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Estimating the Probability of Distress for Capital Projects

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Abstract. Identifying the key determinants of project performance is important. However, few studies examine discriminatory power of variables for estimating distressed capital projects. Thus, this longitudinal study of 72 capital projects identifies key variables in the initiation and planning phases of projects that differentiate between healthy and distressed projects at completion. We develop a project-outcome estimating model that demonstrates an overall classification rate of 83.3%. Our research results suggest that it is feasible to discriminate simultaneously between healthy and distressed projects prior to the project execution phase.

Keywords: Project Management, Distressed Projects, Performance Assessment.

1. Introduction

Successful project management depends on identifying the critical determinants of success (Scott-Young and Samson, 2008) to engineer critical issues scientifically during execution. Not surprisingly, researchers and professional associations (e.g., Anand et al., 2010; Schwab and Anne, 2008; Hoang and Rothaermel, 2005; Song et al., 2007; Hoegl and Gemuenden, 2001; Hoegl *et al.*, 2003) conduct extensive studies to examine and identify these key determinants of project outcomes.

For example, Hoegl and Gemuenden (2001) and Hoegl *et al.* (2003) use regression analysis to examine the effects of teamwork quality on project performance. Based on data from 145 projects in four software development organizations, they conclude that teamwork quality is associated with the outcomes of projects posing high task innovativeness.

Hoang and Rothaermel (2005) use binary logistic analysis to examine the outcomes of 158 joint R&D projects in 43 pharmaceutical firms. They claim that the general alliance experience of biotechnology partners, but not of pharmaceutical firms, positively affects joint project outcomes.

Song *et al.* (2007) conclude that initial planning conditions and the effectiveness of front-end planning management affect how well R&D plans and the later R&D process perform based on two R&D projects. Similarly, Schwab and Anne (2008) examine 239 U.S. movie projects from 1931 to 1940 and determine, using regression analysis, that project outcome depends on the perceived relevance of prior performance and on organizational control over project participants.

Recently, Anand *et al.* (2010) analyze 98 projects in five companies using hierarchical regression. They show that the inclusion of softer, people-oriented practices for capturing tacit knowledge explains a significant amount of variance in project outcomes. More recently, Calamel et al. (2012) examine two collaborative R&D projects in a large global innovation cluster in France. They conclude that team collaboration is important factor in project performance.

Although many studies use a wide variety of measures to describe project outcomes and the input characteristics that affect those outcomes, most studies emphasize the project-execution phase (e.g., Baiden et al., 2006) or the overall project life cycle (e.g., Duffy and Thomas, 1989; Ling *et al.*, 2009).

Further, most studies identify the critical determinants of project performance using contemporaneous data (e.g., Anand et al., 2010; Duffy and Thomas, 1989; Ling *et al.*, 2009). As a result, there appears to be a lack of research using longitudinal experiments to develop forecasting models that are able to estimate the outcomes of capital projects prior to the project execution phase. (The capital projects industry includes both

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the delivery and the maintenance of facilities (e.g., commercial and institutional, industrial, residential buildings, transportation, energy, water and sewage, and communication systems). Our focus is on the delivery process of capital projects, e.g., from the initiating to closing phases of projects.)

2. Research Methodology

2.1. The data

The survey instrument was designed based on a detailed examination of literature in the project-management and organization-theory, fields, and consultation with several experienced researchers and practitioners. In particular, prior to the data collection, a panel of experts from Taiwan's Chinese National Association of General Contractors (CNAGC) critiqued the questionnaire for structure, readability, clarity, and completeness. Based on the feedback from these experts, the survey instrument was then modified to strengthen its validity.

The final version of the survey questionnaire comprises two sections. The first section, composed of open-ended questions, gathers detailed background information such as annual revenue; project type; project cost including contract price, budget, contract price for project changes, and actual cost; and the project schedule including the contract schedule, scheduled time, contract schedule for project change, and actual schedule.

Section two consists of multiple-choice questions in which respondents indicate on a 9-point Likert scale the extent to which certain project variables likely affect project performance. (If not otherwise indicated, all measures use a scale in which 1 means "strongly disagree" and 9 means "strongly agree." High scores suggest good performance; low scores indicate poor performance.)

Data collection occurred in two stages and lasted two years. In the first stage, immediately after the end of a project's initiation and planning stages, participants respond to the portion of the questionnaire that excludes questions regarding project actual cost, project actual schedule, contract price and schedule for project changes, and actual cost and schedule for project changes. In the second stage, right after the close of the capital project, participants respond to the all the questions included in stage one.

All the data were collected from 72 capital projects, which fall into four categories: buildings (20 projects), transportation facilities (14 projects), environmental facilities (12), and industrial facilities (26 projects). Project managers average between one and 25 years of experience; 31 participants had fewer than five years of experience; 18 had between five and 10 years; 17 had between 10 and 20 years; and six participants had over 20 years of experience.

2.2. Measures and analysis

This study chooses project time, cost, and profitability as the criteria for capital-project outcomes (healthy versus distressed). (Our dependent variable, *Project Outcome*, is binary, with 0, healthy, indicating that a capital project finishes within budget and scheduled time frame and makes a profit; otherwise, it is 1, distressed.) Measurements of project performance prior to project execution (including the *Communication*, *Team*, *Scope*, *Innovation*, *Risk*, *Quality*, and *Materials* variables) are based on a detailed examination of literature in project management, and organization theory; consultation with several experienced researchers; and consultation with a panel of experts from Taiwan's Chinese National Association of General Contractors (CNAGC). The measurements are similar to the project-performance measures most project-contracting organizations use to assess performance during the overall project life cycle.

Communication (α = 0.960) is measured according to a nine-item scale based on the representative studies, including Anand *et al.* (2010), and Duffy and Thomas (1989). The sample items are "Co1: The project team identifies all the key stakeholders of the project," "Co2: The project team meets the communications needs of the stakeholders," Co3: The project team meets the information needs of the stakeholders," and "Co9: Communication within project team members is effective."

Team (α = 0.962) is measured according to a 10-item scale based on the representative studies, including Song *et al.* (2007), and Hoegl and Gemuenden (2001). Sample items are "Te2: Enthusiasm about project success is high," "Te5: The cooperation of the project team can be regarded as successful," and "Te8: The interpersonal relationship in the project team is good."

Scope (α = 0.932) is measured according to a five-item scale based on the representative studies, including Ling *et al.* (2009), and Hoang and Rothaermel (2005). Sample items are "Sc1: The scope of project is well defined," "Sc4: Work breakdown structure (WBS) of the project is well defined and manageable," and "Sc5: Quality of the control system for scope change is good."

Innovation (α = 0.975) is measured according to a 19-item scale based on the representative studies, including Anand *et al.* (2010), Duffy and Thomas (1989), and Song *et al.* (2007). Sample items are "Inno12: Our company seeks to remain on the leading edge of new project practices and technologies in the industry," "Inno13: We always evaluate the potential of using new project practices and technologies," and "Inno15: We are continuously thinking of the next generation of project technology."

Risk (α = 0.956) is measured according to a 13-item scale based on the representative studies, including Hoegl et al. (2003), and Zou *et al.* (2007). Sample items "Ri1: Project team handles inflation and sudden changes in prices well," "Ri10: Extent of implementation of safety management on the project construction sites is good," and "Ri13: We provide personal protective equipment to project team and workers."

Quality (α = 0.951) is measured according to an 11-item scale based on the representative studies, including Ling *et al.* (2009), and Hoang and Rothaermel (2005). Sample items include "Qu6: The project team re-evaluates quality standards on a regular basis," "Qu7: The project team performs quality audits on a regular basis," and "Qu9: The project team has a working knowledge of the tools and techniques used for Quality Control."

Materials (α = 0.941) is measured according to a four-item scale based on the representative studies, including Hoegl and Gemuenden (2001), and Zou *et al.* (2007). Sample items "Ma1: Material management plan clearly describes how materials will be managed and executed," "Ma2: Project team effectively keeps a record of material usage and inventory," and "Ma3: The supervision of project team in receiving and delivering materials on sites is well maintained."

The methodology to construct optimal project-outcome forecasting models is by conducting a hierarchical logistic-regression analysis using a maximum Nagelkerke R-squared improvement procedure. We evaluate the estimating accuracy of the models using Type I errors (i.e., a healthy project misclassified as a distressed project), Type II errors (i.e., a distressed project misclassified as a healthy project), and overall correct classification rates.

3. Research Results

3.1. The model

Based on the longitudinal data collected by this study, we conducted a hierarchical logistic-regression analysis using a maximum Nagelkerke R-squared improvement procedure to develop optimal project-outcome prediction models. The final optimal project-outcome forecasting model is the one with the *Scope*, *Quality*, *Team*, *Communication*, *Risk*, *Materials*, and *Innovation* variables, where Nagelkerke R-Squared is 0.792, suggesting that 79.2% of the variation in the sample data is explained. This project-outcome forecasting model is summarized as the following:

$$P(Disress) = \beta_0 + \beta_s Scope + \beta_Q Quality + \beta_T Team + \beta_C Communication + \beta_R Risk + \beta_M Materials + \beta_I Innovation \qquad (1)$$

where

P(Distress) = the odds of project in distress
Scope = scope performance measured by *Sc1*, *Sc4*, and *Sc5*[1]
Quality = quality performance measured by *Qu6*, *Qu7*, and *Qu9*[2]

[1] "*Sc1*: The scope of project is well defined," "*Sc4*: Work breakdown structure (WBS) of the project is well defined and manageable," and "*Sc5*: Quality of the control system for scope change is good."
[2] "*Qu6*: The project team re-evaluates quality standards on a regular basis," "*Qu7*: The project team performs quality audits on a regular basis," and "*Qu9*: The project team has a working knowledge of the tools and techniques used for Quality Control."

Team = team performance measured by *Te2*, *Te5*, and *Te8*[3]
Communication = communication performance measured by *Co1*, *Co2*, *Co3*, and *Co9*[4]
Risk = risk performance measured by *Ri1*, *Ri10*, and *Ri13*[5]
Materials = materials performance measured by *Ma1*, *Ma2*, and *Ma3*[6]
Innovation = innovation performance measured by *Inno7*, *Inno8*, *Inno9*, *Inno12*, *Inno13*, and *Inno15*[7]

3.2. Validation of the model

Type I errors (i.e., a healthy project misclassified as a distressed project), Type II errors (i.e., a distressed project misclassified as a healthy project), and overall correct classification rates evaluate forecasting accuracy using the sample data collected from the 72 capital projects during the project-initiation and planning phases. Table I reports the forecasting results of our project-outcome prediction model.

Table I: Forecasts by the Optimal Project-Outcome Prediction Model Using the Sample Data from the Project-Initiation and Planning Phases

	Predicted Results		
	Project Outcomes		
Variables	Healthy (0)	Distressed (1)	Percentage Correct
Healthy (0)	16	7	69.6 (Type I error = 100 - 69.6 = 30.4)
Distressed (1)	5	44	89.8 (Type I error = 100 – 89.9 = 10.2)
Overall Percentage			83.3

As seen in the table, the respective average Type I error, Type II error, and correct classifications of the sample data are 30.4%, 10.2%, and 83.3.3%. The relatively high classification rates for the sample data suggest that the project-outcome prediction model based on *Scope*, *Quality*, *Team*, *Communication*, *Risk*, *Materials*, and *Innovation* is viable and practical.

In order to further assess the measurement model of our project-outcome prediction model, we use confirmatory factor analysis (CFA). We use the maximum likelihood (ML) method for estimation because the absolute values of the kurtosis indices are all smaller than 2.5, indicating that the data are normally distributed (Harrington, 2008). The analysis results of the measurement-theory model suggest an adequate fit with the data. The model chi-square (χ^2)/degrees of freedom = 1.816, which is smaller than the threshold value of 2.000 suggested by Kline (2010); CFI = 0.955 and TLI = 0.934 are both higher than the threshold value of 0.900 suggested by Harrington (2008); and the root mean square error of approximation (RMSEA) = 0.080 does not exceed the threshold value of 0.080 (Kline, 2010).

4. Conclusion

Our research investigates the relationship between project outcomes and performance variables in the project-initiation and planning phases. A multivariate logit prediction model (see equation 1) on the

[3] "*Te2*: Enthusiasm about project success is high," "*Te5*: The cooperation of the project team can be regarded as successful," and "*Te8*: The interpersonal relationship in the project team is good."

[4] "*Co1*: The project team identifies all the key stakeholders of the project," "*Co2*: The project team meets the communications needs of the stakeholders," *Co3*: The project team meets the information needs of the stakeholders," and "*Co9*: Communication within project team members is effective."

[5] "*Ri1*: Project team handles inflation and sudden changes in prices well," "*Ri10*: Extent of implementation of safety management on the project construction sites is good," and "*Ri13*: We provide personal protective equipment to project team and workers."

[6] "*Ma1*: Material management plan clearly describes how materials will be managed and executed," "*Ma2*: Project team effectively keeps a record of material usage and inventory," and "*Ma3*: The supervision of project team in receiving and delivering materials on sites is well maintained."

[7] "*Inno7*: We provide time and resources team members to generate and experiment innovative ideas/solutions," "*Inno8*: Project members work in diversely skilled work groups where free and open communication exists among the group members," "Inno9: Cognitive conflict among project team members is moderately high," "*Inno12*: Our company seeks to remain on the leading edge of new project practices and technologies in the industry," "*Inno13*: We always evaluate the potential of using new project practices and technologies," and "*Inno15*: We are continuously thinking of the next generation of project technology."

longitudinal data of the performance variables demonstrates that a combination of *Scope*, *Quality*, *Team*, *Communication*, *Risk*, *Materials*, and *Innovation* variables provides a high overall classification rate of 83.3.3%.

Our findings regarding the importance of *Communication*, *Team*, *Scope*, *Innovation*, *Risk*, *Quality*, and *Materials* are consistent with prior studies based on the project-execution phase (e.g., Hoegl et al., 2003; Tabassi and Bakar 2009; Wang *et al.* 2005) and the overall project life cycle (e.g., e.g., Duffy and Thomas, 1989; Ling et al., 2009). The present research extends the state of knowledge concerning the predictive power of these variables during the successive phases before capital projects become distressed. As an extension of this research in this study, a broader evaluation of these variables that includes NPD and R&D projects will provide management a comprehensive picture of how the predictive power of these variables varies in response to project financial performance (profitability, cost, and time) under different types of projects.

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