and assess risk mitigation measures. To attain this goal, 14 risk factors and 12 mitigation measures were determined through an extensive literature review. A questionnaire was administered to architects practicing green building design and criticality index was employed to assess major risk factors and mitigation measures. This study identified 'adoption of new technology and process', 'green building certification results', 'building products and materials', and 'energy saving uncertainty' as the major risk factors of green building projects. Additionally, the questionnaire proposed 'contract indicating each party's role, liability and limitations clearly', 'utilizing integrated design process', and 'understanding client's goal in green building projects' as the three most effective risk mitigation measures in designing green buildings. There are few studies that focus on architects' perceived risks concerning green building projects; this study contributes to a deeper knowledge and attempts to fill the current literature gap, which would benefit South Korea's green building design practice by aiding in the development of better risk management strategies.

Keywords: green building; risk management; risk factors; risk mitigation measures; architect

Introduction

After the Industrial Revolution, humans have become dependent on the heavy use of fossil fuels, thus directly causing global warming and climate change [1]. Energy used by buildings accounts for a substantial proportion of carbon dioxide emissions. Evidence shows that buildings consume 40% of energy and materials, as well as 16% of water around the world [2]. In the United States, 68% of electricity consumption, 38% of carbon dioxide emissions, 39% of energy consumption, and 12% of potable water consumption are from buildings according to Environment Protection Agency (EPA) of the United States [3].

Architecture, Engineering, Construction (AEC) experts and government officials have taken the environmental crisis seriously. Consequently, the green building movement is gaining popularity over the traditional buildings in the United States. In 2005, the green building market consisted of only 2% of all new non-residential construction, then the number had grown to 28%-35% in the United States by 2010 [4]. Factors such as client demand, low-cost building operation, and necessity are found to be the factors that will raise the demand for green buildings in the future [5]. Two factors that are considered to be the main drivers of increased demand for green building include participation in resolving global environmental problems and the variety of economic profits these buildings can bring [6].

As changes in the construction industry shift the focus to the prioritization of green buildings, government agencies are developing regulations to promote them. Accordingly, architects are required to acquire a higher standard of expertise and responsibility, which eventually affects the architects' "standard of care." The standard of reasonable care is the minimum expectation for architects by law, and "the most widespread and generally accepted baseline for evaluating the adequacy of design professional performance" [7]. The AIA (American Institute of Architects) establishes this standard by B101-2007, Standard Form of Agreement Between Owner and Architect, indicating "the architect shall perform its services consistent with the professional skill and care ordinarily provided by architects practicing in the same or similar locality under the same or similar circumstances‥and The architect is to render services as expeditiously as possible, consistent with professional skill and care and the orderly progress of the project" [8].

Traditional buildings were designed and built in a way that complied with minimum legal requirements. Architects who design green buildings must not only fulfill such requirements, but also achieve better performance, as is expected of green buildings. However, green buildings pose risks due to application of relatively newer construction materials, technologies, and processes to achieve green building status. If a green building fails to fulfill its performance indices addressed above, client dissatisfaction and conflict could ultimately result. Litigation cases have been reported involving innovative green building materials (*The Chesapeake Bay Foundation, Inc. v. Weyerhaeuser Company*), sales misrepresentation (*Shaw Development v. Southern Builders*), and failure to obtain green building certification (*Bain v. Vertex Architects*) [9-11]. Therefore, it is imperative that architects diagnose the potential risks in green building practices and prepare information on additional risks and legal liability. Correct and detailed diagnosis of architects' perception of green building risk is a required prerequisite to supplement and reinforce risk management expertise.

This study aims to identify and evaluate risk factors and mitigation strategies in green buildings to determine a scientific basis for better risk management in the South Korean context. Architects are provided to prepare strategies for the upcoming green building projects by understanding potential risks in undertaking such projects. Additionally, this study contributes to previous literature, mainly focused on the risks in the construction industry, by suggesting a perspective oriented toward design professionals.

South Korea is on the threshold of transitioning beyond a developing country to an advanced country. It is one of the countries participating in the Organization for Economic Corporation and Development (OECD) that exhibits a substantial influence on the global economy. As a member of the global society, South Korea has a duty to reduce greenhouse gas emissions according to climate change conventions and has been making diversified efforts to achieve this reduction goal. Notably, the South Korean government has established a basic roadmap for national gas reduction by the year 2030. Essentially, the government is pushing forward with a 37% national greenhouse gas reduction target against business as usual (BAU). According to this roadmap, South Korea has agreed to reduce a total of 219 million tons of greenhouse gas. Out of that amount, the building sector plans to reduce its production of greenhouse gases by 35.8 million tons, which is 18.1% of the total reduction target volume. The South Korean government intends to respond more actively to climate change and take the opportunity to shift to a new paradigm of growth. As part of their efforts, the South Korean government announced its Greenhouse Gas Reduction Road Map developed by associated government ministries [12]. In addition, Zero Energy Building obligation roadmap was promulgated in December 2017 as a detailed action plan in AEC sector. According to the timeline established by Korea Energy Agency (KEA), implementation of the roadmap in the public sector begins in 2020 and a phased implementation in the private sector targets a goal of completion by 2025. In South Korea, the construction industry holds a substantial position in the national economy and plays a pivotal role [13]. The demand for green buildings and resulting proportion of green buildings will continue to rise in South Korea based on the shift in policy.

Literature Review

Although risk identification studies regarding architectural practice are limited, growing awareness of risks in the green building has been raised.

One line of literature investigated cost as the main risk factor in green building design and construction. Gurgun et al. [14] recognized the top risk factors to minimize cost impacts in LEED certified projects: (1) when contractors and subcontractors disagree as to standards within their expertise and competence; (2) the high cost of certification; (3) the lack of expertise in new products, materials and technologies; and (4) inadequate definition of parties to the project's contractual roles and responsibilities. Finally, in using a fuzzy synthetic evaluation approach, Zhao et al. [15] assessed inaccurate cost estimation as the top risk factor. Further, the cost overrun risk was the most critical group in green building projects in Singapore. Al Rumanithi and Beheiry [16] found that utilizing green project management processes could lower the costs and risks of green projects. It could also raise their competitive advantage over conventional projects by presenting the case study in the United Arab Emirates. Chan et al. [17] identified and evaluated 20 barriers to adopt green building technologies in Ghana from a comprehensive literature review. Results from a questionnaire survey performed by green building professionals substantiated that the top three critical barriers were higher initial cost, lack of government incentives, and lack of financing.

Identifying risk factors while comparing traditional and green building was conducted in retrofit and commercial green building projects. Hwang et al. (2015) [18] summarized 20 risk factors and 37 mitigation measures associated with green retrofit projects and conducted a questionnaire survey reflecting Singapore context. They found that 19 risks were more critical in green retrofits than its traditional counterpart. Major risk factors were identified as "regulations, market demand, post-retrofit tenant's cooperation, pre-retrofit tenant's cooperation, project finance, and concerns from stakeholders, material supply and availability." Cattano et al. [19] identified that unforeseen conditions were the cause of both schedule delay and cost increase when delivering renovation projects for improved energy performance. Additionally, Cattano et al. [19] proposed the use of a comprehensive building inspection guide that could reduce the risk of unforeseen conditions. Regarding green commercial building projects, Hwang et al. (2017a) [20] identified the top five critical risk factors after a comprehensive literature and structured interview. Risk factors involve inflation, currency and interest rate volatility that can be worsened by the import of green materials, durability of green materials, damages caused by human error, and shortage of green materials. They found that adoptions of green ideas, materials, and technologies had posed additional risks to green commercial projects.

Other researchers have developed stakeholder decision-making models to identify risks in green building. Pearce et al. [21] initiated a study to promote the adoption of green building renovations and employed a process of interactive stakeholder mapping. This process aims to identify possible points of influence for changing stakeholders' decisions about specific innovations in green building and demonstrating the rewards that green building can bring. Similar to these studies, Yang et al. [22] modeled the interactive networks of risks associated with different stakeholders in green building projects to comprehend the key risk networks. By using social network analysis methods, risk factors are identified differently between China and Australia; specifically, reputation risk is important in both countries. However, the 'ethical risk of assessment expertise and fairness' has been highlighted as crucial in the Chinese context. Namely, the government plays a critical role in improving the societies' knowledge and awareness in green technology uptake in China.

As demonstrated above, the literature review provides a solid foundation for identification of risks in green building. Finally, the total 23 literatures are categorized according to the classical elements of project management: (1) cost, (2) schedule, and (3) quality. This quality attribute is subdivided in terms of factors affecting production of design drawings (R5, R10), design quality (R11, R13) and consulting services (R8, R9, and R12). Performance risks have been added in order to evaluate the performance of materials and technology applied in the building as well as results of any energy savings in green building certification level (R3, R4, R6, and R7). Contracts without clear lines of responsibilities, roles, and limitations have been added into one of the risk factors since it is a means to prevent legal and administrative risk that can lead to a claim (R14). As a result, fourteen risk factors were identified to conduct a subsequent questionnaire as shown in Table 1.

Although these studies provide some evidence of comprehensive studies of green building risk, our knowledge regarding the risk perceptions of architects within the context of design service scope remains limited. Therefore, the challenge of this paper is to answer the following questions: (1) According to South Korean architects, do specific risk factors exist in the development of green buildings compared to traditional buildings in South Korea and, if so, how do they rank? and (2) What risk mitigation measures are considered effective by South Korean architects and how do they rank? To date, research has been conducted on green building risks in terms of

Table 1. Risk factors associated with green building design

Code	Risk factors	References
R1	Financial risk	Grugun et al. [14], Zhao et al. [15], Al Rumanithi and Beheiry [16], Chan et al. [17], Hwang et al. (2015) [18], Hwang et al. (2017a) [20], Bowers & Cohen [23], Marsh [24], Yudelson [25]
R2	Delay in schedule risk	O’Connor [11], Yudelson [25], Slone et al. [26]
R3	Building products and materials	Latham & Watkins [10], O’Connor [11], Grugun et al. [14], Al Rumanithi and Beheiry [16], Hwang et al. (2015) [18], Hwang et al. (2017a) [20], Marsh [24], Slone et al. [26], Longley & Yoakum [27], Odom et al. [28]
R4	Adoption of new technology and processes	Wendt [9], Latham & Watkins [10], Grugun et al. [14], Al Rumanithi and Beheiry [16], Hwang et al. (2017a) [20], Yang et al. [22], Bowers & Cohen [23], Marsh [24], Odom et al. [28]
R5	Design guideline availability	Han & Kim [29]
R6	Energy saving uncertainty	Yudelson [25], Longley & Yoakum [27], Kubba [30], Tollin [31]
R7	Green building certification results	Wendt [9], O’Connor [11], Bowers & Cohen [23], Yudelson [25], Slone et al. [26], Longley & Yoakum [27], Kubba [30], Tollin [31], Anderson et al. [32]
R8	Team performance risk	Wendt [9], O’Connor [11], Grugun et al. [14], Marsh [24], Longley & Yoakum [27], Tollin [31], Yang et al. [22]
R9	Client’s goal uncertainty	Wendt [9], O’Connor [11], Slone et al. [26], Longley & Yoakum [27]
R10	Regulatory/Legislative risk	Hwang et al. (2015) [18], Yang et al. [22], Marsh [24], Slone et al. [26], Longley & Yoakum [27]
R11	Design changes	O’Connor [11], Anderson et al. [32]
R12	Lack of communications	O’Connor [11], Sloan et al. [26]
R13	Incomplete drawings & specs	Cattano et al. [19], Tollin [31], Keen [illegible]
R14	Lack of contract	Wendt [9], Gru[illegible] al. [illegible], Bowers & [illegible]hen [illegible] Mars[illegible], Anderson et al. [32]

Retraction

constructi[illegible]eme[illegible]here[illegible]ave [illegible]en fe[illegible]es on the risk factors perceived by architects themselves. Therefore, [illegible]ding [illegible]nt o[illegible]rchit[illegible] perception, this study will ultimately contribute to the improvement of the quality in gr[illegible]n bu[illegible]ngs, thereby helping to further advance the construction industry.

Methods

Data collection and presentation

For this study, a questionnaire survey was administered to compare the risk factors and risk mitigation measures for traditional buildings and green buildings as perceived by South Korean architects. Regarding the risk factors, the risk occurrence likelihood and their degree of impact on traditional buildings and green buildings were examined separately.

Before beginning the questionnaire survey, it was mandated that the scope of green buildings include those that obtained the following: Green Standard for Energy and Environmental Design (G-SEED), Korean green building rating system; Leadership in Energy and Environmental Design (LEED), another green building rating system developed by the U.S. Green Building Council; the Building Energy Efficiency Certificate and Zero Energy Building Certificate developed and administered by Korea Energy Agency; the Passive Construction Certificate of Passive House Institute Korea. In addition, before it was distributed to respondents, the questionnaire was reviewed overall by two experts who have full knowledge in questionnaire survey methodology, as well as by an architect with more than 10 years of experience in architectural design. This reciprocal process allowed to revise redundant and unclear content to meet the clearly defined survey objective.

After undergoing a revision process for survey items and questions, the final version of the questionnaire was written using Google Survey. The subject of the survey was South Korea's leading architectural design firms which are ranked within 15th in sales volume from Korea Financial Supervisory Service. Among them, 10 companies able to answer the questionnaire were selected; the number of respondents from each company was limited to 20 staff members working in architectural design. The questionnaire was sent through e-mail in February 2018 and respondents were given four weeks to answer. Weekly reminders were sent via phone or e-mail to encourage respondents to answer the questionnaire. A total of 96 out of 200 questionnaire copies were collected, three of which were excluded due to insufficient answers. A total of 93 copies of the questionnaire were analyzed. The response rate for the questionnaire survey was 47.5%.

Table 2 shows the distribution of respondent's experiences in the field. As shown, 74.1% of the respondents with more than five years of practice in designing traditional buildings, while 52.6% had more than three years' experience in designing green buildings. Such distribution proves that the respondents had sufficient experience for the study's objective and that the collected data was representative.

Table 2. Profiles of survey respondents (n=93)

Profile	Frequency (n)	Percentage (%)
Years of experience in traditional building projects		
Less than one year	3	3.2
1 to 2 years	4	4.3
3 to 4 years	17	18.2
5 to 10 years	29	31.1
More than ten years	40	43.0
Years of experience in green building projects		
Less than one year	26	27.9
1 to 2 years	18	19.3
3 to 4 years	20	21.5
5 to 10 years	23	24.7
More than ten years	6	6.4

Criticality index

To evaluate the criticality of each risk, this study adopted the risk criticality (RC) index. This RC index has been extensively perceived as the function of the likelihood and impact used in previous relevant studies [34-38]. In this study, respondents were asked to evaluate the likelihood and impact using five-point Likert scales as shown in Table 3.

Table 3. Rating scales for Likelihood and Impact

Likelihood			Impact	
Scale	Linguistic Terms	References	Scale	Linguistic Terms
1	Rare	<20%	1	Insignificant
2	Unlikely	20%-40%	2	Minor
3	Moderate	40%-60%	3	Moderate
4	Likely	60%-80%	4	Major
5	Almost certain	>80%	5	Catastrophic

By using equations (1), (2), (3), and (4), Likelihood (L), Impact (I), and RC can be measured respectively:

$$L^i = \frac{1}{n}\Sigma_{j=1}^{n} L^i, \tag{1}$$

$$I^i = \frac{1}{n}\Sigma_{j=1}^{n} I_j^i, \tag{2}$$

where n means the total number of respondents, L^i is the likelihood evaluation regarding risk i, L_j^i is the likelihood evaluation regarding risk *i* by respondent *j*, I^i is the impact evaluation on risk i, and I_j^i is the impact evaluation regarding risk *i* by respondent *j* [37].

$$RC_j^i = L_j^i \times I_j^i \tag{3}$$

$$RC^i = \frac{1}{n}\Sigma_{j=1}^{n} RC_j^i, \tag{4}$$

where n means the total number of respondents, RC_j^i is the risk criticality regarding risk *i* by respondent *j*, and RC^i is the risk criticality of risk *i* [37].

Results and Discussions

Risk criticalities: Traditional versus Green Building Projects

As actively practicing architectural design service in South Korea, the respondents were asked to evaluate the Likelihood and Impact for the 14 risk factors. RC values, ranking, and difference were calculated between green and traditional projects as shown in Table 4. The paired t-test was implemented to verify the difference in RC values between the two groups. The results showed that p-values of 6 risk factors were below 0.05, implying that there were convincing differences in RC values between green and traditional projects. The RC values of these 6 risks in green projects were higher than those in traditional projects, suggesting that the research hypothesis was supported.

Table 4. Comparison of RC values between green and traditional building projects

Code	Green		Traditional		Wilcoxon signed-Rank Test	
	RC	Rank	RC	Rank	Difference	p-Value
R1	16.1	1	15.18	3	0.92	0.019*
R11	15.23	2	16.47	1	-1.24	0.069
R9	15.19	3	15.35	2	-0.16	0.733
R10	14.6	4	13.05	5	1.55	0.217
R2	14.57	5	14.44	4	0.13	0.710
R14	13.56	6	12.84	7	0.72	0.118
R12	13.05	7	13.05	5	0	0.951
R8	12.8	8	11.66	8	1.14	0.097
R5	12.46	9	11.43	9	1.03	0.136
R13	12.08	10	10.99	10	1.09	0.048*
R6	12.03	11	10.38	11	1.65	0.005*
R3	11.75	12	9.80	12	1.95	0.001*
R4	11.73	13	8.76	14	2.97	0.000*
R7	10.98	14	8.82	13	2.16	0.000*

*indicates the paired t-test result is significant at the 0.05 significance level.

The risk 'R4-Adoption of new technologies and processes' indicates the largest difference (Diff.=2.97). Contemporary green building is relatively young with innovative new approaches and technologies introduced to improve building performance. These recent practices, however, add a layer of complexity that requires diligent maintenance and monitoring to prevent potential water or moisture issues that could damage the building's integrity. For example, installation of green roof, the practice of increased ventilation and building flush out, and increased insulation within the exterior walls which change the location of the dew point, can bring unintended moisture into the building, resulting in mold issues, especially in hot and humid climates [28]. Architect needs to make decisions of their applications based on technical data from the manufacturer and to test and evaluate its effectiveness using mock-ups before applying in the construction fields [32]. Communication among project stakeholders is essential; architects needs to inform any risks uncovered during the selection process and to discuss contractors with any potential issues during construction phase.

The risk 'R7-Green Building Certification Results' has the second largest difference (Diff.=2.16). Green building rating system such as G-SEED or LEED performs the evaluation per each criteria and gives the final grade for the purpose of an objective evaluation by a third party. In addition, the certification grade can be a very sensitive issue for clients who are the beneficiary of green buildings, as the tax benefit or incentive granted to them can differ according to the result of the certification. There exists a likelihood of dispute between architects and clients if the final grade is lower than expected or the certification itself fails. It is recommended that architects need to explain fully to clients about difficulty of warranty in the level of certification a building will attain. If an architect warrants that a building will achieve a specific level of certification, they may assume a high amount of risks based on the fact that insurance companies often do not cover such warranties [27, 39].

The risk 'R3-Building products and materials' has the third largest difference (Diff.=1.95). Some green products are in high demand and low supply, which results in a long lead time, thereby affecting the project schedule. Additionally, use of salvaged and recycled content building materials, and selection of locally produced buildings materials is highly encouraged to reduce the environmental footprint associated with extraction, production, and transportation of the building materials. However, the performance of new products can create a risk since they are developed without enough time to field test. When these untested products fail to meet the expected levels of performance, this can lead to legal disputes over who is responsible. In order to prevent potential liability issues out of specifying green products and materials, architects have a duty to discuss untested or new products with the client. Additionally, they must describe any possible impacts on the project, including, but not limited to, product performance and achieving an expected green building certification level. Language in the contract should address the issue of risks of new materials in order to protect architects from claim. Examples may include (1) "the owner will render a decision [about untested materials] and (2) the architect shall be permitted to rely on the manufacturers' or suppliers' representations and shall not be responsible for any failure of the Project to achieve the Sustainable Objective as a result of the use of such materials or equipment [40]."

The risk 'R6-Energy Saving Uncertainty' has the fourth largest difference (Diff.=1.65). When considering a building's operational performance, clients and tenants tend to expect that green buildings will reduce environmental impacts, reduce energy and water costs, and involve less maintenance and other long-term benefits to the building owner. Energy efficiency is one of the most compelling green building performance factors to reduce operating costs. However, there are all too many factors beyond the control of the architects to meet energy saving goals. Most of all, even though architects incorporate green features into the building, there is a considerable gap between design and occupancy. Any outcome in energy consumption is predicated based on assumptions which need to be understood by the owner, facilities manager, and tenants who must properly operate and maintain the equipment systems. It is recommended architects hire a commissioning agent before and after construction to catch potential problems as necessary to achieve the planned energy savings [23].

The risk 'R13-Incomplete drawings and specifications' ranked the fifth (Diff.=1.09). Contract documents consist of drawings and specifications as well as related supplementary paper work. Incomplete contract documents result from unclear and inadequate documentation, insufficient site investigation, and design changes [11]. This ultimately results in design changes and an increase in construction cost and period of time it takes to build. As green buildings require higher performance than traditional buildings, thereby bearing high complexity [41,42], a greater influence is exerted onto green buildings than traditional buildings in case the design documents and specifications are not perfectly matched.

The statistical analysis results from this study's questionnaire survey revealed similarities between the risk factors for green buildings and the risk factors for traditional buildings in R1-Financial risk, R11-Design changes, R9-Client's goal uncertainty, R10-Regulatory and legislative risk, R2-Delay in schedule risk, R14-Lack of contract, and R12-Lack of communications.

The result of the Wilcoxon-rank test verified that R1-Financial Risk was the primary risk factor for green buildings that differed from traditional buildings. Diverse factors that arise in the process of pushing forward with green building design and construction are thought to be the cause. The factors involved in financial risks likely include the following: design change due to the client's unexpected new direction, the architect's lack of experience and knowledge of the system of green buildings; unexpected increases in budget or cost that consequently occur; and increase in the budget following the selection of products and materials available to fulfill green building certification standards. In short, (1) the risk factors for traditional buildings are also relevant as green buildings risk factors; and (2) unlike traditional buildings, the budget impact could be an additional risk for green buildings.

Proposed risk mitigation measures

Table 5 shows identified 12 risk mitigation measures associated with discussed risk factors and ranked to tackle potential risks practicing green building design service. Mitigation measures above 3.85 values are discussed as follows.

Table 5. Risk mitigation measures in green building projects in South Korea

Code	Associated Risk Factor(s)	Risk Mitigation Measures	Mean	Rank
RMM8	R14	Contract indicating each parties' role, liability and limitations clearly	3.93	1
RMM11	R12, R13	Utilizing integrated design process	3.9	2
RMM9	R9	Understanding client's goal [illegible] green building projects	3.88	3
RMM7	R12	Improving communication and coordination among stakeholders	3.86	4
RMM2	R7	Using previous successful green building projects as reference	3.83	5
RMM10	R1[illegible]	Quality control for construction drawings and specifications	3.83	6
RMM1	R1	Contingency funds in case of emergency	3.82	7
RMM6	R11	Effective management system for design changes	3.75	8
RMM3	R3	Research on green building products and materials	3.69	9
RMM5	R4, R5, R8	Development of education programs for team members	3.58	10
RMM4	R6	Adoption of commissioning agent	3.52	11
RMM12	R1	Purchase of insurance at risk allocation	3.45	12

The risk mitigation measure 'RMM8-Contract indicating each party's role, liability and limitations clearly' was identified as the most effective measure with the highest value of 3.93. Many disputes arise from miscommunications and misunderstandings on roles, responsibilities, and limitations that could be lessened by using precise contract language. The contracting parties should clearly define the scope of work, schedule, building performance expectations, certification levels, and risk allocation in their contracts [10]. AIA Document 'D503-2013 Guide for Sustainable Projects' developed by the AIA can be considered as a reference guide [40].

The risk mitigation measure 'RMM11-Utilizing integrated design process' scored the second-highest value at 3.9. The process of an integrated design process (IDP) represents the prospect for risk reduction by architects in a green building project. The traditional delivery method is the design-bid-build process in which the client contracts with separate entities for design and construction. Specifically, the project is designed by separate teams of architects and engineers and then put out for bidding to general contractors. The contractors build the project according to developed designs. However, this project delivery method is not ideal when employing an IDP because it may discourage collaboration among parties involved in construction projects. In contrast to traditional processes, the integrated design processes can pull together a multi-disciplinary team of architects, consultants, clients, tenants, contractors to work from the project's start and promote better communication. The goal of the IDP is to optimize the building's performance while reducing any rework, delay, and cost overrun that can challenge a successful green building project with complicated systems and technologies. Alternative project delivery methods can facilitate the integrated design process [9, 23, 43] and close collaboration; specifically, adoption of design-build contracts, construction managers at-risk, and integrated project delivery (IPD).

The risk mitigation measure 'RMM9-Undertanding client's goal in green building projects' received the third highest value at 3.88 in the effectiveness evaluation. It is highly recommended that clients establish sustainability goals, the level of certification where relevant, and related project requirements in the early design stage. Identifying client's goals and expectations ultimately reduces the potential for misunderstanding among clients, architects, and contractors, defines clear goals and responsibilities in the design process and provides the potential to reduce project time and costs resulting from miscommunications among related parties.

The risk mitigation measure 'RMM7-Improving communication and coordination among stakeholders' was assessed as the fourth most effective measure with an evaluation of 3.[illegible]. It is important to assure the flow of information throughout the project development process in order to reduce defects in design and construction. This is particularly prominent since some parties may be new to green building. Measures to assure information flow include: (1) holding meetings with the design team to review project requirements and goals; (2) clarifying additional documentation and other certification-related requirements particularly with general contractors and attorneys; (3) holding meetings with general contractors, subcontractors, and attorneys to ensure that they understand the purpose of green-related requirements; and (4) providing additional training and materials to subcontractors where necessary [23]. 'The greatest risk management tool is reaching understanding and clear communication between the architect, owner, and contractor' [26]. Such mutual understanding requires in-depth collaboration among parties to minimize the potential risks associated with new practice with innovative technologies and materials applied in the green building design.

Conclusions

The demand for green building has increased in recent years due to global crisis and benefits from saving related to energy and natural resources. However, this relatively new practice is exposed to potential risks generated from new materials and methods, along with raised expectations of higher performance than that of traditional buildings.

This study first conducted a questionnaire survey to determine the risk factors associated with the green building design services in South Korea from the architect's point of view. The findings revealed that 'adoption of new technology and process' had the largest difference in criticality between green and traditional building projects.

In addition, the survey identified the three most effective risk mitigation measures in green building projects: 'contract that clearly indicates each party's role, liability, and limitations,' 'utilizing integrated design processes,' 'understanding client's goal in green building project.' In order to avoid potential risks for a green building project, the integrated design process must be based on open communications based on the contracts with clearly defined performance expectations.

There are two basic limitations inherent in this study. First, respondents were selected from major only architectural design firms. Architects working in small or mid-sized firms were excluded. Thus, any generalizations or further applications of these results should be conducted carefully. Second, findings from this study apply to South Korea exclusively; similarly obtained results may vary in other countries under different conditions.

Thus, in spite of the limitations addressed above, this study's findings are still beneficial. This is the first study to investigate mitigation measures and diverse risk factors that affect architects' practice in green building projects. By analyzing potential foreseeable risks and taking reasonable precautions, architects are able to minimize exposure to losses and potential disputes by employing more effective risk management in contracts and better communication among stakeholders. Contractors can obtain a deeper understanding of potential risks in construction defects and building performance failures when applying new technology and materials. In addition, green building clients can be fully equipped with precautionary knowledge regarding potential tax credits and financial incentives from achieving certification and expected energy saving performance levels for upcoming green building projects.

Three research topics can be suggested for future research subjects: (1) comparison studies that assess and identify the risk factors perceived between architects and contractors or between South Korea and other countries within the same profession; (2) systematic risk mitigation guideline development based on collecting and analyzing the legal cases involving green building design and construction; and (3) identifying risk factors and effective risk mitigation measures through in-depth interviews with AEC industry professionals.

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