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THREE-STAGED RISK EVALUATION MODEL FOR BIDDING ON INTERNATIONAL CONSTRUCTION PROJECTS

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ABSTRACT: Risk evaluation approaches for bidding on international construction projects are typically partitioned into three stages: country selection, project classification, and bid-cost evaluation. However, previous studies are frequently under attack in that they have several crucial limitations: 1) a dearth of studies about country selection risk tailored for the overseas construction market at a corporate level; 2) no consideration of uncertainties for input variable per se; 3) less probabilistic approaches in estimating a range of cost variance; and 4) less inclusion of covariance impacts. This study thus suggests a three-staged risk evaluation model to resolve these inherent problems. In the first stage, a country portfolio model that maximizes the expected construction market growth rate and profit rate while decreasing market uncertainty is formulated using multi-objective genetic analysis. Following this, probabilistic approaches for screening bad projects are suggested through applying various data mining methods such as discriminant logistic regression, neural network, C5.0, and support vector machine. For the last stage, the cost overrun prediction model is simulated for determining a reasonable bid cost, while considering non-parametric distribution, effects of systematic risks, and the firm's specific capability accrued in a given country. Through the three consecutive models, this study verifies that international construction risk can be allocated, reduced, and projected to some degree, thereby contributing to sustaining stable profits and revenues in both the short-term and the long-term perspective.

Keywords: Risk Evaluation, International Project, Portfolio Optimization, Project Selection, Cost Variance

1. INTRODUCTION

Due to emerging market and oil revenues, the market volume of international construction has grown 12.9% per year over the 10 years and is roughly estimated at more than $6,000 billion in 2008 [1], [2], which is around three times greater than the market volume of the global semi-conductor and global mobile phone market [3], [4]. However, the market growth volatility of international construction is 13.9%, whereas the global domestic construction market is 2.6% over the same 10 years [1], [5]. Even more, this market volatility differs considerably according to country. Therefore, contractors have to decide how many countries to enter and how best to weigh the distribution of their work in various countries in order to achieve sustainable performances. In addition, the average profit rate of international projects and domestic projects of the top 225 contractors are almost the same, 7.1% and 6.5%, respectively, whereas the average loss probability of international contractors and domestic contractors is quite different, 14.5% for international contractors as compared to 11.1% for domestic contractors [1]. These values imply that international construction is both high risk and similar return. Moreover, Korean international contractors show only an average 4.5% profit rate and 9.8% volatility of profit rate over the 10 years. Examining these trends, many researchers also have concluded that international construction has greater uncertainty than domestic construction [6], [7], [8], [9], [10]. In particular, Levitt [11], insists that the international construction market basically cannot be as fair to foreign contractors as it is to the host country's contractors, and this unfairness makes international construction projects more risky. In addition, Shane [12], indicates that the contractors who have insufficient abilities in risk management have a tendency to underestimate the risk in order to win a bid because they usually have a bias that they can do well. In these contexts, international contractors need to evaluate the risk strictly and objectively using more quantitative and reliable methods in order to bid more competitively and to create greater profits.

Han [13], introduced the conceptualized three-staged sequential decision process model for comprehensive market entry decision to select profitable international construction projects, as shown in Figure 1. A great deal of research about risk evaluation has been carried out within this decision framework. However, to date, there are several crucial limitations that have not yet been solved, as follows:

First, there is a dearth of studies about country selection by risk tailored for the overseas construction market at a corporate level. Even though the selection of the entry country at stage I is a crucial decision, most research about country risk focuses on the evaluation of only a single, specific country [14], [15], [16], [17]. These kinds of studies make an important contribution to the understanding of the entry risk and institution of a specific country. However, in order to improve the decision of county selection, research based on quantitative methods comparing each country is necessary.

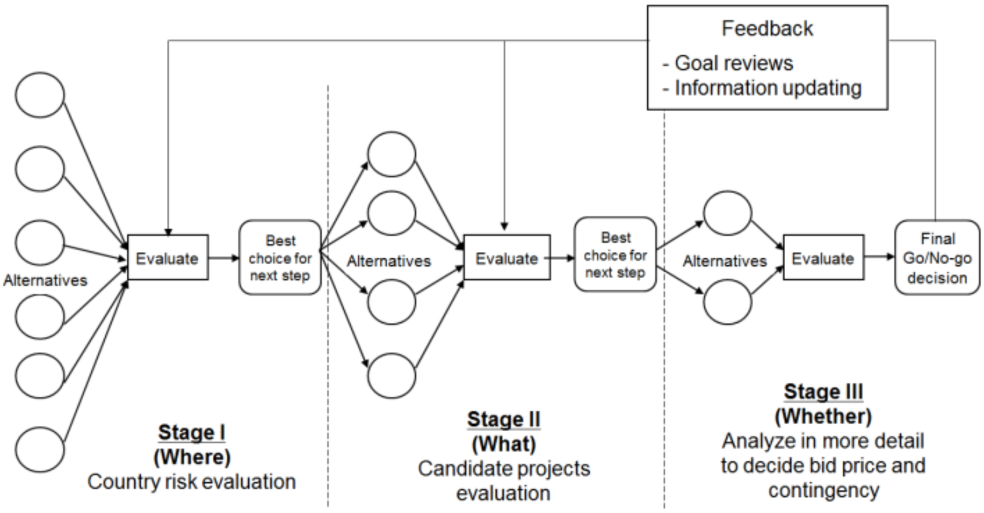


Figure 1 Multi-staged sequential decision process [13]

Second, the level of required input at the second stage is not consistent with the corresponding bidding process. Actually, many studies have dealt with the second stage, and concern the evaluation of good or bad projects. However, the level of required input is very high, and much of this input can be acquired at the third stage [18], [19]. In other words, at stage II, a bidder is estimating the risk of a project, but the actual details he needs to know emerge only in stage III. Therefore, a model is needed to evaluate projects based on the level of data available before the more detailed analysis in stage III, even though the accuracy of this data (i.e. the data before stage III) is relatively low.

Third, the uncertainties for input variable per se at the third stage are not considered. Most risk evaluation models at stage III are based on real risk data that are investigated after finishing the projects, which means that each responder can estimate the risk appropriately corresponding to each completed project [20], [21]. Therefore, strictly speaking, this answer is not the predicted uncertainty of the risk but the residual result of the risk. However, when this kind of model is applied to a new project at stage III, even though the users analyze the risk in detail, they cannot answer the questionnaire as accurately as the former cases (i.e. the cases after completion of projects).In other words, their predicted risk can be changed as the project goes on. Therefore, the uncertainties for input variable have to be considered according to the user's capacities for risk evaluation.

Fourth, most risk evaluation models at the third stage usually do not provide the probabilistic performance. Basically, risk involves uncertainty, which means that the evaluation of risk as simple range or grade has a limitation. Therefore, the cost overrun or contingency evaluation model at stage III should be predicted based on the probability. After that, the decision maker determines the planned cost overrun or contingency through reference to this prediction model. However, most cost estimation models for international construction projects suggest only the fixed predicted results [22], [23].

Finally, theoretical approaches of risk governance for international construction project have not been studied extensively, which means that most risk factors and the relationships between risk and performance have been established not by the economy or management theories but by expert opinions. Even though several researchers have studied the strategies of international project based on transaction cost theory and institutional theory [24], [25], [26] [27], [28], more fundamental approaches are needed via economic theories and management theories such as industrial organization theory, transaction cost theory, resource-based theory, and institutional theory.

Therefore, the first stage of this study proposes a quantitative country portfolio that maximizes expected construction market growth rate and profit rate while decreasing market uncertainty and which is formulated according to the preferred strategy of the decision maker. Following this, probabilistic approaches for screening out bad projects through the three data mining tools are suggested using explicit knowledge that can be obtained easily and quickly. For the last stage, a probabilistic cost overrun prediction model is simulated for deciding a reasonable bid cost, while considering input uncertainties, non-parametric distribution, the effects of systematic risks, and the organizational capability accrued in a given country. In addition, every risk evaluation model is formulated based on theoretical approaches.

2. PRACTICES OF RISK EVALUATION

This study carried out an in-depth interview with risk managers of the five top Korean international contractors. The managers have an average of 17.2 years in international construction and are in charge of evaluating the risk of international projects before bidding. Even though the practices and methodologies of risk evaluation differ according to the individual company, almost all construction companies have a similar decision process for bidding, as shown in Figure 2. They usually have several gateways to decide whether or not to prepare the project and how much to estimate for project cost.

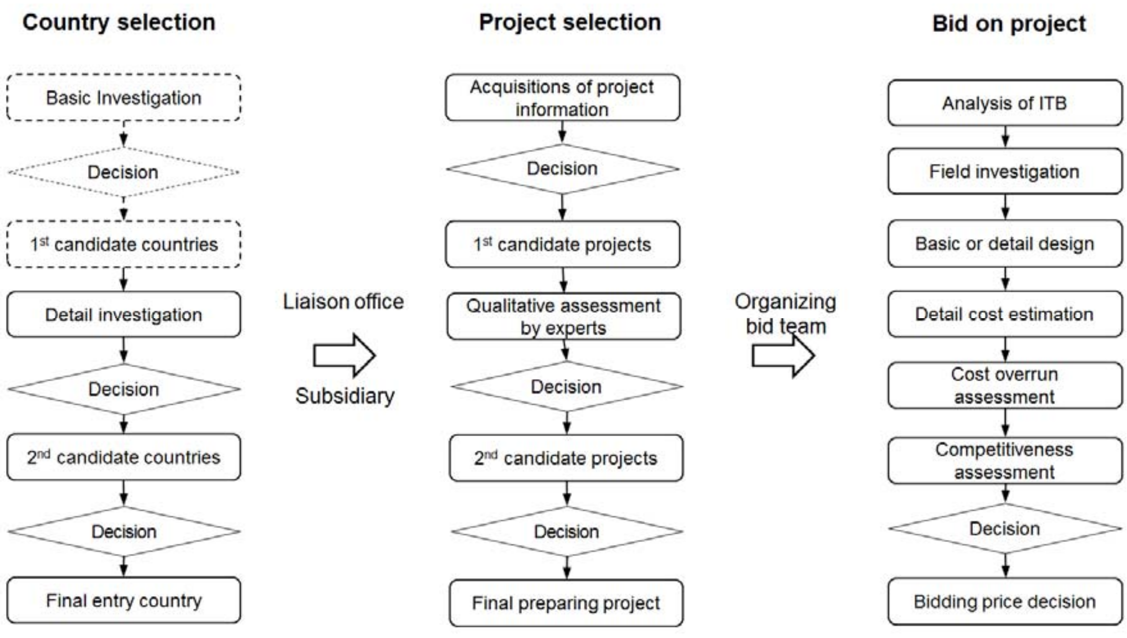
However, several companies do not have a regular process for country selection. That is a role played by their business departments or executives. In addition, the task of country selection does not happen as often as the process of bidding on a project. Nevertheless, a well-organized company considers the risk of country selection through a regular process. In addition, some companies have just one gate to decide whether or not to prepare bidding on a project in the project selection stage. However, general practices and values of risk evaluation are as follows:

At the stage of country selection, they do not generally employ specific risk evaluation models. Rather, they investigate only the information about candidate countries and sometimes request additional information from consultants. They usually try to understand the institution, market size, future economics, and performance of companies that have already worked in the host country. Sometimes they consider the country portfolio. Therefore, they try to achieve geographical balance in the areas in which they work. For example, if they have already entered several countries of Asia and the Middle East, they try to balance this with entry into an African country. However, they do not consider the quantitative effect of the country portfolio. That effect means that the markets of two countries grow up simultaneously or separately, thereby increasing or decreasing the market risk. In addition, entry into a new country requires considerable time and cost. Moreover, if they try to withdraw from that country, they usually cannot reimburse their investment. Therefore, which country to select and how to allocate the distribution of business within each country are very important in the long term.

At the stage of project selection, these companies usually have a meeting of experts. Experts generally include the engineer, estimator, project manager, legal officer, business officer, and risk manager. At the first meeting, they usually share information about the project and the country. After that meeting, some companies produce a risk rating either by all of the experts or by the risk manager. Finally, the executive director or president decides whether or not to prepare a bid on the project. There are two important reasons for this stage to be studied more. One is that, in this procedure, experts do not have detailed information about the bidding candidate projects because they do not start field investigation, design, and estimation yet. Therefore, they usually use their own subjective criteria and frequently have bias in the view of each one's opportunism. For this reason, a more objective evaluation model is required based on easily accessible project information. The other reason is the transaction cost for exploring the new project and for preparing the bidding on projects. For example, over the span of three years, one Korean contractor reviewed more than 500 project candidates, prepared the bidding for about 300 projects, and won the bidding for about 50 projects. In this procedure, a project with good potential might be abandoned before preparing bidding, and a project with bad potential might proceed with bidding. Therefore, if the more accurate project selection model is developed, the traction cost for bidding can be reduced.

At the bidding stage, all companies estimate the cost overrun through their own estimation methods. Nevertheless, there are frequent arguments between the business officer and the risk manager. The business officer has a tendency to underestimate cost overrun in

Figure 2 General process of bidding on international construction projects



order to win a project. However, the risk manager usually estimates the project as being more risky than the business officer's evaluation. During these conflicts, the evaluation results produced by risk managers are not usually reflected enough because the estimation of cost overrun is based on historical data or expert opinion. Therefore, they usually insist on the smaller contingency under the bias that they can do well. Fortunately, nowadays, many companies try to analyze the project risk qualitatively in detail, thereby preparing the risk. However, quantitative evaluation based on probability is not used extensively because most quantitative risk evaluation models are still considered less reliable in practice.

3. FRAMEWORK OF MODELING

Based on the conceptual framework of the multi-staged sequential decision process suggested by Han [13], as shown Figure 1, this study suggests a framework of a modified three-staged risk evaluation model as follows.

At stage I, the contractor determines the new entry country or allocates the business weight of the current portfolio. In order to support these decisions, this study proposes the country portfolio optimization model. This model provides an optimized solution that maximizes market growth and market profit while minimizing the volatility of market growth and profit. These objectives are derived from the industrial organization theory that the profit of a company follows the profit of the industry as a whole in the long term. In order to accomplish this model, this study applied the Markowitz portfolio theory to the international construction market and collected the market growth rate of 20 countries over the past 10 years and Korean contractors' average profit of 20 countries over the past 10 years. Han's model focuses the country risk evaluation for selecting the appropriate project, but this study focuses on the country risk evaluation for selecting the entry country.

At stage II, the contractor has to choose the project for bidding. This process also requires many kinds of evaluations, such as expert opinion, past experience, resource accessibility, competitiveness, and long-term strategic value. However, this model only suggests the quantitative probability of project loss based on explicit knowledge of historical data. This supporting analysis helps the contractor to reduce transaction cost in order to reduce the probability of bad project selection. The various information of 1,311 international construction projects over the 10 years is taken from the International Construction Information Service [29]. In addition, this study investigated the number and price of international construction projects in the host country and overall overseas. Moreover, this study calculates the volatility of oil prices and the currency rate at contract day of each project. Among the 102 explicit information of each project, this study chooses the 28 variables to get more accurate and effective results through date mining, such as linear discriminant analysis, neural network, and C5.0.

At the last stage, the contractor has to determine expected cost overrun according to probability. According to the expected risk and cost overrun, the contractor determines the bid price. However, the contractor sometimes might withdraw the bidding or submit an uncompetitive high bidding price when the expected risk is considerably high. If this stage is used before the process of estimation, it is the same as Han's model. But, if this stage is used on the process of estimation, it would be a further stage next to stage III in Han's model. This study at stage III has several differentiations from previous studies. In order to reflect input uncertainty, this model investigates 71 risk factors at two stage risks before and after bidding for the 137 international construction projects. In addition, this model considers the localization capability of contractors to deal with risk and covariance between the risk factors. Through these considerations, this model uses a simulation based on no-parametric distribution. Table 1 shows the summary of the framework of the three-staged risk evaluation model for bidding on international construction projects.

4. STAGE I: COUNTRY PORTFOLIO OPTIMIZATION MODEL

4.1 Portfolio Optimization According to Market Growth Rate

Objective Functions

Table 1 Framework of modeling according to stage

List	Stage I	Stage II	Stage III
Objective	□ Country portfolio optimization	□ Bad project selection	□ Cost overrun simulation
Background Theory	□ Industrial organization □ Diversification □ Markowitz portfolio theory	□ Transaction cost □ Resource-based theory □ Institutional theory	□ Resource-based theory □ Institutional theory
Sample data	□Market growth and profit rate in 20 countries over the 10y.	□ 1311 international projects by Korean contractors over the 10y.	□ 137 projects case survey
Methodologies	□ Multi-objective genetic analysis (MATLAB 2009b)	□ LDA, ANN, C5.0 (SPSS Modeler)	□ Non-parametric distribution Simulation (MATLAB 2009b)

This study builds the multi-objective function to find the best portfolios to maximize market growth rate while decreasing market volatility of market growth rate following equation (1) and (2).

$$\text{maximize } f_1(\omega) = \sum_{i=1}^{n} \omega_i r_{g,i} \quad (1)$$
$$\text{minimize } f_2(\omega) = \sum_{i=1}^{n}\sum_{j=1}^{n} \omega_i \, \omega_j \sigma_{g,ij} \quad (2)$$

f_1 is the market growth rate of portfolios (ω), f_2 is the standard deviation of market growth rate of portfolios (ω), ω_i is the weight portion of country i among the portfolios (ω), ω_j is the weight portion of country j among the portfolios (ω), $r_{g,i}$ is the market growth rate in country i, $\sigma_{g,ij}$ is the covariance of market growth rates in country i and j,

However, no portfolio can satisfy two of the above objective functions simultaneously. Therefore, two objective functions can be expressed including the weight of each objective function as an equation (3). If these weights are fixed by the decision maker, the optimization solution becomes one. However, if the decision maker does not do so, the optimization solutions as Pareto solutions are to be many. This study suggests Pareto solutions because these weights are different according to the risk attitude of the decision maker, and the determination of the weight is not the scope of this study.

$$\text{maximize } f(\omega) = \gamma_1 f_1 - \gamma_2 f_2$$
$$= \gamma_1 \sum_{i=1}^{n} \omega_i r_{g,i} - \gamma_2 \sum_{i=1}^{n}\sum_{j=1}^{n} \omega_i \, \omega_j \sigma_{g,ij} \quad (3)$$

γ_1 is the weight of the market growth rate of portfolios, γ_2 is the weight of the standard deviation of market growth rate of portfolios.

Constraint Conditions

In order to perform the multi-objective genetic analysis, the following constraint conditions are need. The minimum weight of a specific country among the portfolios differs according to the decision-maker. This study assumes this value as 1%.

$$\sum_{i=1}^{n} \omega_i = 1 \quad (4)$$
$$0.01 \le \omega_i \le 1 \quad (5)$$
$$\sum_{i=1}^{n} \gamma_i = 1 \quad (6)$$

As shown in Figure 3, the Pareto solutions by linear programming and multi-objective genetic analysis (MOGA) are almost the same. The result of linear programming is almost same of exact solution, which means that the solutions of MOGA are reliable. However, linear programming finds more fine solutions but the MOGA finds less fine and wider solutions. This means that the Pareto solutions by MOGA are optimal solutions but do not include all, which involve that there are some possibilities to exit another solution on the Pareto frontier. In the two objective functions, this Pareto frontier is easily to be conjectured but, in cases where there are more than three objective functions, it is difficult to infer the Pareto frontier. In addition, the Pareto solutions imply that an appropriate portfolio produces higher growth rate given the same risk of market growth or yields less risk of market growth given the same market growth.

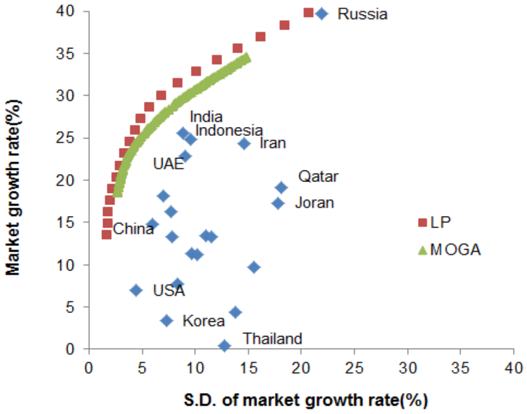


Figure 3 Pareto solutions according to market growth rate

4.2 Portfolio Optimization According to Market Profit Rate

Objective Functions

In the perspective of profit rate, objective function is similar with (3) and constrain conditions are same with Eq. (4), (5) and (6).

$$\text{maximize } f(\omega) = \gamma_3 \sum_{i=1}^{n} \omega_i r_{p,i} - \gamma_4 \sum_{i=1}^{n}\sum_{j=1}^{n} \omega_i \, \omega_j \sigma_{p,ij} \quad (7)$$

ω_i is the weight portion of country i among the portfolios (ω), ω_j is the weight portion of country j among the portfolios (ω), $r_{p,i}$ is the market profit rate in country i, $\sigma_{p,ij}$ is the covariance of market profit rates in country i and j

As shown in Figure 4, the Pareto solutions by linear programming and MOGA implies that the appropriate portfolio results in a higher profit rate given the same market profit risk or yields less market profit risk given the same market profit rate.

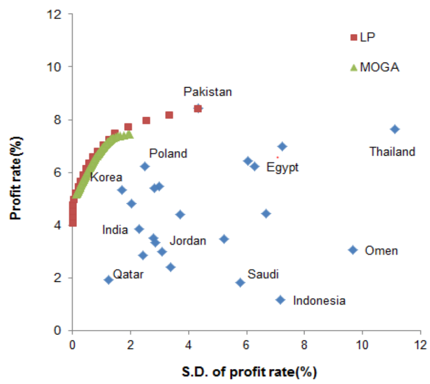


Figure 4 Pareto solutions according to market profit rate

5. STAGE II: PROJECT CLASSIFICATION MODEL

5.1 Input Variables

Initially, this study obtained 98 independent variables, each of which were meaningful in terms of project information. However, if we had used all of these variables, the total numbers of sample data would have been insufficient in comparing the number of the input variables. Moreover, many of these are non-countable variables, which make so many dummy variables to cause failure of the analysis. Heo and Lee [30] suggest that the desirable ratio between input variable and sample data is 1:20. Therefore, this study chose 32 important variables based on the following criteria. First, this study categorized the variables according to industrial organization theory, resource-based theory, and institutional theory. This study tried to consider each of these three theories to select the final variables. Second, this study used the "Feature Selection" option provided by SPSS modeler. This module prioritizes variables through the following criteria: 1) maximum percentage of missing values; 2) maximum percentage of records in a single category; 3) maximum number of categories as a percentage of records; 4) minimum coefficient of variations; and 5) minimum standard deviation. Through these two considerations, this study finally determined 32 input variables, as shown in Table 2. In particular, approximate resource allocations express project characteristics because each resource usually has a different risk level according to the type of product.

5.2 Out Variables

In order to distinguish good projects from bad, this study used profit performance. If the profit earned by a project was greater than zero, this study considered it as a good project; if less than zero, this study considered it to be a bad project. Using these criteria, 380 of the 1,311 projects, or 29%, were considered to be bad projects.

5.3 Training Data and Test Data

This study tried to avoid the sample choosing bias by intention or un-intention. Therefore, at first, this study used 651 training data and 650 test data. After fitting and evaluating these data, this study replaced test data and training data. This was followed by additional fitting and evaluating of the model. Finally, this study used the average value of accuracy rate.

5.4 Results

C5.0 suggests the best result selecting bad projects. In particular, C5.0 indicates that accumulated total project day, delivery type, project volume comparing revenue, accumulated cost corresponding to product, political risk, and government risk are important. This study only shows the result of C5.0 because of limited pages.

The percentage of actual bad projects among the predicted bad projects is 51%, which is increased more than 20% compared to initial prior probability. The percentage of actual good projects among the predicted good projects is 81%, as shown Table 3. In particular, C5.0 has the highest accuracy rate of bad project selection among the three methods, which implies that the institutional theory and resource-based theory explain well which projects are bad.

Table 2. Selected input variables

Variable group	Variable name
Country risk	Voice and accountability
	Political stability and absence of violence
	Government effectiveness
	Control of corruption
	Regulatory quality
	Rule of raw risk
Economic risk	Average currency rate over a year
	Average oil price over a year
	S.D. of currency rate over a year
	S.D. of oil price over a year
Project condition	Contract position
	Delivery type
	Ownership type
	Project duration
	Product type
	Contract price
Project characteristics	Equipment cost ratio
	Management cost ratio
	Labor cost ratio
	Material cost ratio
Organization capability	Accumulated total project cost
	Accumulated total project day
	Accumulated project cost of host country
	Accumulated project day of host country
	Accumulated cost corresponding to product
	Accumulated day corresponding to product
	Project volume comparing revenue
Financial capability	Revenue
	Current ratio
	Net profit
	Operating profit
	Leverage ratio

Table 3 Confusion matrix by C5.0

Sort		Predicted class: Bad	Predicted class: Good	Predicted class: Sum
Actual class	Bad	103	87	190
	Hori.	54%	46%	100%
	Verti.	51%	19%	29%
	Good	101	365	466
	Hori.	22%	78%	100%
	Verti.	50%	81%	71%
	Sum	204	452	656
	Hori.	31%	69%	100%
	Verti.	100%	100%	100%

Through the evaluation of three predicting models, this study provides that the bad project selection rate improves from 29% to 51% by C5.0 model and that the good project selection rate develops from 71% to 82% by ANN model. These improvements might not seem to be great. However, this Bayesian updating does not require additional cost or time because this updating is based on the explicit information that can be obtained easily by anyone. Therefore, this improvement is somewhat meaningful.

6. STAGE III: COST OVERRUN SIMULATION MODEL

6.1 Procedure of Modeling

This model is structured in complex and multi-processes in order to overcome above-mentioned limitations. Overall analyses are carried out through MATLAB R2009b. The framework of the model is as follows:

First, the user has to input predicted risk for 71 risk factors, host country experience year of project manager, and local contents rate of contractor. Second, the model extracts appropriate sample data from the database using localization similarity index. Third, this model considers two delicate analyses for more accurate and practical evaluation before the simulation. One derives the non-parametric distribution for effective risk corresponding to predicted risk factor. The other calculates the covariance matrix between risk factors. Fourth, this model simulates the effective risk distribution by 1,000 times considering the above preliminary analysis. Finally, this model predicts cost variance through simple linear regression and multi-variable linear regression using the simulated effective risk distribution.

6.2 Input Variables

This study investigated the previous literature related to the risk index for international construction projects. Hastak and Shaked [8] applied 73 risk indicators relating to country, market, and project levels and Han et al. [21] used 64 risk factors in five classes. After evaluating the relative weight of each factor in previous literature, we finally applied 48 external risk factors and 23 internal risk factors as shown in Figure 5. External risks are mainly incurred by the host country, market, owner, and project condition. Internal risks are primarily due to the contractor's own skills and capabilities.

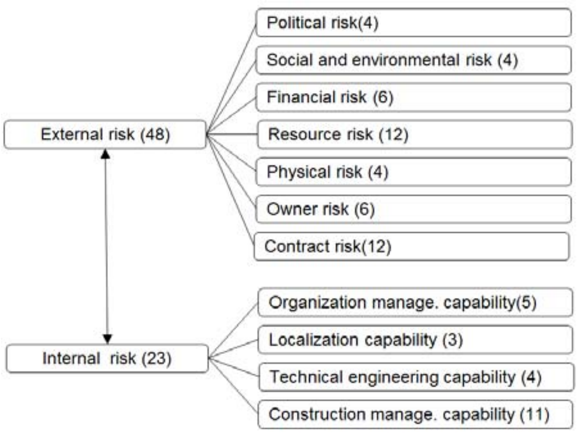


Figure 5 Structure of risk factors

6.2 Input Variables

This study shows four application examples as shown in Table 4. High localized contractors (cases A and C) have a tendency to yield less distributed cost overrun than less-localized contractors (cases B and D). In addition, the user can determine the allowable cost overrun or contingency considering cost overrun distribution diagram as in Figure 6.

Table 4 Cost overrun according to the cases

Type	Case A	Case B	Case C	Case D
Predicted average risk rating	1	1	2	2
Host country experience of PM	20y	2y	20y	2y
Local contents of contractor	70%	30%	70%	30%
Expected cost overrun (50% probability)	0%	2.7%	2.5%	8.2%
Expected cost overrun (90% probability)	3.5%	11.5%	8.5%	20.1%

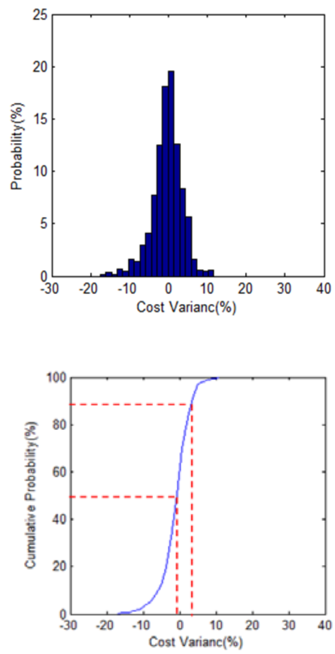


Figure 6 Cost overrun by highly localized contractor in low-risk predicted project (Case A)

6. CONCLUSION AND DISCUSSIONS

This three-stage model gives more informed decision support as following. First stage model can evaluate the strategic positions of contractor's country portfolio and suggest the desirable new entry country that yields more profitability and stability than the current portfolio. Second stage model increases the accuracy of bad selection rate from 29% to 51% without expert's opinion. Last stage model provides a cost overrun distribution that enables the decision maker to estimate the expected contingency according to the user's allowed probabilistic significance. Consequently, this study verifies that international construction risk can be allocated, reduced, and projected to some degree, thereby contributing to sustaining the stable profits and revenues. .

However, this model has several limitations. First, the analysis is based only on Korean contractors. Therefore, users have to focus on not the results but the methodologies. Second, stage I involves many assumptions. Therefore, the user has to use additional support tool. Third, stage II has to be integrated with the subject opinion by experts. Finally, stage III has to be developed through the more projects and more realistic data.

ACKNOWLEDGMENTS

This research was supported by the Korea Science and Engineering Foundation funded by the Ministry of Education, Science and Technology (2009-0081326).

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