EXPLORATION OF CRITICAL EXTERNAL PARTNERS OF ARCHITECTURE/ENGINEERING/CONSTRUCTION (AEC) FIRMS FOR DELIVERING GREEN BUILDING PROJECTS IN SINGAPORE

Yuan Yuan Li,[1] Po-Han Chen,[2] David Ah Seng Chew,[3]
Chee Chong Teo,[4] and Rong Gui Ding[5]

ABSTRACT

Green Building involves many parties and has attracted attention recently. In this paper, the main external actors for Green Building were explored based on literature review. Then, a structured questionnaire was developed to facilitate systematic data collection. Finally, a stepwise multiple regression analysis was applied and "clients," "government," "qualified/certified materials and products suppliers," and "good green consultants" were found to be significant external partners of Architecture/Engineering/Construction (AEC) firms for successful delivery of Green Mark certified projects. The research findings will help AEC firms understand how to achieve competitive advantages in the Green Building market in Singapore by using external resources.

KEYWORDS

critical external relationships; critical partners; Architecture/Engineering/Construction (AEC) firms; Green Building; Green Mark; Singapore; multiple regressions

INTRODUCTION

A building market contributes a lot to the development of the economy. However, it is also responsible for a substantial amount of global resource use and waste emission, which has a significant impact on many of the environmental problems faced by society. Due to regulations and growing environmental awareness, Green Building has been promoted in recent years and an increasing number of studies have been conducted in project delivery of Green

[1]School of Civil and Environmental Engineering, Nanyang Technological University, Singapore, 639798, E-mail: liyu0011@ntu.edu.sg
[2]Department of Civil Engineering, National Taiwan University, Taipei, 10617 Taiwan, E-mail: pohanchen@ntu.edu.tw (Corresponding Author)
[3]School of Civil and Environmental Engineering, Nanyang Technological University, Singapore, 639798, E-mail: caschew@ntu.edu.sg
[4]School of Civil and Environmental Engineering, Nanyang Technological University, Singapore, 639798, E-mail: teocc@ntu.edu.sg
[5]Management School, Shandong University, Jinan, Shandong Province, 250100, P. R. China, E-mail: ding_rgui@sdu.edu.cn

Buildings. For example, Korkmaz (2010) explored the important factors for successfully delivering Green Building projects, with "owner commitment," "project delivery system," "project team procurement," "contract conditions," "design integration," "project team characteristics," and "construction process" as independent variables, and schedule, cost, quality and sustainable high-performance as dependent variables. As a result, "timing of project participants' involvement in the delivery process" and "owner type" were found to be important factors for project outcomes. The impacts of main delivery methods, including Design-Bid-Build (DBB), Construction Manager at Risk (CMR), and Design Build (DB) for achieving sustainable, high performance building projects were investigated in Molenaar's (2009) research work. The critical project management factors for delivering Green Building projects of Architecture/Engineering/Construction (AEC) firms in Singapore were also explored recently (Li *et al.*, 2011). However, most of the previous efforts mainly focus on the internal resource and factors of AEC firms. Although improvements within AEC firms are prerequisite to reduce environmental impacts of buildings, they are not enough.

Construction is a multi-stage process, including planning, design, construction, operation and maintenance, as well as demolition, and it involves many different organizations, such as designer, contractor, supplier, consultant, etc. (Xue *et al.*, 2007). Moreover, the process of delivering Green Building projects often requires more design iterations, advanced simulation and analysis, higher construction standards, additional site precautions, and the use of new and unfamiliar materials, which can be more difficult than delivering traditional projects (Pulaski, Horman, & Riley, 2006). Therefore, successful Green Building requires more close cooperation of actors involved in various life cycle stages and at various spatial scales (Leah, 2005; Bueren & Jong, 2007). Recently, a few research papers began to explore the critical actors to improve project environmental outcomes. For example, Imada (2002) stated it would be very difficult to undertake a LEED certified project without collaboration between the owner, architect and contractor. Associations between LEED® (Leadership in Energy and Environmental Design launched by U. S. Green Building Council) criteria, project lifecycle, the stakeholders' interests, lean process improvements and typical delivery systems used in building construction were explored in Castro-Lacouture's (2008) research work and a matrix of weighted indexes to explain and provide increased collaboration among project participants throughout the project lifecycle was proposed. The important role of clients for the successful implementation of traditional building construction was widely accepted (Chan, 1996; Kamara *et al.*, 2000). Their roles for the environmental performance of building projects were also studied recently (Ofori, 2007). A survey conducted by Khoo (2002) concluded that architects, contractors and engineers were regarded as the most important participants in influencing the practice of Green Building. However, it appears that most of these studies, which emphasized exploring the critical actors for delivering Green Building projects, were project-based.

The relationships with the stakeholders involved in typical construction projects such as clients, regulatory agencies, subcontractors, and financial institutions have been regarded as this firm's external resources (Isik *et al.*, 2009). The strength of a company's relationships with these stakeholders constitutes a social dimension of project environment (Kendra, 2004) and has an important influence on the sustainable performance of their building projects (Isik *et al.*, 2009). However, far less attention has been devoted to exploring critical external partners of AEC firms for the implementation of Green Building projects. Thus, more comprehensive studies on this problem should be conducted.

Studies showed that the level of environmental awareness in Singapore's construction industry is rising (Ofori *et al*., 2000). Green Mark, a certification for Green Building in Singapore, became a compulsory requirement for new buildings since 2008. It indicates Green Building will become a new dominant market in Singapore in the near future, and it leaves AEC firms no choice but to cooperate with other players to maximize sustainability. However, since Green Mark is a relative new requirement for buildings, the critical external partners of AEC firms for delivering Green Mark certified building projects is still vague. Therefore, the purpose of this study is to explore the critical external relationships that AEC firms should focus on for better delivering Green Mark certified projects in Singapore.

LITERATURE REVIEW

Project Performance

"Green Building refers to the design and construction of buildings that have a minimal negative impact on the environment" (Liu, 2005). An objective measurement of environmental performance of building projects appears to be difficult and is often subjective. Several environmental performance assessment tools have been developed in different countries. Besides Green Mark in Singapore, other examples include Building Research Establishment Environmental Assessment Method (BREEAM) in the U.K., Leadership in Energy & Environmental Design (LEED) in the U.S. and Hong Kong Building Environmental Assessment Method (HK-BEAM).

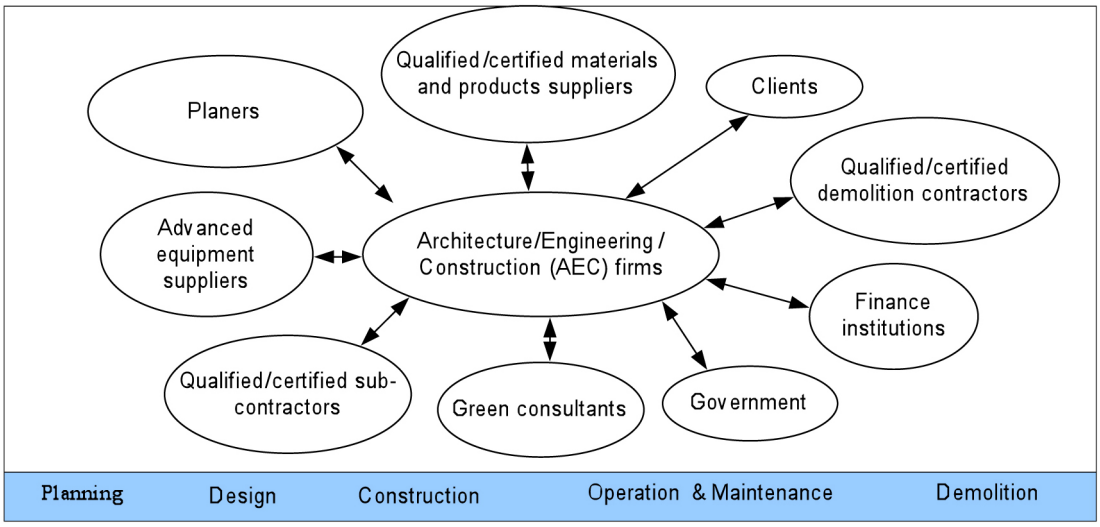
In this paper, environmental impact and performance are measured using the Green Mark assessment system. The Green Mark certification was developed by the Building and Construction Authority (BCA) of Singapore and was launched in January 2005. Starting from 15 April 2008, all new buildings with a Gross Floor Area of more than 2,000 m^2 are required by law to meet the minimum Green Mark standard. The master plan of BCA is to achieve "80 percent of all buildings in Singapore to be Green Mark certified by 2030." It aims to promote a sustainable built environment by incorporating the best practices in environmental design and construction.

Green Mark measures building projects by evaluating the environmental performance in five areas: (1) Energy Efficiency; (2) Water Efficiency; (3) Site and Project Development and Management; (4) Indoor Environmental Quality and Environmental Protection; and (5) Innovation. This assessment system is based on a point-scoring approach. Depending on the total points awarded for each of these five areas, one of the four ratings can be awarded: Platinum, Gold^{Plus}, Gold, and Certified. The rating provides a benchmark of the building's environmental performance and allows comparison between buildings.

External Relationships

Recently, researchers paid more attention to the Life Cycle Analysis (LCA) method, which was considered as the most comprehensive and appropriate method to analyze the activities contributing to the sustainability of buildings. The life cycle of Green Building includes planning and design, construction, operation and maintenance, and demolition. In order to bring improvements within the built environment, the building industry has to pay attention to activities in each of the above phases (Suzy, 2003). The different stages of a building's life cycle are handled by different stakeholders. Adjacent stakeholders and external linkages can lead to

FIGURE 1. External partners of AEC firms in Green Building projects.



significant reduction of environmental impacts of building projects. This indicates that successful implementation of Green Building requires communication and collaboration between AEC firms and other stakeholders. Therefore, AEC firms should establish good, long-term relationships with other stakeholders, which include qualified/certified materials and products suppliers, advanced equipment suppliers, qualified/certified sub-contractors, green consultants, planners, clients, qualified/certified demolition contractors, finance institutions and government, as shown in Figure 1. These relationships are within the realm of control of AEC firms and have been regarded as external resources of AEC firms. The effects of these stakeholders on Green Building projects are discussed as follows.

Relationship with qualified/certified materials and products suppliers

AEC firms transform the conceptual ideas of clients into "constructed reality" by using a wide range of resource inputs. Obviously, the sustainable performance of building projects is closely related to the amount and extent of sustainable materials the buildings used, such as low-VOC paint, non-ureaformaldehyde particleboard, recycled carpet, and 100 percent recycled sheetrock. The application of environmental friendly materials can help reduce resource consumption, lower the materials embodied energy, and lessen landfill and associated impacts, including potential ground water pollution (Beyer, 2002). Generally, construction companies procure these important resource inputs by forming exchange relationships with materials vendors (Kale, 1999). Strong relationships between AEC firms and qualified/certified materials and products suppliers have a direct impact on the availability of environmental friendly materials and in turn on the sustainable performance of building projects. Besides, AEC firms can consult with suppliers for advice on greener technologies and materials. Bourdeau (1999) once suggested that building designers should work together with suppliers to create new designs which facilitate material recycling. The good relationships also make substantial reduction of packing containers and wrapping materials possible. Moreover, sustainable materials and products generally cost more than their traditional counterparts. The good relationships with suppliers can also present some potential cost advantages.

Relationship with advanced equipment suppliers

Generally, the contractors do not possess all necessary machinery and equipment, especially advanced ones, and they just coordinate various stakeholders for a project. In order to enhance the outdoor environmental performance on site, advanced machinery and equipment should be used (Bao, 2003). For example, electric machines can help reduce energy consumption and harmful gas generation; laser cutting machines and hydraulic piling equipment can help reduce noise pollution and harmful gas generation (Chen, Li, & Wong, 2000). Not all equipment suppliers have the financial ability to provide this needed machinery and equipment for Green Building. Therefore, the relationship with advanced equipment suppliers will affect the quality, cost, and timely completion of Green Building projects.

Relationship with qualified/certified sub-contractors

Construction firms cannot turn design requirements into end products by themselves, and usually turn to their subcontractors for more capital and resources. Ofori (2002) stated one-third of the contractors will transfer part of the environmental responsibility to their subcontractors in Singapore. Therefore, the subcontractors should have environmental responsibilities and have experience and necessary knowledge in this respect. It will ensure that the subcontractors fully understand the green requirements, use green materials, minimize the threat of pollution from construction activities, reduce energy consumption, and prepare all the necessary documentation. Considering the great contribution provided by qualified/certified sub-contractors, establishing good relationship with them is essential to achieve sustainability goals of the project effectively and efficiently.

Relationship with good green consultants

A consultant is a professional who is hired to provide consultation during a project's various phases (Munib, 2003). There are many reasons to hire consultants. According to Francks (1992), the first and most obvious reason to engage a consultant is to make use of his/her knowledge and experience, in case a project team encounters a problem with which its members are unfamiliar. Green Building is a relatively new concept and generally involves more complex design and construction processes. An experienced green consultant can advise on environmentally friendly materials, sustainable structural design, critical management factors and other green features to improve the sustainable performance (Shen *et al*., 2010). Therefore, engaging professionals who are well-trained can help deliver green outcomes more efficiently (Chu, 2008). Chan (2004) conducted a survey and found when faced with a new Green Building market, 19% of construction firms hired outside green-building experts as consultants to avoid unnecessary time delays and cost increase.

Relationship with planners

The planning/pre-design phase of a building is an important stage for successful completion of a project. Many failure cases showed that poor planning was the major cause of unsuccessful green building projects (Zwikael & Globerson, 2006). It is in this phase that planners can make decisions to improve sustainable performance of building projects at very little (or no) cost (Azhar, Brown, & Sattineni, 2010). Specific elements considered in this phase include the definition of work tasks, estimation of durations and costs, establishment of sustainability goals, sustainable site selection and characteristics within a sustainability perspective (Gorostiza, Hendrickson, & Rehak, 1990; Zwikael & Globerson, 2006). In the following phases, detailed design documents and construction processes are developed to achieve the

planning goals. Generally, the implementation of green technologies and selection of environmentally friendly materials have a crucial influence on cost, duration and quality performance of building projects. Therefore, designers and contractors should work collaboratively with planners to ensure the sustainability of building projects and to meet duration and budgetary requirements.

Relationship with clients

Kamara (2000) defined a client as the person or firm responsible for commissioning and paying for the design and construction of a facility and what is to built should depend on their requirements. The important role of clients for the successful implementation of building projects in terms of cost, time and quality were stressed by Chan (1996) and Lam (2005). In order to produce a Green Building, the client has to be the one to demand and request for it. Cohen-Rosenthal and Schlarb (2000) proposed that, "for the majority of builders, incentives for adopting energy efficient practices and renewable technologies depend on [the client and] what they are building." Imada (2002) also concluded it would be very difficult to undertake a LEED certified project without collaboration between the owner, architect and contractor. Establishing a good relationship and communicating frequently with the client can ensure the client's requirements well understood by other project participants. This can indirectly force project participants to take appropriate actions at an early stage of the project so as to deliver Green Building effectively and efficiently.

Relationship with qualified/certified demolition contractors

Demolition of a building will generate a large amount of waste materials, which has become a major contributor to landfills. Proper reuse and recycling of demolition wastes can reduce the consumption of new materials to a large extent (Imada, 2002). Establishing good relationships with qualified/certified demolition contractors will help AEC firms know more about low-waste technologies and appropriately recycle or reuse demolition waste materials on other construction sites to minimize waste generation and lower construction costs.

Relationship with finance institutions

Capital costs are an important factor that limits the realization of green design ideas in building projects. Some green features that are expected to have significant environmental impacts may not be implemented simply because they cost more upfront, for example rainwater collection systems, solar heating and photovoltaics. Notwithstanding the life cycle savings, upfront capital outlay may also be an issue. Moore (1994) stated "inadequate funds to support the implementation of environmental initiatives can prevent their realization." Kats (2003) also recognized that "the cost issue was becoming more and more of a prohibitive factor in the mainstreaming of Green Building." It is logical to postulate that AEC firms, which will share the cost burden, should establish long-term good relationships with financial institutions to ensure obtaining enough sources of capital for the implementation of Green Building projects.

Relationship with government

Government is a significant driving force in promoting Green Building by applying a combination of regulations and economic instruments to encourage all the stakeholders in construction industry to take actions that will protect and enhance the environment (Ofori, 2007). Governments in many countries have been increasingly imposing stringent regulations on AEC firms to reduce environmental impacts of construction activities. Slivka (1998) stated

construction companies are facing serious environmental issues and liabilities even in non-environmental projects. The government can also be seen as a major construction client and drive sustainability agenda by improving its own performance and translating that into its demand on AEC firms (Khoo, 2002). However, lots of AEC firms lack required knowledge on green technologies and do not know how to develop and implement green features into construction practices (Yang, 2006). Besides, implementation of innovative environmental friendly technologies and materials is full of risks for AEC firms. Only mandatory requirements enables AEC firms to adopt a more proactive attitude to incorporate environmental considerations into its work. Therefore, recently, green materials guidelines, education and training courses, design tools, as well as appropriate incentives are offered by governments in many countries (Yang, 2006). Establishing strong, long-term relationship with local government can help AEC firms enjoy faster design and construction processes, faster plan checks, lower permit fees, priority field inspections, and complimentary advertising (Leah, 2005). Besides, it can also help AEC firms get more public projects in the future.

According to the above discussions, deepened relationships between AEC firms and other stakeholders are seen as solutions to maximize sustainability of building projects. However, all these stakeholders are not of equal importance to AEC firms. In reality, the importance level of them will differ from country to country because of different firm environment and environmental assessment systems. In this study, the critical partners that AEC firms should focus on for the implementation of Green Building projects in Singapore will be analyzed.

METHODOLOGY

Based on the literature review discussed above, the external resources of AEC firms for delivering Green Building projects, which would have an impact on the environmental performance of Green Mark certified building projects, were explored. A questionnaire was then designed with the objective of identifying the important partners of AEC firms. Part I of the questionnaire requested respondents' background information, for the purpose of identifying whether the respondents are suitable targets. Obviously, the questionnaire targeted mainly professionals and decision-makers in AEC firms who have extensive experience in the building industry and Green Mark certified projects in Singapore. This part contained three questions, including the respondent's designation, years of experience in the construction industry, and the number of Green Mark certified projects involved. In Part II of the questionnaire, each respondent was requested to evaluate the performance of his/her firm's external relationships with other stakeholders (as shown in Table 1) and to record the Green Mark rating of at least one completed Green Mark certified project undertaken by the firm.

As shown in Table 1, the extent of quality of relationship for each stakeholder was scored on a five-point interval measure: [1=Poor] to [5=Excellent]. Based on these measurements, the stakeholders, who are more important for Green Mark certified projects, will be extracted later. Eventually, open-ended questions were provided for respondents to list any other important external relationships of AEC firms for the Green Mark projects. They can also list other comments for improvement, if any.

A pilot study was first carried out to test the relevance and comprehensiveness of the questionnaire before it was sent to the respondents in the industry. The pilot survey involved eight participants: four certified Green Mark managers who have been involved in Green

TABLE 1. AEC firms' external relationships.

Codes	External Relationships	Definition
E1	Relationship with qualified/certified materials and products suppliers	Scale 1–5; 1=Poor; 5=Excellent
E2	Relationship with advanced equipment suppliers	Scale 1–5; 1=Poor; 5=Excellent
E3	Relationship with qualified/certified sub-contractors	Scale 1–5; 1=Poor; 5=Excellent
E4	Relationship with good green consultants	Scale 1–5; 1=Poor; 5=Excellent
E5	Relationship with planners	Scale 1–5; 1=Poor; 5=Excellent
E6	Relationship with clients	Scale 1–5; 1=Poor; 5=Excellent
E7	Relationship with qualified/certified demolition contractors	Scale 1–5; 1=Poor; 5=Excellent
E8	Relationship with finance institutions	Scale 1–5; 1=Poor; 5=Excellent
E9	Relationship with government	Scale 1–5; 1=Poor; 5=Excellent

Mark certified projects before, and two professors and two researchers who were very familiar with this research topic. "Certified Green Mark managers" should have completed the Certification Course and are recognized by the Building and Construction Authority of Singapore (BCA). They generally have extensive experience in the construction industry and are in senior management positions in their firms. Therefore, they possess the requisite knowledge about Green Mark projects and know their firms very well. Based on the pilot survey, the questionnaire was finalized and a total of 89 questionnaires were distributed.

Responses from the survey were analyzed using the Statistical Package for Social Sciences (SPSS) software. First, the reliability of the five-point scale used in the survey was determined using the Cronbach's coefficient alpha. After that, multiple stepwise regression was employed to explore the important external stakeholders to improve the environmental performance of building projects so that a higher Green Mark rating could be achieved.

DATA ANALYSIS

Response Rate

Out of the 89 questionnaires that were sent out, 42 were received by the end of 2009. Five responses were eliminated due to a high degree of incompleteness. Consequently, this study was based on 37 valid replies from the respondents who had experiences with Green Mark certified projects. Considering the limited number of Green Mark projects completed in Singapore in recent years, 37 responses from experienced experts could be deemed representative. Besides, this agrees with the suggestion from many researchers that a minimum sample size of 30 is considered representative for any group (Sproull, 1995; Ott & Longnecker 2001). The effective response rate was about 41.6%, higher than the average response rate of 25% for questionnaire surveys for Singapore's construction industry (Tan, 1995).

Profiles of Respondents

Table 2 summarizes the designations of the respondents in the survey. It indicates that the largest group of the respondents belongs to senior management personnel, i.e., directors and presidents (43%). Project managers, department managers, general managers and operation managers account for 40% of the respondents. Designers, including architects and engineers, account for 17%.

TABLE 2. Respondents' designation.

Respondent's Designation	Frequency	Percent (%)	Cumulative Percent (%)
Architect	5	13.5	13.5
Department manager	3	8.1	21.6
Director	15	40.5	62.2
Engineer	1	2.7	64.9
General manager	2	5.4	70.3
Operation manager	1	2.7	73.0
President	1	2.7	75.7
Project manager	9	24.3	100.0
Total	37	100.0	

The respondents' working experiences in the construction industry in Singapore ranged from 5 to 42 years, with 19.8 years as the average (Table 3). 32.4% of the respondents have 16 to 20 years of experience, which is the major group. None of the respondents has less than 5 years of working experience.

TABLE 3. Respondents' working experience in Singapore's construction industry.

Years of Experience in Singapore's Construction	Nos. of Respondents	Percent (%)	Average
5–10	7	18.9	19.8
11–15	4	10.8	
16–20	12	32.4	
21–25	6	16.2	
26–30	4	10.8	
>30	4	10.8	
Total	37	100.0	

As shown in Table 4, all the respondents have been involved in Green Mark certified projects before, while half of them (51%) have participated in more than three Green Mark certified projects in Singapore.

TABLE 4. Respondents' working experience in Green Mark certified projects.

Nos. of Green Mark Projects	Frequency	Percent (%)	Cumulative Percent (%)
1	5	13.5	13.5
2	6	16.2	29.7
3	7	18.9	48.6
>3	19	51.3	100.0
Total	37	100.0	

It can be seen from the respondents' profiles that the majority of them are middle or senior managers, with extensive experience in the construction industry and Green Mark certified projects. Data collected from these people should be representative and reliable. Additionally, among the 89 professionals, 13 are certified Green Mark managers and their participations in the questionnaire survey also ensure the validity of the data.

Measurement of AEC Firm's External Relationships

The external relationships of AEC firms mainly include: qualified/certified materials and products suppliers; advanced equipment suppliers; qualified/certified subcontractors; green consultants; planners; clients; qualified/certified demolition contractors; finance institutions and government. The scale of measurement, mean, standard deviation, and median of these relationship factors are summarized in Table 5.

TABLE 5. Scale of measurement, mean, and standard deviation of AEC firm's external relationships.

External Relationships	Scale of Measurement	Mean	Median	Std. Deviation
E1. Relationship with qualified/certified materials and products suppliers	1–5	3.76	4.00	1.011
E2. Relationship with advanced equipment suppliers	1–5	3.46	4.00	1.016
E3. Relationship with qualified/certified sub-contractors	1–5	3.86	4.00	0.822
E4. Relationship with good green consultants	1–5	3.70	4.00	1.024
E5. Relationship with planners		3.62	4.00	0.861
E6. Relationship with clients	1–5	4.29	4.00	0.618
E7. Relationship with qualified/certified demolition contractors	1–5	3.08	3.00	1.064
E8. Relationship with Finance institutions	1–5	3.35	3.00	0.889
E9. Relationship with government	1–5	4.19	4.00	0.811

Size of sample adopted: N=37

As indicated by the mean values in Table 5, among the external relationships of AEC firms, the relationship with clients is considered extremely well and the relationship with qualified/certified demolition contractors seems relatively weak. It means the importance of the relationship with clients have been recognized by AEC firms in Singapore. However, the qualified/certified demolition contractors are usually ignored at early stages of building projects. One suggestion for AEC firms in Singapore is that they should pay more attention to the relationship with qualified/certified demolition contractors in the future in order to improve the environmental performance of their building projects.

Internal Reliability

The internal consistency of scales is usually assessed by the Cronbach Alpha method. The Cronbach Alpha coefficient (α) has a value that ranges from 0 to 1, and may be used to describe the reliability of factors extracted from dichotomous and/or multi-point formatted questionnaires or scales (Santos, 1999). A high α value indicates high internal consistency of scales. It has been suggested that reliabilities of 0.50 and 0.60 should suffice (Churchill, 1979; Nunnally, 1978). Using the SPSS software, the calculated Cronbach Alpha coefficient (α) is 0.82, which indicates the constructs of AEC firms' external relationships are internally consistent and can be used for further analysis.

Regression Analysis

Regression analysis is by far the most widely used and versatile dependence technique, applicable in every facet of business decision-making, ranging from the most general problems to the most specific ones (Hair *et al.*, 1995). It is a statistical technique that can be used to explore the importance level of several independent (predictor) variables contributing to a single dependent (criterion) variable by studying the relations among them. The specific objective of this research is to examine the relative significance of AEC firms' external relationships for Green Mark certified building projects. This technique can best achieve this objective and is therefore chosen to be the principal instrument for this study. The regression results are listed in Table 6.

TABLE 6. Stepwise multiple regression results of AEC firm's external relationships and Green Mark.

Independent Variables	Beta Coefficient (β)	Sig.	F Value	R^2	Adjusted R^2
Relationship with clients	0.461	0.001	17.814****	0.690	0.651
Relationship with government	0.333	0.013			
Relationship with qualified/ certified materials and products suppliers	0.267	0.014			
Relationship with good green consultants	0.247	0.043			

Constant term: 1.079
Size of sample adopted: N=37
Note: ****P<0.001

As can be seen from Table 6, the model is significant at the level of $p<0.001$. Only four external relationships, "relationship with clients," "relationship with government," "relationship with qualified/certified materials and products suppliers" and "relationship with good green consultants," meet the entry requirements and are statistically significant at the level of $p\leq0.05$. "Relationship with advanced equipment suppliers," "relationship with qualified/certified sub-contractors," "relationship with planners," "relationship with qualified/certified demolition contractors," and "relationship with finance institutions" do not meet the entrance criteria and fail to enter into the regression model. As R^2 is 0.690, that signifies that 69% of the total variance could be explained by these four relationships. Of these four relationships, "relationship with clients" has the higher beta coefficient ($\beta=0.461$) compared with the other relationships. It can be inferred that "clients" plays the most important role for the Green Mark certified projects. Therefore, AEC firms should establish good relationships with their "clients" to get Green Mark certificates for their building projects.

DISCUSSION ON THE FINDINGS

As shown in Table 6, four external relationships, "relationship with qualified/certified materials and products suppliers," "relationship with clients," "relationship with government" and "relationship with good green consultants" have obvious influence on Green Mark certified projects. The possible explanations are explored as follows:

Discussion on the Relationship with Clients

In this study, clients are found to be the most important external stakeholders for successful implementation of Green Mark certified projects in Singapore. This result is not surprising. The professionals in the pilot study have emphasized the importance of the support from clients for Green Mark certified projects. Generally, clients can have an influence on Green Mark certified projects through the following five ways:

1. Clients can require AEC firms to pursue a higher Green Mark certification level for their projects. Generally speaking, it is up to the client to decide what level of Green Mark certification is required. In Singapore, most completed projects have targeted at low-ranking Green Mark certificates (*i.e.*, Gold and Certified). The reason might be that a higher Green Mark level would require more upfront cost (Chu, 2008).
2. Clients can make use of procurement systems to influence Green Building. For example, clients can call for design-build tenders. In a design-build contract, necessary conditions that address the responsibility and way of cooperation of the designer and the contractor can be specified, which will indirectly promote the implementation of sustainable design in a building project. Also, clients can specify sustainability as one of the goals on the contract (Khoo, 2002).
3. The willingness of clients to commit themselves to more innovative and radical ideas, which might be less polluting or more resource efficient, is important in the move toward sustainable construction. Khoo (2002) explored some relatively innovative projects in the world and realized that common attributes in these projects were that construction clients were willing to commit themselves to the projects, to explore new ideas and to invest more time and money.

4. The construction industry in Singapore operates predominantly on the basis of subcontracting (Teo, 1999). Clients are allowed to specify or nominate some subcontractors with good track records of environmental protection to main contractors.
5. Clients can adopt the "environment" as a fourth project objective in addition to time, quality, and cost, and consider environmental track records in the selection of AEC firms. Ofori (2000) suggested that clients should seek contractors with ISO 14000 certification as a pre-qualification for contractors. In Singapore, the Building and Construction Authority (BCA) has made it mandatory for contractors undertaking public projects to be ISO 14000 certified since 2004.

Discussion on the Relationship with Government

Besides clients, the government also plays an important role for successful implementation of Green Mark certified projects, as revealed in Table 6. In Singapore, the government has imposed a mandatory level of performance on AEC firms, such as the noise and dust level on site. BCA has made it mandatory for AEC firms undertaking public projects to be ISO 14000 certified since 2004 and required construction companies under the BCA Registry categories A1 and A2 to attain ISO 14000 by July 1, since 2004 (Ng, 2004). Besides these mandatory requirements, different kinds of technical support were also provided recently. For example, many searchable databases on Green Building in Singapore have been created by the government, such as the sustainable building information system (http://www.sbis.info), which will help AEC firms keep abreast of green technologies. Lots of training courses on educating architects and other professionals on the subject of Green Building were also provided by BCA. In addition, the Environmental Control Officer (ECO) scheme was launched. The ECO is responsible for the identification of potential or actual environmental health problems on the construction site and provides advice and recommended measures to the contractor on how to best solve the problems. Educating workers on possible environmental health hazards is another important aspect of an ECO's responsibility (Ng, 2004). Therefore, most AEC firms in Singapore try to establish good long-term relationship with the government to ensure less construction time and lower cost in the implementation of Green Mark certified projects. Great performance in Green Building projects can also help AEC firm get more public projects from the government.

Discussion on the Relationship with Qualified/Certified Materials and Products Suppliers

As indicated by the regression findings, good relationships with qualified/certified materials and products suppliers play a major role in the implementation of Green Mark certified projects. This is easy to understand, because Green Mark certified projects require the use of high-tech components and sustainable materials which should be sourced from qualified/certified suppliers to ensure that the used components and materials meet the environmental performance requirements. Furthermore, Green Mark places a significant weight on innovation, and, thus, manufacturers and suppliers of innovative building-related products become important sources (Anderson & Manseau, 1999). In this regard, maintaining good relationships with qualified/certified materials and products suppliers can secure the procurement of quality building materials. However, in Singapore, the market for sustainable products and materials is not fully developed. The suppliers of sustainable materials and products are not many. Therefore, it is difficult to establish strong relationships with these certified suppliers.

Discussion on the Relationship with Good Green Consultants

The regression results show that good relationships between AEC firms and consultants with environmental track records could help complete Green Mark certified projects smoothly. This result is expected since Green Mark emphasizes the adoption of high-tech innovative components, such as eco-roofs, solar power and stormwater retention systems, which are usually the suggestions provided by consultants. Besides, Green Mark is a relatively new assessment system in Singapore, and most AEC firms, especially small and medium ones, still lack adequate experience and expertise with the required green technologies. These experienced experts can help source sustainable materials, identify the potential environmental risks and provide recommendations for improvement. They can help evaluate all costs for innovative green measures and assist project teams in making cost-effective decisions. Since green consultants usually have better knowledge of Green Mark credit and documentation requirements, they can help with the application process for Green Mark certificates. However, since green consultants are not widely involved in the design and construction stages in Singapore, architects and engineers are often trained to act as green consultants. The Green Building assessors from the Building and Construction Authority of Singapore (BCA) may also render assistance to project teams in the preparation of documents for Green Mark application. Since the architect or engineer plays a significant role in the design and construction stages of a building project, acting as a green consultant at the same time may squeeze the time required to perform normal tasks as an architect or engineer (Harrigan, 2004). Therefore, AEC firms in Singapore should establish good relationships with external green consultants to make the design and building of a Green Mark certified project easier and less expensive.

CONCLUSIONS

Green Mark is a relatively new compulsory assessment method in Singapore for measuring environmental friendliness and impact of building projects. Effective coordination between actors involved in various life cycle stages is recommended for the successful performance of Green Building projects. Therefore, it leaves the AEC firms no choice but to cooperate with other actors to maximize sustainability of their building projects. The main contribution of this study is to identify the critical external relationships that AEC firms should cultivate in the long-term for better delivering Green Mark certified projects in Singapore. First, with the help of Life Cycle Analysis, all the external partners of AEC firms were explored. Then, multiple regression analysis was conducted based on the data collected from questionnaire survey and "clients," "government," "qualified/certified materials and products suppliers," and "good green consultants" were found to be more important than others. Among them, clients play the most important role and are the ultimate driver of green building as they make the initial and final decisions on whether or not to build green and to what extent. For AEC firms with less experience in Green Mark certified projects and planning to enter into the new Green Building markets in Singapore, this study may assist them in establishing effective external firm-specific resources to achieve good project outcomes. Although lots of conclusions and findings have been presented in this paper, there are several limitations: firstly, only 37 samples are obtained for this study. Although the sample size of the responses is large enough to obtain representative results, more data are needed to have better results. Secondly, all the Green Building projects samples in this study, are the Green Mark projects

in Singapore. More and more building projects samples certified by other Green Building assessments systems in different regions should be collected for exploring the critical external relationships. The conclusions between them can be compared to get more useful results. Finally, only quantitative data analysis was conducted in the paper. Since complicated relationships exist between building performance and external relationships of AEC firms, more qualitative studies can be conducted and more cases firms which did very well in Green Mark projects can be provided. More meaningful studies in these areas will be discussed in the future research work.

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