Models for Predicting Project Performance in China Using Project Management Practices Adopted by Foreign AEC Firms

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Abstract: China is a new market to many international architectural, engineering, and construction (AEC) firms and it is not known what would be the likely project outcomes, based on different project management (PM) practices adopted. This research developed and tested five models to predict the likely project success levels, based on PM practices adopted by foreign AEC firms in China. Based on data obtained from 33 projects, multiple linear regression (MLR) models for predicting the performance of foreign managed projects in China were constructed. The models were tested against 13 new cases, and the results show that they are able to predict project outcomes with some level of accuracy. The models show that certain scope management practices can be used to predict owner satisfaction, profit margin, and cost and quality performance of the project. Construction industry practitioners who are managing projects in China may benefit from the findings by focusing more on upstream management, like managing project scope, in order to ensure project success. It is recommended that construction industry practitioners use the MLR models to make preliminary assessment of the possibility of project success based on the type of PM practices they intend to adopt in China. From the results, they can then decide if they should change their practices or abort the project.

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Introduction

The rapid economic expansion in China has resulted in many construction activities, which make its construction industry one of the largest in the world (NBSC 2002). Problems such as cost overrun, schedule delay, low quality, and stakeholders' dissatisfaction are frequently reported in China (Wang et al. 2006). As foreign architectural, engineering, and construction (AEC) firms are expected to tap into these opportunities and participate in developing China's built environment, it would be useful to know the project management (PM) practices that should be used to overcome these problems.

This paper investigates PM practices used by international (non-Chinese) AEC firms in China. The study explores these firms' practices at the project level. The specific objectives of this paper are: (1) to find explanatory variables (PM practices) that significantly affect the performance of projects managed by foreign firms in China and (2) to construct and test models to predict the performance of foreign managed projects in China, based on their PM practices. The first objective is important because it identifies aspects of PM practices that foreign firms operating in China could improve on so as to achieve project success. The second objective is also important because project performance prediction models developed in this study would enable owners, consultants, and contractors to predict how successful their projects are likely to be, based on different PM practices to be adopted.

The international construction focus is chosen because unlike domestic construction, international construction is marked by the combination of business and PM skills with both mobile factors of production and location-bound support industries (Enderwick 1993). This study is significant because many foreign firms are entering China's construction industry for the first time and knowing the more critical PM practices to adopt would help to enhance project performance. In this study, an "international project" is one that is located outside the country where the AEC firm's headquarters is based. This international project is then said to be located in the "host country," which, in this paper, refers to China. Foreign AEC firms in this paper refer to non-Chinese international firms that are operating in China.

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Literature Review

International Construction

In addition to the typical risks of a domestic project, the international construction process has unique political, economic, and

Table 1. Performance Measures

Measures	Label	Description	Measurement scale (1–7)
Cost performance	Y1	Cost performance of service (actual versus budget)	1=overrun budget by >5% 4=cost same as budget 7=savings below budget by >5%
Time performance	Y2	Time/schedule performance of service (actual versus plan)	1=late finish by >5% 4=finish on time 7=early finish by >5%
Quality performance	Y3	Output quality of your service (e.g., technical quality, workmanship quality)	1=expectations not met 4=expectations met 7=exceed expectations
Owner satisfaction	Y4	Owner satisfaction with your service (service quality)	Same as Y3
Profit margin	Y5	Profit margin derived from service	Same as Y3

cultural risks (Lee and Walters 1989; Han and Diekmann 2001). The management of international construction projects entails the handling of several complex patterns of relationships among clients, contractors, financiers, customers, insurers, PM team, designers, and others (Simkoko 1992). International projects involve complex risks that are particular to international transactions (Lee and Walters 1989). Despite these complexities, most construction firms have entered international markets based on personal intuition or previous experience. It is therefore necessary to ascertain effective PM practices that should be adopted in international construction to bring about project success.

Performance Measures

Project performance indicators are the influential forces that either facilitate or impede project success (Lim and Mohamed 1999). Konchar and Sanvido (1998) measured success in terms of unit cost, construction speed, delivery speed, cost growth, schedule growth, and several quality measures. Chan and Chan (2000) produced a consolidated framework that included the additional dimensions of user expectation, participant's satisfaction, environmental performance, health and safety, and commercial value. To this list, Ling et al. (2004) added owner's satisfaction and owner's administrative burden. From these studies, this research chose five performance measures to ascertain project success (see Table 1) on the basis of minimizing overlaps among the performance measures. These were used as the dependent variables of this study.

PM Practices Affecting Project Success

After defining performance measures (Table 1), the next step is to review PM actions that affect project success. The U.K.-based Chartered Institute of Building published a code of practice for PM (CIOB 2002) and the U.S.-based Project Management Institute (PMI) has its guide to PM body of knowledge (PMI 2004). This study adopted the PMI's nine PM knowledge areas and correspondingly, identified PM actions following PMBOK (PMI 2004). The PM functions or knowledge areas are: (1) project scope; (2) time; (3) cost; (4) risk; (5) quality; (6) human resources; (7) communications; (8) procurement management; and (9) integration of these functions. Knowledge, skills, tools, and techniques are applied to manage these functions in an iterative process.

PM practices within each PM knowledge area that may affect project success were then systematically identified. Altogether, 78 PM practices were operationalized: six under Scope Management (labeled as Scop11–Scop16); six under Time Management (Time21–Time26); nine under Cost Management (Cost31–Cost39); nine under Quality Management (Qlty41–Qlty49); 16 under Risk Management (Risk51–Risk516); nine under Human Resource Management (HRM61–HRM69); nine under Communication Management (Com71–Com79); seven under Procurement Management (Proc81–Proc87); and seven under Integration Management (Integ91–Integ97). These were used as the independent variables of this study.

Limitations of Current Practices and Previous Studies: Knowledge Gap

The review of literature revealed that although many studies on project success factors have been done, these focused primarily on indigenous firms working in their home countries (Konchar and Sanvido 1998; Chua et al. 1999; Ling 2004; Fortune and White 2006). For example, Ling (2004) investigated how the characteristics of projects, clients, consultants, and contractors affect project performance when AEC firms are undertaking projects in their home countries.

There appears to be little study on predicting success of projects outside of one's home country (international projects). These projects are more difficult to manage than domestic projects because of multiple ownership, elaborate financial provisions (Gunhan and Arditi 2005), and higher uncertainty, complexity, and cost (CII 2004).

Factors affecting foreign AEC firms' project success in international markets can be investigated from several angles: market entry modes; business strategies adopted at the organizational headquarters level; and PM practices adopted at the construction site. Market entry modes have been previously investigated (Gunhan and Arditi 2005; Ling et al. 2005), and so have organizational level management strategies (Ling et al. 2005, 2006; Gale and Luo 2004). However, these did not focus on how PM practices adopted at the construction site (*project* level) can be used to predict the success of an international project.

The extent to which foreign firms' PM practices can be used to predict the success of an international project remains unclear. This study therefore aimed to fill the gap by exploring how project success in China can be predicted, based on the PM practices adopted by Singaporean AEC firms. In this study, it is hypothesized that some PM practices adopted by foreign firms in China could be used to predict project performance. PM practices were operationalized from the nine PM functions, and their role in predicting project performance (Table 1) was tested in the fieldwork.

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Research Method

From the literature review, 5 performance measures (Table 1) 78 PM practices were identified. The purpose of this research was to examine the extent to which PM practices adopted by international AEC firms in China could affect project performance (defined in Table 1). The research design was based on a survey, and data collected through the post and via e-mail. The data collection instrument was a questionnaire that was specially designed for this study. Respondents were requested to base their responses on one particular China-based project of their choice. Section A of the questionnaire requested information of the project in China and required each respondent to rate its level of success in five areas (Table 1) on a seven-point scale. Y1 (cost performance), Y2 (time performance), and Y5 (profit margin) can be ascertained quantitatively. Taking Y1 as an example, if the project exceeded budget by more than 5%, the respondent would rate "1," whereas if the project achieved cost savings of more than 5%, the rating should be "7." Respondents rated two qualitative measures, Y3 (quality) and Y4 (owner satisfaction), based on their perception of whether expectations were met or not, on a seven-point Likert scale. In Section B, respondents were asked to indicate the PM practices adopted on a seven-point Likert scale (Table 2). The last section gathered demographic characteristics of respondents and their companies. The questionnaire was pretested before an industry-wide survey was conducted.

The survey package was comprised of an introductory letter, a set of questionnaires, and a self-addressed stamped envelope. A summary of the survey findings was available to respondents who were interested in the research as an incentive to encourage participation.

The population frame in this study was comprised of international AEC firms that had undertaken and completed projects in China. Two sampling frames were used. The first was comprised of 200 randomly selected AEC firms based in Singapore that were known to export construction services. The list of targeted respondents was drawn up from the records maintained by the government, professional institutions, and other published information. The second sampling frame was comprised of consultants and contractors selected from the top 225 engineering news record (ENR) list of AEC firms for 2005, which had undertaken projects in China. From the first batch, 33 usable responses were received between January and February 2006. The response rate of 17% is relatively low indicating that relatively few Singapore-incorporated AEC firms had won and managed projects in China's market. Notwithstanding this, statistical analysis could still be carried out, because in accordance with the generally accepted rule, central limit theorem holds true when the sample size is $\geqslant 30$ (Ott and Longnecker 2001). Among the ENR listed firms, only three responses were received. Due to the low number of responses from ENR listed firms, these were not included in the statistical analysis, but subsequently used for model validation.

Data Sample Characteristics

Among the 33 respondents, 45% were senior management, whereas the rest were professionals. Ninety one percent were personally involved in the reported China-based project. The number of years of respondents' experience in the construction industry ranged from 3 to 30 years with an average of 16 years. More than half of the respondents had more than 20 years of experience. The respondents' firms had an average of 979 staff, US$79 million annual revenue and 32% of these were derived from international projects.

Table 2 shows the characteristics of the China-based projects reported by respondents. Most of the projects are located in China's eastern seaboard and owned by private enterprises. Foreign firms are not handling more public projects because China is still transitioning to a market economy and many public-sector projects are still executed by its state-owned enterprises. Many of the projects were won through selective bidding and negotiation. This suggests that international AEC firms need to network (form *guanxi*) with the private enterprises and should have good inter-

Table 2. Characteristics of Projects

Category	Frequency	Percentage (%)
Location		
Shanghai	12	36.4
Beijing	5	15.3
Suzhou	7	21.2
Tianjin	3	9.1
Shenzhen	2	6.1
Kunming	2	6.1
Chengdu	2	6.1
Contract sum ($SD/million)		
Up to 1	2	6.1
1.1–50	14	36.4
51–100	9	33.5
101–500	8	24.0
Duration of service (years)		
1–3	19	57.6
4–6	13	39.4
7–10	1	3.03
Service provided		
Management	10	30.3
Consultancy	5	15.2
Construction	18	54.6
Ownership of facility		
Public	4	12.1
Private	24	72.7
Joint venture	5	15.2
Selection procedure		
Open bidding	8	24.2
Selective bidding	14	42.4
Negotiation	11	33.3
Facility type		
Residential	5	15.2
Commercial	5	15.2
Mixed use	5	15.2
Recreational	3	9.1
Factories/plants	10	30.3
Petrochemical	3	9.1
Institutional	2	6.1
Gross floor area (m^2/million)		
Up to 10,000	6	18.2
10,001–100,000	8	24.2
100,001–500,000	18	54.6
500,001–1,000,000	1	3.0
Above 1,000,000	2	6.1

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Table 3. MLR Results

Independent variable	Predictors	β	t-value	p-value	VIF	Durbin Watson
Y1: Cost performance	Scop12	0.473	3.37	0.002	1.003	
$R^2=0.430$; Adj. $R^2=0.371$	Scop14	−0.367	−2.595	0.015	1.019	
Max Y1=5.24; Min=−1.77	Cost37	0.328	2.321	0.027	1.018	1.793
Y2: Time performance	Time21	0.496	3.585	0.001	1.090	
$R^2=0.49$; Adj. $R^2=0.437$	Cost35	−0.596	−3.849	0.001	1.366	
Max Y1=6.17; Min=−3.21	Com74	0.471	3.086	0.004	1.327	2.034
Y3: Quality performance	Scop12	0.391	4.644	0.000	1.109	
$R^2=0.821$; Adj. $R^2=0.795$	Scop16	0.677	7.142	0.000	1.405	
Max Y1=11.94; Min=0.18	Qlty45	0.670	6.347	0.000	1.742	
	HRM68	−0.222	−2.183	0.038	1.619	2.273
Y4: Owner satisfaction	Scop12	0.316	3.275	0.003	1.458	
$R^2$0.828; Adj. $R^2=0.796$	Cost37	0.282	3.404	0.002	1.075	
Max Y1=12.71; Min=1.82	Scop16	0.519	5.383	0.000	1.458	
	Qlty45	0.440	4.734	0.000	1.357	
	Time22	0.259	2.693	0.012	1.446	2.332
Y5: Profit margin	Scop12	0.632	5.258	0.000	1.016	
$R^2=0.574$; Adj. $R^2=0.545$	Risk512	0.346	2.881	0.007	1.016	2.159
Max Y1=6.85; Min=0.98						

Note: Standardized regression coefficient (β), calculated using ordinary least square method; t-value=value of t-statistic, to be compared to the theoretical t-distribution for accuracy; p-value=significance of t-statistic. For significance <0.05, the null hypothesis that $\beta=0$ is rejected, there is less than a 5% chance that the t-statistic is wrong due to random occurrence. VIF=variance inflation factor measures the collinearity of each exploratory variable; and Durbin-watson=detects and measures autocorrelation.

national reputation in order to be invited to bid. The services provided by the respondents included consultancy, management and construction work.

The data were input into the computer and analyzed using the Statistical Package for Social Sciences (SPSS) software.

Data Analysis

Multiple linear regression (MLR) analysis was used to predict the performance of projects undertaken by foreign firms in China based on the PM practices adopted by them. The independent/predictor variables are the PM practices (and/or their attributes) adopted by foreign firms when operating in China and the dependent variable is one of the project success measures (Table 1). Each model is expressed by

$$Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_{ki} + \varepsilon_i \qquad (1)$$

where Y_i is measure of project success (dependent variable) based on respondents' ratings of the items in Table 1; X_i=PM practice adopted by foreign firms in China (independent variable); β =estimated regression coefficient; α=constant; and ε=error term, which is a random variable with mean 0.

In applying MLR, it is assumed that the relationship between Y and the independent variables can be approximated by a linear model that provides best fit estimates of the model parameters by minimizing the error of the model (Otto and Longnecker 2001). The stepwise method was used to select variables for the MLR analysis. This method was chosen because it accommodates partial correlation structures for variables already in the model. The predictive power of the model is judged through adjusted R^2, which is a better estimate of the model's goodness-of-fit than the coefficient of determination (R^2). Adjusted R^2 does not inevitably increase as the number of included independent variables increases. The optimum regression model should be the one that best fits the data and yields the most accurate prediction of the dependent variable.

Model Development

As regression models should only be constructed from internally reliable variables, a reliability test was carried out on the PM practices in an iterative process by estimating Cronbach's alpha (α). Each variable was added into the computation, and those that do not contribute to increasing the value of Cronbach's alpha are not considered internally consistent, and would be excluded. Using the SPSS software, α was calculated as 0.925, whereas the conventional cutoff for Cronbach's alpha is 0.7 (Otto and Longnecker 2001). This indicates that the PM practices are internally consistent, and therefore all were included in model construction.

Using SPSS software, five optimum MLR models were developed to predict likely project outcomes based on PM practices adopted by foreign AEC firms in China (see Table 3). The following discussion focuses on significant explanatory variables (PM practices) that affect each performance measure. Construction industry practitioners could adopt these PM practices, which may help in achieving project success.

Discussion

Cost Performance (Y1)

Cost Performance (Y1) indicates a comparison between the actual and the budgeted cost of the project. Table 3 shows that 37% of foreign firms' project cost performance in China can be predicted by three PM practices that they adopt, and the prediction model is

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given in the following equation. To achieve cost savings in the project, foreign firms in China should have high quality responses to perceived variations (Scop12); have low extent of claims/disputes in the contract (Scop14); and have high financial strength (Cost37)

$$\begin{aligned}\text{Y1 Cost Performance}&\\ &= 0.473(\text{Scop }12) - 0.367(\text{Scop }14) + 0.328(\text{Cost }37)\end{aligned} \tag{2}$$

where Y1=predicted cost performance (max=5.24; min=−1.77); Scop12=quality of a firm's response to perceived change orders (Scale 1–7; 1=low; 7=high); Scop14=extent of claims or disputes (Scale 1–7; 1=low; 7=high); and Cost37=firm's financial strength (Scale 1–7; 1=low; 7=high).

Firms with higher quality responses toward perceived variations (Scop12) are likely to have better cost performance (Y1). This is consistent with the findings of Love and Irani (2003) that early implementation of a change control mechanism ensures that changes are properly monitored, and this reduces reworks. Minimum reworks lead to cost savings and/or lower chance of cost growth. Firms need to be financially strong (Cost37) to handle the project and maintain a healthy cash flow. This is important in international projects, as this study shows, and also in domestic projects (Ling 2004). The extent of claims and disputes in the contract should be reduced (Scop14) by careful definition of the project scope and detailed drafting of contract conditions.

Time Performance (Y2)

Schedule performance is a comparison made between the actual and planned duration for the project. Time performance would be improved if timing of acceptance, approval, and commitment of the schedule by the project team (Time21) is early, firms have few monitoring activities to detect cost overruns (Cost35) and the likelihood of being engaged by client or project team members in future is high (Com74). Table 3 shows that 44% of variance in time performance can be explained by three variables and the prediction model is given in

$$\begin{aligned}\text{Y2 Time Performance}&\\ &= 0.496(\text{Time21}) - 0.596(\text{Cost35}) + 0.471(\text{Com74})\end{aligned} \tag{3}$$

where Y2=predicted time performance (max=6.17; min=−3.21); Time21=timing of acceptance, approval and commitment of schedule (Scale 1–7; 1=very late; 7=very early); Cost35=extent of monitoring activities to detect cost over runs (Scale 1–7; 1=low; 7=high); and Com 74=likelihood of being engaged by client or project team members in future (Scale 1–7; 1=poor; 7=excellent).

With early acceptance, approval, and commitment from the project team on the schedule (Time21), time performance is improved. The earlier the project team approves and complies with the schedule, the better the chance for the project to proceed on schedule. Work sequences should be viewed as an entirety because the impact of one event or decision could affect overall project performance (Lee et al. 2006).

Surprisingly, more monitoring activities to detect cost overrun (Cost35) would lead to poorer schedule performance ($\beta = -0.385$). It departs from the study of Ling (2004) of domestic construction in which contractors with high ability in financial management would have projects that have good schedule performance. This may be because more resources put into detecting cost overrun may result in less focus on managing the project execution, resulting in project delays.

Quality Performance (Y3)

Quality Performance (Y3) gives an indication of workmanship, technical and functional quality performance. Table 3 shows that 80% of project quality performance can be explained by four PM practices. Quality performance would be improved if: a firm's responses to perceived variations (Scop12) are of high quality; the contract is subdivided into smaller components (Scop16); quality of technical staff or workmen is high (Qlty45); and compensation level to expatriate staff is not generous (HRM68). The prediction model for Y3 is given in

$$\begin{aligned}\text{Y3 Quality Performance}&\\ &= 0.391(\text{Scop12}) + 0.677(\text{Scop16}) + 0.67(\text{Qlty45})\\ &\quad - 0.222(\text{HRM68})\end{aligned} \tag{4}$$

where Y3=predicted quality performance (max=11.94; min=0.18); Scop12=quality of a firm's response to perceived change orders (Scale 1–7; 1=low; 7=high); Scop16=extent of subdividing the contract (Scale 1–7; 1=one large integrated contract; 7=many smaller contracts); Qlty45=quality of technical staff/workmen (Scale 1–7; 1=low; 7=high); and HRM68 is the compensation level to expatriate staff (Scale 1–7; 1=standard salary; 7=generous allowance).

Y3 shares three predictive variables (Scop12, Scop16, and Qlty45) with Y4 and these are discussed in the next section. Previous studies have not investigated the relationship between compensation level of expatriate staff and project performance. This study found a negative relationship between level of expatriate staff compensation and project quality performance ($\beta = -0.222$). This indicates that giving expatriate staff a generous allowance to be in China does not help in elevating quality performance. On the other hand, increasing quality of workmen leads to higher project quality ($\beta = +0.67$). The implication is that money should be spent more on recruiting and retaining high quality workers than expatriate staff as the former undertake the physical work and if they can do things right the first time, this would lead to higher quality performance.

Owner Satisfaction (Y4)

Owner satisfaction (Y4) is an indication of how satisfied the owner is with the project. Table 3 shows that 80% of owner satisfaction can be explained by five PM practices. Owner satisfaction would be improved if: a firm's responses to perceived variations (Scop12) are of high quality; the contract is subdivided into smaller components (Scop16); quality of technical staff or workmen is high (Qlty45); quality of schedule is high (Time22); and the foreign firm has high financial strength (Cost37). The prediction model for Y4 is given in

$$\begin{aligned}\text{Y4 Owner Satisfaction} &= 0.316(\text{Scop12}) + 0.519(\text{Scop16})\\ &\quad + 0.44(\text{Qlty45}) + 0.259(\text{Time22})\\ &\quad + 0.282(\text{Cost37})\end{aligned} \tag{5}$$

where Y4=predicted owner satisfaction level (max=12.71; min=1.82); Scop12=quality of a firm's response to perceived change orders (Scale 1–7; 1=low; 7=high); Scop16=extent of subdividing the contract (Scale 1–7; 1=one large integrated contract; 7

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Table 4. Background of Test Cases

Facility	Ownership[a]	Location	Area (m^2)	Contract sum ($ million)	Service provided	Respondent designation
Assembly plant	Pte	Chengdu	25,000	30	Design, and Construction	Senior engineer
Residential building	Pte	Qing Dao	44,000	114	Construction	Assistant engineer
Public building	JV	Chongqing	80,000	5	Construction	Project engineer
Fertilizer plant	JV	Nanjing	30,000	150	Procurement, supervision	Chief China representative
Chemical plant	Pte	Shanghai	32,000	30	Design, procurement, construction	Deputy China representative
Road tunnel	Pte	Zhuhai	30,000	2.58	Construction	Executive director
Chemical plant	JV	Kunshan	35,000	15	Construction	Project manager
Chemical plant	Pte	Chengdu	20,000	30	Construction	Senior engineer
Residential building	Pte	Beijing	3,000	84	Construction	Project manager
Office building	Pub	Shanghai	40,000	10.6	Construction	Project manager
Residential building	Pte	Shijiazhuang	127,000	22.7	Construction	Project manager
Community center	JV	Beijing	700,000	75.5	Project management	Project manager
Sports center	Pub	Neimenggu	67,000	22.5	Construction	Deputy manager

[a]Pte=private sector; Pub=public sector; and JV=public–private joint venture.

=many smaller contracts); Qlty45=quality of technical staff/workmen (Scale 1–7; 1=low; 7=high); Time22=quality of schedule (Scale 1–7; 1=low; 7=high); and Cost37=firm's financial strength (Scale 1–7; 1=low; 7=high).

Giving high quality responses toward perceived variations (Scop12) would ensure that changes to the contract are quickly identified and implemented. These indicate the importance of close monitoring of changes, which would minimize reworks and result in high quality outputs and increased owner satisfaction.

The result shows that subdividing the contract into smaller packages (Scop16) leads to better quality performance and higher owner satisfaction. This differs from the study of Love and Iran (2003), which found that quality management becomes complex and difficult to implement when many organizations are involved. However, it is possible for the smaller work packages to result in better quality because the work is done by specialist subcontractors, and specialization leads to better quality output and higher owner satisfaction.

Having high quality technical staff or workmen (Qlty45) would lead to higher owner satisfaction and better quality performance. This is similar to domestic construction, in which contractors' high technical expertise is correlated with satisfaction (Ling 2004).

High quality schedule (Time22) also leads to high owner satisfaction. The implication is the importance of preparing a realistic schedule, which takes into account all important activities, thus enabling activities to be carried out in proper sequences and using correct procedures, and reducing the chance of project delay.

Profit Margin (Y5)

Profit Margin (Y5) is the profit derived by international AEC firms from their projects in China. Table 3 shows that 55% of a project's profitability can be explained by two variables. To obtain higher profit margin, foreign AEC firms operating in China should provide high quality responses to perceived variations (Scop12) and be able to control labor issues and management risks (Risk512). The prediction model is given in

$$\text{Y5 Profit Margin} = 0.632(\text{Scop12}) + 0.346(\text{Risk512}) \quad (6)$$

where Y5=predicted profit margin (max=6.85; min=0.98); Scop12=quality of the firm's response to perceived change orders (Scale 1–7; 1=low; 7=high); and Risk512=ability to control labor issues and management risk (Scale 1–7; 1=poor; 7=high).

Previous studies did not investigate factors affecting profit margins in international projects. This study found the importance of having high quality responses toward perceived variations (Scop12) to increase profitability. If changes are left unchecked and claims for additional payments are not made, additional costs are incurred and reduction in profit may result. Close monitoring of changes and submitting properly substantiated claims could lead to a higher chance of being paid extra and thereby increasing the profit margin.

The results show that failure to control labor issues and management risk (Risk512) effectively would lead to reduction in profitability level. Construction processes in China depend heavily on manual labor (Low and Jiang 2003). Even though the labor is cheap, they are unskilled and require proper training (Chan et al. 1999). It is therefore important to train the workers so that there would be fewer reworks, resulting in higher profits. Labor issues may be overcome if foreign firms partner with local Chinese firms that have access to cheap labor and can exercise adequate control over them (Ling et al. 2005).

Model Validation

Model validation was conducted to ensure that the constructed MLR models are generalizable to the population and not specific to the sample used in estimation. A diagnostic test was first conducted and the residual plots of R (being actual Y less the predicted Y) versus predicted Y showed a random distribution. This indicates that the normality assumption is valid. Next, in order to check for collinearity, the variance inflation factor (VIF) was calculated for each explanatory variable. In this study, the VIFs calculated (see Table 3) were within the acceptable range of 5.0, indicating that there is little evidence of collinearity among the set of explanatory variables (Haan 2002).

To validate the MLR models, 13 new sets of project data were collected (see Table 4). The predicted project performance levels (predicted Y) were derived mathematically from the models [Eqs. (2)–(6)]. These predicted results were compared to the actual performance (actual Y) of the projects. The equations used to measure the accuracy of the results predicted by the models are given by the following equations, following Upton and Cook (2006):

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Table 5. Comparison of Predicted and Actual Performances

Performance measures	Mean percentage error (%)	Mean absolute percentage error (%)
Cost performance (Y1)	−0.54	44.92
Time performance (Y2)	37.05	41.27
Quality performance (Y3)	2.31	11.24
Owner satisfaction (Y4)	−0.67	14.99
Profit margin (Y5)	−15.44	26.60

$$\text{Percentage error (PE)} = \frac{\text{Actual value} - \text{Model's predicted value}}{\text{Actual value}} \times 100\% \quad (7)$$

$$\text{Mean percentage error (MPE)} = \frac{\Sigma \text{PE}}{n} \quad (8)$$

where n = number of predictions

$$\text{Mean absolute percentage error (MAPE)} = \frac{\Sigma |\text{PE}|}{n} \quad (9)$$

where $|\text{PE}|$ = absolute value of the percentage error.

The MPE results in Table 5 show that Models Y1, Y3, Y4, and Y5 are able to predict project performance between −15 and +2% accuracy. Model Y5 may give a prediction that is 15% lower than actual profit margin, whereas Model Y3 over estimates quality performance by 2%.

The MAPE results showed that Models Y3, Y4, and Y5 are able to predict a project's performance between 11 and 27% accuracy. Based on both the MPE and MAPE test results, it is concluded that robust models to predict Y3, Y4, and Y5 have been developed. On the other hand, Models Y1 and Y2 are not able to predict accurately. This is consistent with their low R2 values. Notwithstanding this, for each model, three predictive variables were uncovered, which could explain up to 37% and 44% of cost (Y1) and time (Y2) performance respectively (see Table 3).

Practical Application

This research developed and tested five models [Eqs. (2)–(6)] that foreign firms can use to predict how successful their projects in China are likely to be, based on different PM practices adopted. The PM practices revealed in the models could serve as a guide for them to adopt when operating in China's construction industry. The five models are also useful to foreign firms that are assessing if they would like to manage a project in China, because the likely outcome may be forecasted before they embark on the project.

Limitations

The first limitation of this study is that only 33 project data sets were used to construct the models, which appeared to be small. Notwithstanding this, the five models were tested using additional 13 sets of data, and it was shown that the models are reasonably robust. Further studies could be conducted to check whether the models are still applicable when more data sets are used.

The second limitation relates to the use of perception rating via a Likert scale, and the presence of qualitative measures such as output quality and owner satisfaction. Although, this technique is particularly helpful in examining respondents' perceptions, respondents may be biased when answering some of the questions. For example, Owner's Satisfaction (Y4) may not be accurately answered by foreign AEC firms due to lack of objectivity.

Conclusion

This study examined the impact of PM practices of international firms on the performance of their projects in China. Explanatory variables that significantly affect performance of projects managed by foreign firms in China were identified (Table 3). Five predictive models were constructed and tested. Using several PM practices, these MLR models can explain between 37 and 80% of different aspects of project performance.

Compared to domestic construction, some new methods for driving international project in China are uncovered in this study. Of utmost importance is the overarching importance of scope management in international construction. Of the PM practices available, this study found that a firm's response to perceived change orders (Scop12), is the most important PM practice that affects five areas of project performance (see Table 3, where Scop12 is a predictor for Y1, Y3, Y4, and Y5). The extent of claims or disputes in a project (Scop14) is a predictor for Y1; and extent of subdividing the contract (Scop16) is a predictor for Y3 and Y4. These findings indicate that for foreign firms that are venturing into China or already in China, upstream activities, such as managing project scope, is a critical factor influencing overall project performance. Changes in projects can cause substantial adjustment to the contract duration and time, total direct and indirect cost, or both (Ibbs 1997; Ibbs et al. 1998). It is therefore necessary to control scope throughout the project life cycle. Hence, more attention should be paid to managing project scope in order to ensure project success.

This study also found that international construction needs to adopt some unconventional PM practices. First, project managers should not be too focused on monitoring activities to detect cost overrun (Cost35) as the study found that this would lead to time schedule performance, perhaps because more effort is spent in claims instead of getting the job done expeditiously. Second, foreign AEC firms should not adopt a mindset of sending their most talented (and usually handsomely paid) staff to China to solve all the project problems. This study found that paying expatriate staff generous allowance (HRM68) in China does not help in improving quality performance, indicating the importance of training local staff to do the work. Third, foreign AEC firms should refrain from placing out one mammoth project. They should subdivide a big project into smaller packages (Scop16) as this leads to better quality performance and higher owner satisfaction. This suggests that specialist contractors should be engaged for different work packages as their ability to specialize leads to better project outcomes.

This study also found a way to predict profit margins of international projects; which has not been previously done. Using two variables; quality of response to perceived variations (Scop12) and ability to control labor issues and management risks (Risk512); 55% of a project's profitability can be explained.

The advantage of the models is that they can be used to make a preliminary assessment of the likelihood of project success based on the type of PM practices to be adopted. Consultants and

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contractors play important roles in bringing about project success. It is recommended that both consultants and contractors implement appropriate PM practices as identified in this study in order to achieve good project performance and success.

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