Predicting Project Cost Performance Level by Assessing Risk Factors of Building Construction in South Korea

Hee Sung Cha* and Kang Yong Shin

*1Associate Professor, Department of Architectural Engineering, Ajou University, South Korea
2Former Graduate Student, Department of Architectural Engineering, Ajou University, South Korea

Abstract
There exists a strong relationship between the level of planning effort and overall project performance. Project stakeholders are concerned about various project objectives among which cost performance has long been regarded as one of the most crucial. Recognizing the lack of a systematic approach in assessing building project risk in association with cost performance prediction, this study identified 49 risk factors from various sources and quantified the relative impact of each factor. By normalizing these values, a Project Risk Score (PRS) has been developed for the purpose of predicting cost performance on a particular project. The 13 real case studies showed a statistically significant relationship between the PRS and cost performance. Predicting cost performance is not simple. Project managers must consider not only factors that are innate to the project, but also project-independent circumstances. This study provides straightforward guidance in assessing a particular project in order to recognize the level of cost performance before project execution. This risk-based performance prediction can improve early-stage project evaluation and enhances the possibility of achieving a sustainable business in a challenging environment.

Keywords: building project; cost performance; quantitative analysis; risk assessment

1. Introduction
Unarguably, there exists a strong relationship between early stage planning effort and overall project performance. One of the industry's current best practices, the Construction Industry Institute (CII)'s Pre-Project Planning (PPP), was structured based on this hypothesis (CII 1999). During that research, Project Definition Rate Index (PDRI) was developed to measure the level of project definition. A subsequent study verified the relationship between a good PDRI score and project success (Wang 2002). Although this tool is very useful in providing guidance to achieve overall project success, it fails to give project participants guidance on further action to take in the case that a project only achieves a poor PDRI score. If a project has worse conditions than another, the poorly conditioned project organizers should take action to compensate for a potentially poor overall performance. This compensation may include a rigorous risk control program, an appropriate contingency allocation, and a full-scale site management endeavor. These strategies are more helpful when they are activated in the early stages of a project, e.g., during feasibility studies or preliminary design. As a project progresses, the impacts of any management efforts are decreased (Barrie and Paulson 1992). It is necessary that the project stakeholders analyze the project from a diverse range of perspectives in order to effectively recognize the project status in advance. Furthermore, while analyzing a project, project managers must bear in mind a broad range of project objectives, including cost/schedule efficiency, regulatory compliance, and environmental stewardship (Cha and O'Connor 2005). Among them, cost performance has long been regarded as the most important especially in a competitive business environment. Compared to other performance indicators, cost performance is relatively easy to measure. Simply put, it is calculated by dividing "actual cost" by "planned budget."

To prevent poor cost performance, it is often required to evaluate a project's vulnerability to cost overrun before it is too late. Since the cost performance of a project is highly dependent on its potential risk, many researchers have studied the relationship between project risk and performance. Many of them have developed risk assessment tools using various theories, e.g. network modeling (Moussa et al. 2007), fuzzy concept (Choi et al. 2004), and utility theory (Hsueh et al. 2007). However, since industry practitioners are
not familiar with these concepts they may not be useful in practical applications. Therefore, it is more valuable to develop a simple-to-use diagnosis tool for risk assessment in order to predict the level of project cost performance at an early stage.

On the other hand, the building sector increasingly occupies a large percentage of total revenue of the construction industry. According to Engineering News Record (ENR), the building sector comprises 54% of total revenue from the top 500 global contractors (ENR 2007). However, compared to other work types, building work is very complicated to manage. In addition, it is highly dependent on numerous disciplines, i.e., architectural, civil, electrical, mechanical, and landscaping. In addition, many unpredictable factors are involved in executing such projects. Accordingly, it is not easy to precisely forecast the whole project performance in the early stages of planning. Furthermore, a challenging business environment forces project stakeholders into setting aside only a marginal contingency for project markup. Therefore, even well managed projects are regarded as unsuccessful when they fail to effectively incorporate potential risks while estimating their project costs.

With the problems stated above, the objective of this study is to identify and determine the relationship between cost performance and project risk factors and to develop a practical tool for risk assessment to effectively predict cost performance on a particular project. Although the research purpose may apply to any type of project, this study is mainly focused on building projects. Survey participants and case studies are also limited to building construction projects.

Recognizing that there is a strong need for a new approach in evaluating risk exposure against cost performance, the problem statement is refined and research objectives are set in the first step of this research. An extensive literature review encompassing conference papers, project reviews and academic journals was conducted before interviewing selected experts in regard to risk factor identification. Based on these efforts, over 60 factors were identified. Screening the unimportant items from the initial list, a final set of 49 items was finalized and categorized into seven classes based on their characteristics. An industry survey was given to project practitioners in order to quantify the relative importance of the finalized risk items. Using these quantified results, a computerized tool for risk assessment has been developed to facilitate the project evaluation process. The tool was then validated in terms of the level of predictability of cost performance. In the final step, conclusions and recommendations were compiled.

Following this introductory section, risk factors identified in this study are discussed and divided into categories by their characteristics, i.e., schedule, budget, quality, safety, environment, contract, and management. These factors are then subjected to an industry-wide survey of project practitioners and a methodology is created for converting the relative importance of each factor. Based on these findings, a new risk quantification method on a particular project is designed, providing an electronic risk assessment tool. Next, a statistical analysis for validating this model is followed by conclusions and recommendations.

2. Identifying Project Risk Factors

In building construction, project success is highly dependent on unforeseen risk factors, for example, weather conditions, labor productivity, site conditions including various project characteristics. Risk is a buzzword used in every industry. The word 'risk' originates from the French word 'risqué,' and became a widely used term in insurance transactions in the early 1800s (Smith 1999). In Webster's dictionary, 'risk' is defined as 'the possibility of loss, injury, disadvantage, or destruction.' Compared to uncertainty, risk is often considered as being where the outcome of an event can be examined and quantified statistically. In assessing risk, two different perspectives are involved. One is focused on the significance of an event, while the other is related to the frequency of that event. By measuring these two aspects of risk, any project can be effectively evaluated. These evaluations are regarded as valuable sources of information for decision makers (Jannadi and Almishari 2003). For the purpose of this study, 'risk' is defined as 'a possibility of any event which affects the overall performance of a project.' When it comes to performance, this study refers to the cost performance index (CPI) because it can be easily quantified by using the following equation (CII 2001).

$$\text{CPI} = \frac{\text{Actual Cost} - \text{Predicted Cost}}{\text{Predicted Cost}}$$ (1)

An extensive literature review was conducted to identify various risk factors. A variety of these factors were collected from diverse sources, including academic journals, conference proceedings, and technical reports. The authors tried to identify any types of influential factors that might impact the performance of a building project. These factors should be measurable in terms of the magnitude of the impact on performance of a particular project. Through a series of workshops and discussions, the authors picked out 49 project risk factors from over 60 candidate factors. The complete list of the 49 factors is provided in Table 1.

The finalized factors cover a wide range of risky circumstances that may result in cost overrun while executing building projects. A number of field managers and engineers also participated in the screening process. These factors are classified into seven categories. They include schedule, budget,
quality, safety, environmental, contractual, and management issues as follows.

A. Schedule issues (10 items): Risk factors that may directly or indirectly impact the schedule are included in this category. When these factors are disregarded in the project analysis, cost overruns will be inevitable.

B. Budget issues (13 items): Cost overrun may occur when prediction of cost performance is too optimistic. These items include factors that are directly related with cost estimation of a project, e.g., inflation, interest rate, and tax rate.

C. Quality issues (8 items): Needless to say, quality problems cause significant cost overruns in project execution. If a project manager fails to thoroughly investigate quality related items, cost performance can hardly be guaranteed.

D. Safety issues (3 items): When it comes to safety in the industry, both construction and operation issues should be considered. In this study, operation safety is out of consideration because construction safety is the major concern in building projects.

E. Environmental issues (5 items): Stricter regulations on environmental issues are common in modern building projects. In particular, noise, dust, and waste from construction sites may tremendously impact the cost performance of projects.

F. Contractual issues (6 items): From the contractors' perspective, subcontractors are a necessary evil. When there are contractual problems during project execution, cost performance cannot be achieved to a satisfactory level.

G. Managerial issues (4 items): Many researchers maintain that management practice is crucial in dealing with project performance. Timely and appropriate decision-making results in better cost performance.

3. Survey Results and Analysis
The identified risk factors were further investigated through an extensive industry survey. To expedite the survey, a simple questionnaire tool was developed (see Fig.1.). The tool is used to ascertain the relative importance of each factor based on the participants' perception. As seen in Fig.1., the tool has all the 49 factors along with seven selection options. Using this tool, the participants chose the most appropriate option for the impact level on cost performance (1: lowest, 2: low, 3: medium-low, 4: medium, 5: medium-high, 6: high, 7: highest). The total number of survey participants was 142 and their average work experience in the building industry amounted to more than 10 years. The survey was conducted from September 2005 to October 2005 and the respondents participated in the survey on a voluntary basis.

| Table 1. Project Risk Factors Affecting Cost Performance |
| ID | Risk Factor |
|----|-------------|
| A1 | The project has a serious labor shortage |
| A2 | Labor productivity is estimated to be below the industry average |
| A3 | There is no adequate subcontract management plan |
| A4 | There is a delay in procurement of materials |
| A5 | There is a delay in procurement of equipment |
| A6 | The site has the disadvantage of poor geological conditions |
| A7 | Local weather conditions are probably poor |
| A8 | Regulatory provisions cause a delay in construction |
| A9 | Design changes may occur frequently |
| A10 | Building technologies are selected improperly |
| B1 | National tax regulations are increasingly tight |
| B2 | Economic inflation may cause budget deficit |
| B3 | Interest rate causes budget deficit |
| B4 | Increase in the cost of raw materials is inflationary |
| B5 | Exchange rate fluctuation causes budget deficit |
| B6 | The damage in terms of material loss is severe |
| B7 | The unit labor cost may be accelerated |
| B8 | Equipment rental rates may be accelerated |
| B9 | Land acquisition rate is high |
| B10 | Civil appeals bring about monetary compensation |
| B11 | Construction claims and disputes may occur |
| B12 | There are errors and/or omissions in cost estimation |
| B13 | Payment is going to be delayed and reduced |
| C1 | There are design errors in construction engineering drawings |
| C2 | There is a difference between drawings and specifications |
| C3 | Drawings and construction documents are incomplete |
| C4 | Conformance of quality requirement is hard to satisfy |
| C5 | Non-conformance of quality caused by improper field inspections |
| C6 | Non-conformance of quality caused by misuse of materials/equipment |
| C7 | Compensation for defects due to unskilled labor |
| C8 | There are frequent construction errors and/or omissions |
| D1 | Inexperienced workers are exposed to unsafe and unhealthy conditions |
| D2 | Safety equipment and/or facilities are deficient |
| D3 | The safety training program is not rigorously maintained |
| E1 | There is a strong need to observe environmental laws and ordinances |
| E2 | Civil appeals caused by construction noise are likely to arise |
| E3 | Civil appeals caused by construction dust are likely to arise |
| E4 | Civil appeals caused by construction wastes are likely to arise |
| E5 | No proper natural disaster prevention strategy is provided |
| F1 | The contracting process is not systematic |
| F2 | Unfair terms are included in the contract conditions |
| F3 | Vague contract terms cause disputes |
| F4 | Site supervisor(s) are relatively inexperienced |
| F5 | Construction manager(s) are not fully qualified |
| F6 | Owner’s project manager(s) are not committed to the project |
| G1 | Well-established risk management is not provided |
| G2 | Unclear work scope and/or project definition |
| G3 | Deficit in site condition analysis |
| G4 | Schedule optimization is incomplete due to tight schedule |
It is noteworthy that this survey was targeted at domestic construction companies in South Korea. In Table 2., a profile of the survey participants is provided. The majority of the participants (39%) were from the top 10 Korean construction contractors. Responses from the owners of companies comprise 16.2% of the total number of participants. As building projects are related to many diverse disciplines, the survey data came from various areas of expertise, including estimation, planning, architectural, civil, mechanical, electrical and landscaping. Except for the factor "B1", the survey results showed that the identified factors were all found to have more than a "medium impact (4.0)" in affecting cost performance (see Table 3.). Tax rate increase (B1) is not regarded as an important factor in cost performance. As shown in Table 3., the highest ranked factor turned out to be "A8", which is related to regulatory provisions.

Table 3. Survey Results and Factor Weight

| Factor ID | Raw Data Mean | Standard Deviation | Normalized Mean | Normalized Range Value | Factor Weight |
|-----------|---------------|--------------------|-----------------|------------------------|---------------|
| A01       | 4.58          | 1.38               | -0.253          | 38                     | 0.0157        |
| A02       | 4.56          | 1.12               | -0.258          | 38                     | 0.0157        |
| A03       | 5.04          | 1.18               | 0.159           | 58                     | 0.0240        |
| A04       | 4.98          | 1.13               | 0.158           | 59                     | 0.0244        |
| A05       | 4.95          | 1.17               | 0.164           | 65                     | 0.0269        |
| A06       | 5.24          | 2.93               | 0.286           | 60                     | 0.0248        |
| A07       | 4.92          | 1.16               | 0.119           | 72                     | 0.0298        |
| A08       | 5.28          | 1.31               | 0.423           | 68                     | 0.0281        |
| A09       | 5.23          | 1.22               | 0.353           | 11                     | 0.0045        |
| A10       | 5.07          | 1.23               | 0.259           | 42                     | 0.0174        |
| B01       | 3.89          | 1.26               | -0.787          | 32                     | 0.0132        |
| B02       | 4.54          | 1.39               | -0.175          | 53                     | 0.0219        |
| B03       | 4.33          | 1.39               | -0.361          | 23                     | 0.0095        |
| B04       | 4.81          | 1.21               | 0.056           | 53                     | 0.0219        |
| B05       | 4.12          | 1.45               | -0.556          | 23                     | 0.0095        |
| B06       | 4.26          | 1.24               | -0.481          | 26                     | 0.0108        |
| B07       | 5.2           | 1.09               | 0.354           | 68                     | 0.0281        |
| B08       | 4.7           | 1.23               | -0.045          | 48                     | 0.0199        |
| B09       | 5.09          | 1.53               | 0.303           | 66                     | 0.0273        |
| B10       | 5.01          | 1.33               | 0.209           | 61                     | 0.0252        |
| B11       | 4.89          | 1.18               | 0.058           | 53                     | 0.0219        |
| B12       | 4.62          | 1.19               | -0.179          | 42                     | 0.0174        |
| B13       | 4.67          | 1.46               | 0.077           | 47                     | 0.0194        |
| C01       | 4.44          | 1.07               | -0.387          | 31                     | 0.0128        |
| C02       | 4.65          | 1.13               | -0.146          | 43                     | 0.0178        |
| C03       | 5.05          | 1.21               | 0.175           | 59                     | 0.0244        |
| C04       | 4.42          | 1.14               | -0.37           | 32                     | 0.0132        |
| C05       | 4.23          | 1.14               | -0.465          | 27                     | 0.0112        |
| C06       | 4.62          | 1.13               | -0.142          | 43                     | 0.0178        |
| C07       | 4.88          | 1.26               | 0.091           | 55                     | 0.0227        |
| C08       | 5.21          | 1.06               | 0.391           | 70                     | 0.0289        |
| D01       | 4.83          | 1.21               | 0.049           | 53                     | 0.0219        |
| D02       | 4.96          | 1.11               | 0.145           | 58                     | 0.0240        |
| D03       | 5.12          | 1.16               | 0.226           | 62                     | 0.0256        |
| E01       | 4.96          | 1.07               | 0.112           | 57                     | 0.0236        |
| E02       | 4.75          | 1.01               | -0.063          | 47                     | 0.0194        |
| E03       | 4.53          | 1.02               | -0.248          | 38                     | 0.0157        |
| E04       | 4.55          | 1.23               | -0.196          | 41                     | 0.0170        |
| E05       | 4.69          | 1.41               | -0.06           | 48                     | 0.0199        |
| F01       | 5.01          | 1.13               | 0.15            | 43                     | 0.0178        |
| F02       | 5.17          | 1.21               | 0.273           | 64                     | 0.0265        |
| F03       | 5.06          | 1.17               | 0.158           | 58                     | 0.0240        |
| F04       | 4.43          | 1.17               | -0.332          | 34                     | 0.0141        |
| F05       | 4.8           | 1.18               | 0.037           | 52                     | 0.0215        |
| F06       | 4.69          | 1.29               | -0.075          | 47                     | 0.0194        |
| G01       | 5.07          | 1.05               | 0.208           | 61                     | 0.0252        |
| G02       | 5.01          | 0.94               | 0.156           | 58                     | 0.0240        |
| G03       | 5.11          | 1.04               | 0.261           | 64                     | 0.0265        |
| G04       | 5.16          | 1.26               | 0.325           | 67                     | 0.0277        |

Since the objectives of project execution may be different between owners and contractors, there can be statistically different results between these two groups. The data set was divided into two groups and investigated to see whether there was any difference between them. Statistical tests were conducted using
The t-test results indicated that 8 factors had statistically different means. These factors are shown with both mean values and the corresponding p-values in Table 4. While owners are more sensitive to land fees (B9), potential claims and/or disputes (B11), safety issues concerning equipment/facilities (D2), and construction noise (E2), contractors consider that design changes (A9), biased contract terms (F2), vague contract terms (F3), and incomplete scope definition (G2) are much more important in cost performance. It can be concluded that the definition of cost performance is different between these two groups. Owners are more concerned about total project cost whilst contractors are mainly interested in construction cost.

It is also interesting to investigate whether the contractor size can make any difference in the survey results. The top 10 contractors' revenue is almost the same as that of the rest of the top 100 contractors put together. For the purpose of this study, the data was divided into two groups: top 10 ranked contractors versus others. Among the 49 risk factors, seven items which were identified as statistically significant are shown in Table 5. Compared to small-size contractors, large-size contractors consider all factors relatively less significant except for material delay (A4) and vague contract terms (F3).

### 4. Quantifying Project Risk Factors

Using the survey results, the authors quantified the magnitude of impact for each factor in order to diagnose a particular project in terms of future cost performance. The factors in this study are regarded as influence items which may trigger poor cost performance. On the assumption that these influence factors vary in terms of the magnitude of impact on a particular project, a unique methodology has been developed to effectively utilize the results of the survey. Analytical Hierarchy Process (AHP) is an effective tool in quantifying relative importance using a pair-wise comparison (Saaty 1980). However, the AHP method may not be applicable when there are too many factors to quantify and too many experts are involved in the weighting process. In this study, there are 49 factors and 142 experts involved in the data collection process. Furthermore, the raw scores are purely dependent on personal perceptions, where any biased opinions can be included in the surveying process. To minimize any possible personal biases, a normalizing technique has been adopted. Instead of using the raw data in the original format, each piece of data has been converted into a normalized one. This approach has been further validated through case studies, as described later. The normalizing factor weighting process passes through four steps:

1. Normalize each raw score ($X_{ij}$) using Eq. (2)
   \[
   S_{ij} = \frac{X_{ij} - m_i}{\sigma_i}
   \]  
   (2)
   where, $S_{ij}$= normalized score; $X_{ij}$= raw score; $m_i$ = mean of $i$th factor; $\sigma_i$ = standard deviation of $i$th factor.

2. Calculate normalized mean value ($M_i$) using Eq. (3)
   \[
   M_i = \frac{\sum_{j=1}^{N} S_{ij}}{N}
   \]  
   (3)
   where, $M_i$=normalized mean; $N$=no. of respondents.

3. Calculate range value ($R_i$) using Eq. (4)
   \[
   R_i = \text{Integer}[\frac{M_i - \text{Min}(M_j)}{\text{Max}(M_j) - \text{Min}(M_j)}]
   \]  
   (4)

4. Compute the factor weight ($W_i$) using Eq. (5)
   \[
   W_i = \frac{R_i}{\sum_{j=1}^{L} R_j}
   \]  
   (5)
   where, $R_i$=range value; $L$=no. of factors

Following these steps, all of the 49 factors have been effectively quantified in terms of relative impact in jeopardizing individual projects. The complete list of all factor weights is provided in Table 3.
is open to uncertain circumstances, i.e., project risk. It is very useful to provide guidance in evaluating the overall project risk because each project has its own characteristic factors. Just as a patient should be diagnosed thoroughly before being prescribed a course of treatment, so it is necessary to check a project's condition before the project is executed. In addition, when the performance of a project is precisely forecasted, the project stakeholders can implement a more detailed plan in a rigorous way. In this study, a new project risk assessment methodology is developed. Using the factor weights described in the previous section, a project risk score (PRS) can be computed by Eq. (6)

$$\text{PRS} = \sum_{i=1}^{49} (X_i \times W_i)$$

where, $X_i =$ degree of agreement of $i^{th}$ factor; $W_i =$ weight of $i^{th}$ factor.

The degree of agreement ($X_i$) is used as an indicator which determines how well a subject project is matched to the corresponding risk factor. This value ranges between 1 (lowest level) and 5 (highest level). The PRS is computed by summing up the weighted degree of agreement for each risk factor. It is assumed that a certain level of project cost performance can be evaluated by means of the level of agreement on the factors. For example, when a project is most likely to be open to labor scarcity, the project will be less successful in cost performance than normal projects. Therefore, the PRS is used as a meaningful measure in predicting the cost performance of a project by quantifying the comprehensive level of project risk.

To expedite the assessment process, a computerized tool has been developed. The tool is graphically user-friendly and designed using the Microsoft Excel™ Visual Basic Application software as depicted in Figs. 2. and 3.

6. Predicting Cost Performance Using Regression Model

To verify the power of the relationship between the two quantified metrics, i.e., cost performance and PRS, a linear regression model was developed. Expansive data collection for this validation is relatively difficult because it takes a long time to obtain a projects' final cost performance. In addition, in order to compute the PRS, the 49 factors should be evaluated in terms of whether they are well matched with the already completed project. For the purpose of this study, the participants were requested to evaluate the target project on the assumption that they had been evaluating it at the beginning of the project stage. The data collection was executed by project practitioners who have experience of the particular type of project they were asked to assess and their cost data was obtained based on real performance. Fifteen paired-data sets were collected from this process. However, two projects were eliminated from the analysis because they experienced significant design changes without reimbursement of the costs. In these cases, the risk score is not appropriate and the score does not properly show the project risk.

In Table 6., the 13 volunteered projects are provided with the cost performance, risk score, building type, project size, and contract type. Note that the cost
The performance is computed using the Eq. (1). The results of the regression analysis for cost performance are provided in Fig. 4. The correlation coefficient of the model was 0.72 with a $P$ value of 0.0059. The coefficient of determination ($R^2$) for the regression model was 0.5133. This result indicates that the model can explain 51% of the variations in the cost performance levels with PRS. Using the model, the cost performance can be predicted using the following form.

$$\text{Cost Performance} = 48.7107 + 16.8962 \times \text{PRS}$$ (7)

As shown in Fig. 4., the $P$ values of the two coefficients are 0.0089 and 0.0059 respectively. Although the sample size is not sufficiently large to draw a meaningful conclusion, this model could effectively provide industry guidance in predicting cost performance level in association with a project risk profile.

### 7. Conclusions and Recommendations

Risk has been a great concern in the construction industry. As many researchers maintain, risk is dependent on the timing of a project. Since it is impossible to evaluate every single project risk at an early stage, there has not been a conclusive method in evaluating the target project in terms of potential project risks. As a project's characteristic factors play an important role in assessing an individual project, the identification of these factors is regarded as a crucial step in risk management. This study identified a set of project risk factors from an extensive literature review and expert interviews in order to effectively assess potential project performance.

The purpose of this paper was to develop a new methodology in order to create a risk-based estimate tool incorporating extensive project risk factors. To do this, an extensive industry survey was conducted in both the private and public sectors of the building industry in South Korea. Throughout the survey, significant project characteristics were identified. In addition, their relative impacts on cost performance were quantified and validated using real case studies. Although the data collection was limited to Korean companies, the proposed assessment approach provides the industry with a straightforward tool for effectively quantifying a particular project in terms of project risk.

Although the proposed model was validated using only a limited number of building projects, the industry still benefits from the authors' work in many ways. First of all, the computerized tool is useful for practitioners to evaluate the target project in a systematic way. Secondly, the result of the tool, i.e., the PRS is conclusive so that a decision maker can analyze the project from diverse perspectives. Thirdly, the alignment of project participants can be easily achieved during the assessment process.

Predicting cost performance is not simple. It is dependent on numerous factors, not only factors innate to the project, but also project-independent circumstances, i.e. project delivery system, bureaucratic policy, and administrative regulations. Therefore, the project stakeholders should scrutinize a project from various perspectives. This study can give robust guidance in assessing a particular project in order to obtain a realistic estimate for the level of cost performance in advance.

In summary, front-end planning efforts are crucial to achieving a successful outcome in the construction industry. Risk-based performance prediction can improve early stage project plans and enhance the probability of creating a sustainable business in a challenging environment.

### Acknowledgement

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (2011-0003179).
References

1) Albright, S. C. Winston W., and Zpaae, C. J. (2003) Data Analysis & Decision Making, Thomson, Pacific Grove, CA.

2) Barrie, D. S. and Paulson, B. C. (1992) Professional Construction Management, McGraw-Hill, New York.

3) Cha, H., and O'Connor, J. T. (2005). "Optimizing Implementation of Value Management Processes for Capital Projects," J. Constr. Engrg. and Mgmt, ASCE, 131(2), pp.239-251.

4) Choi, H., Cho, H., and Seo, J. W. (2004) "Risk Assessment Methodology for Underground Construction Projects," J. of Constr. Engr. And Mgmt, ASCE, 130(2).

5) Construction Industry Institute (CII) (1999). PDRI: Project Definition Rate Index for Building Project, Implementation Resource 155-2, CII, Austin, Texas.

6) Construction Industry Institute (CII) (2001). CII Benchmarking and Metrics Data Report 2001, CII, Austin, Tex.

7) Engineering News Record (ENR) (2007), "The Top 400 Contractors," Engineering News Records May 22/29, 2007, pp.42-79.

8) Hsueh, S., Perng, Y., Yan, M., and Lee, J. (2007) "On-line multi-criterion risk assessment model for construction joint venture in China," Automation in Construction 16(2007).

9) Jannadi, O. A., and Almishari, S. (2003). "Risk Assessment in Construction," J. Constr. Engrg. and Mgmt, ASCE, 129(5), pp.492-500.

10) Moussa, M., Ruwanpupra, J. and Jergears, G. (2007) "CTAN for Risk Assessments Using Multilevel Stochastic Networks," J. of Constr. Engrg. And Mgmt, ASCE, 133(1).

11) Saaty, T. L. (1980) The Analytic Hierarchy Process, McGraw Hill, NY.

12) Smith, N. J. (1999). Managing Risk in Construction Projects, Blackwell Science, Oxford, UK.

13) Wang, Y. (2002), Applying the PDRI in Project Risk Management, Ph.D. Dissertation, the University of Texas at Austin.