INFLUENCES OF EARLY-STAGE PROJECT VARIABLES ON PROJECT PERFORMANCE

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Abstract - This longitudinal study of 128 projects shows that project stimulants affects project capacity in the initiation and planning phases, which in return influences project outcomes in the closing phase. Subsequent structural equation modeling shows that risk has the second-largest effect on project outcomes, communication possesses the largest positive effect on project outcomes, despite having no direct link between them. Ultimately, our findings suggest that it is feasible to estimate the impacts of early-stage project variables on project outcomes prior to project execution.

Index Terms - Project management, Project performance, Structural analysis, Longitudinal research.

I. INTRODUCTION

An important task in the project-management study is to examine and identify the critical determinants of project-management performance [1], [2]. Not surprisingly, extensive research in the field of project management has examined and identified a broad variety of measures to delineate project-management performance and the input characteristics that affect project performance [3]-[7]. For example, using data from 56 capital projects in 15 process-industry companies, [7] examine the impact of organizational context, team design, team leadership, and team process factors on project performance using factor analysis and regression analysis. Their results show that these factors are significant determinants of project outcomes. Reference [8] analyzed 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. Reference [9] use hierarchical regression analysis to examine how negative emotions and affective commitment due to project failure affect the performance of subsequent projects. Based on data from 257 research scientists about project teams in 12 different German research institutes, emotions as outcomes may influence emotions as inputs for subsequent projects; that is, the negative emotions of past project failures create an affective commitment to the organization. Using a qualitative field study of drug-development teams in a pharmaceutical firm, [10] analyzes how project teams change their routines based on prior experience with other project teams. Reference [10] then incorporates four distinct subprocesses (identification, translation, adoption, and continuation) into a process model. Reference [11] use the Multiple Regression Quadratic Assignment Procedure (MRQAP) to examine the influence of trust in project teams on innovation performance and conclude that project team trust affects innovation performance. Recently, [12] investigate how goal orientations, leader-leader exchange, and trust influence project outcomes. Based on a cross-sectional analysis of 320 auditing project managers from 50 financial service companies, they demonstrate that leader-leader exchange and trust mediate how goal orientations influence project performance. Reference [12] also find that trust further moderates the effect of leader-leader exchange on project outcomes. Despite the panoply of studies that examine and identify the key determinants of project performance, most studies [9], [13]-[17] focus on describing project performance and the input characteristics that affect the performance. Although some studies [18]-[20] explore relationships among project-management performance variables, and thus with project outcomes. Their treatments, however, are comtemporaneously designed in nature. Consequently, there appears to be a lack of research using longitudinal designs to examine how project-management performnace variables affect one another in the project-initiation and planning phases and, thus, project outcomes in the closing phase.

II. RESEARCH HYPOTHESES

To examine how project-management performnace variables affect one another in the project-initiation and planning phases and, therefore, project outcomes in the closing phase, we propose a research model (Fig. 1) consisting of six performance dimensions. Central to the model is the idea that project stimulants affect project capacity in the initiation and planning phases, which in turn has a direct impact on project outcomes in the closing phase. Constructs of project-management performance regarding project stimulants that concern project leadership, project team building, project communication, and culture are Team and Communication. Those concerning project capacity that relates to the accumulation of project technologies and creativity as well as the capability of

project integration, scope and risk are Innovation, Risk, and Scope.

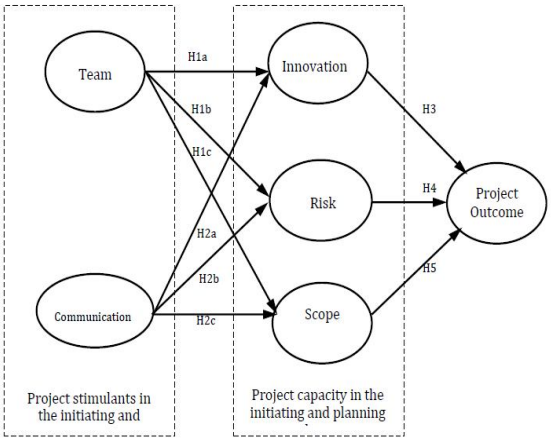


Fig. 1 Research model

Studies have long recognized team quality as a critical factor in overall organizational performance [1], [15], [21], [22]. For example, [23] use systematic case research to examine published studies and conclude that the decision-making process of teams has a fundamental effect on the quality of risk-management performance. Reference [24] use regression analysis and a sample of 562 program participants to examine the impacts of training programs on project management. They find a strong relationship between the degree of collaboration of the project team and its ability to decompose work scope into manageable and verifiable components. Subsequent work by [25] uses regression analysis to examine the relationships between team reflexivity and innovation performance. Based on a sample of 98 primary health care teams in the United Kingdom, they conclude that increases in work quality at the team level positively affect innovation performance. We therefore propose the following hypotheses:

Hypothesis 1a: Team has a direct positive effect on Innovation performance in the initiation and planning phases of capital projects.

Hypothesis 1b: Team has a direct positive effect on Risk performance in the initiation and planning phases of capital projects.

Hypothesis 1c: Team has a direct positive effect on Scope performance in the initiation and planning phases of capital projects.

In particular, a project involving a number of specialists performing related activities to achieve a goal requires communication among the specialists [26]. Not surprisingly, prior research [27]-[29] concludes that communication boosts knowledge sharing, which in return would influence project performance. For example, [17] examine 33 capital projects in China and conclude, using Pearson's correlation analysis, that 24 project-management practices (such as effective communication and high customer satisfaction) are significantly correlated with project performance. Reference [30] examines 60 U.S. technology-driven projects and suggests, using regression analysis, that emphasizing equality, open communication, and cooperation among team members improves project-management practices. Thus, we propose the following hypotheses:

Hypothesis 2a: Communication has a direct positive effect on Innovation performance in the initiation and planning phases of capital projects.

Hypothesis 2b: Communication has a direct positive effect on Risk performance in the initiation and planning phases of capital projects.

Hypothesis 2c: Communication has a direct positive effect on Scope performance in the initiation and planning phases of capital projects.

Further, whilst the relationships between innovation, risk, scope and project performance have drawn much research attention in recent years, several studies show that better management of innovation, risk and scope increases the chances of project success [6], [31], [32]. For example, based on five case studies in the automotive industry, [33] conclude that a significant interplay exists between project performance and innovation management.

Based on data from 18 interviews and 80 surveys with R&D project managers and officers in the pharmaceutical-biotechnology industry, [34] show that innovative capability increases innovation, which in return improves short- and long-term project performance. Subsequent work by [35] examines four incubated technology-based firms to assess risk factors using case study research and concludes that an ambiguous project scope and unclear project goals are the primary risk factors for project success.

In particular, the Project Management Institute (PMI) and the Association of Project Management (APM) include scope and risk management practices as the key disciplines of project management. Hence, we hypothesize:

Hypothesis 3: Innovation performance in the initiation and planning phases has a direct positive effect on capital-project outcomes.

Hypothesis 4: Risk performance in the initiation and planning phases has a direct positive effect on capital-project outcomes.

Hypothesis 5: Scope performance in the initiation and planning phases has a direct positive effect on capital-project outcomes.

III. RESEARCH METHODOLOGY

A. Participants and Procedure

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 5-point Likert scale the extent to which certain project variables likely affect project 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 questions excluded in stage one. Of the 600 members of Taiwan's Chinese National Association of General Contractors (CNAGC) that we randomly selected and invited to participate in this research, 128 companies participated—a 21.33 % response rate. Each of the 128 companies in the sample had assigned a project manager who had just completed the initiation and planning of a capital project scheduled to finish within the next two years. The 128 capital projects fall into three categories: buildings (71 projects), transportation facilities (26 projects), and industrial facilities (31 projects).

B. Measures and Analysis

Communication (Cronbach's Alpha = 0.95) is measured according to a six-item scale based on the representative studies, including [6], [17], [21], [36]. Sample items are "C1: The project team identifies all the key stakeholders of the project," and "C4: Technology use in information-sharing is high."

Team (Cronbach's Alpha = 0.97) is measured according to a 12-item scale based on the representative studies, including [7], [8], [15], [17], [21], [37], [38]. Sample items are "T1: Top management support for the project team is high," and "T4: Degree of cohesiveness of the project team is high." Innovation (Cronbach's Alpha = 0.96) is measured according to a 10-item scale based on the representative studies, including [16], [31], [32], [37], [39]. Sample items are "I1: Management support for innovation is high," and "I4: Extent of elaborating information processing and coordination mechanisms within/across the project is high." Risk (Cronbach's Alpha = 0.94) is measured according to a seven-item scale based on the representative studies, including [4], [40], [41]. Sample items include "R1: Project team handles customer design changes well," and "R4: Project team handles delays in resolving contractual issues well." Scope (Cronbach's Alpha = 0.97) is measured according to a five-item scale based on the representative studies, including [17], [42], [43]. The four items are "S1: Quality of contract documents including project definitions, legal terms, specifications, design instructions, and implementation processes is good," "S2: Project owner defines project scope well," and "S4: Budget, schedule and work breakdown structure (WBS) of the project are well defined and manageable." The data from the closing phase measures capital-project outcomes (Cronbach's Alpha = 0.77) using a four-item scale based on [44], [45]. Sample items are "PO1: All things considered, the project owner feels satisfied when we talk about the project outcome," and "PO2: Quality of the project meets the contract requirements and customer's expectations." Finally, this study uses structural equation modeling (SEM) [46], [47] to test our hypotheses and, thus, estimates the impacts of performance constructs on capital-project outcomes.

IV. RESEARCH RESULTS

We test the hypothesized model (Fig. 1) using SEM [48], [49]. The model-fit indices suggest that the model fits the data adequately, where the model chi-square (χ^2)/degrees of freedom = 1.753, CFI = 0.9591, TLI = 0.949, RMSR = 0.034, and RMSEA = 0.077. This insignificant change in the relative χ^2 from 1.809 to 1.753 is strongly suggestive of model validity [48].

Fig. 2 presents the results of the nine hypothesized relationships (Hypotheses 1a to 5) among the study hypotheses tests. Of the nine, four are significant at the constructs. Table 1 summarizes the results of the 0.001 level, three are significant at the 0.050 level, and two are mildly significant at the 0.100 level. Hypotheses 1a to 1c, which infer that team performance has a direct positive impact on innovation, risk and scope performance, are significant at the 0.100, 0.001, and 0.050 levels, respectively. The coefficients of paths linking Team to Innovation, Risk, and Scope are 0.21, 0.37, and 0.29, respectively. Parameter estimates using the ML method Innovation, Risk, and Scope are 0.21, 0.37, and 0.29, respectively. Parameter estimates using the ML method find the total combined effect of Team through Innovation, Risk, and Scope on Project Outcomes is 0.30, as shown in Table 2. Hypotheses 2a to 2c infer that communication performance has a direct positive impact on the innovation, risk, and scope performance of a capital project. We find all the connections significant at the 0.001. The respective coefficients of the paths linking Communication to Innovation, Risk, and Scope are 0.67, 0.58, and 0.65. Parameter estimates using the ML method (Table 5) find the total combined effect of Communication through Innovation, Risk, and Scope on Project Outcomes is 0.62. Tests of hypotheses 3 to 5 find that innovation affects project outcomes (mildly significant at the 0.100 level), risk affects project

outcomes (significant at the 0.050 level), and scope affect project outcomes (significant at the 0.050 level). The corresponding coefficients of paths linking Innovation, Risk, and Scope to Project Outcomes are 0.20, 0.42, and 0.38. Namely, Innovation has a direct positive effect of 0.20 on Project Outcomes. Likewise, Risk on Project Outcomes is 0.42, and Scope on Project Outcomes is 0.38.

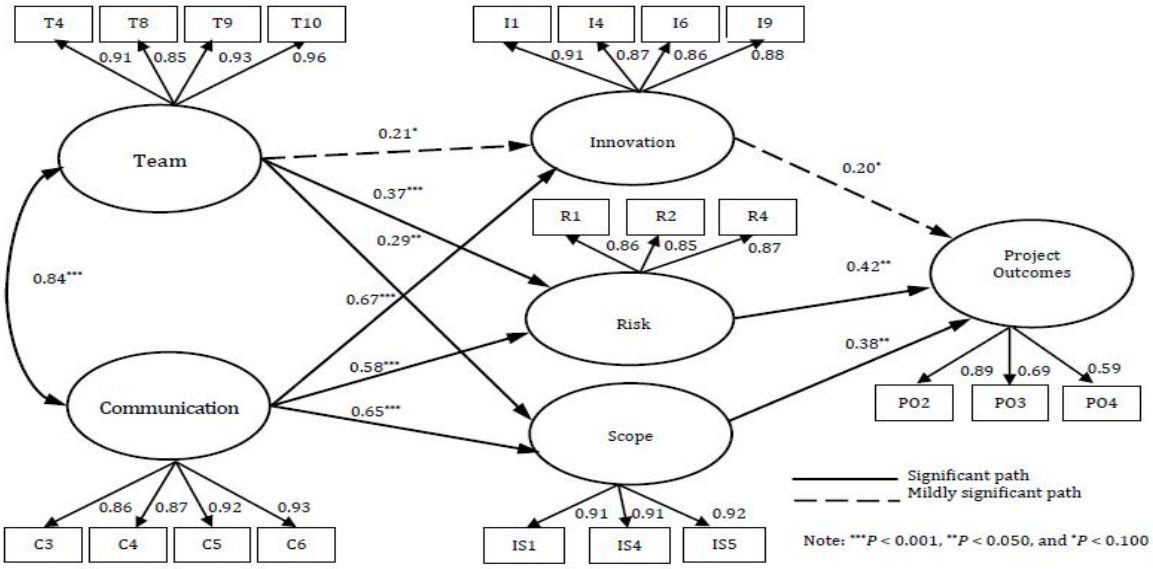


Fig. 2 Early-stage project-management performance's effects on project outcomes

Table 1: Summary of hypothesis test results

Hypothesized Path	Standardized Path Coefficient	Result
H1a: Team → (+) Innovation	0.21^{*}	Mildly Supported
H1b: Team → (+) Risk	0.37^{***}	Supported
H1c: Team → (+) Scope	0.29^{**}	Supported
H2a: Communication → (+) Innovation	0.67^{***}	Supported
H2b: Communication → (+) Risk	0.58^{***}	Supported
H2c: Communication → (+) Scope	0.65^{***}	Supported
H3: Innovation → (+) Project Outcomes	0.20^{*}	Mildly Supported
H4: Risk → (+) Project Outcomes	0.42^{**}	Supported
H5: Scope → (+) Project Outcomes	0.38^{**}	Supported

Note: ***P < 0.001, **P < 0.050, and *P < 0.100

DISCUSSION AND CONCLUSION

Our findings regarding the important impacts of Communication, Team, Innovation, Risk, Scope on Project

Table 2: Direct, indirect and total cause-effects

Variable	Communication			Team			Innovation			Risk			Scope		
	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE
Innovation	0.67		0.67	0.21		0.21									
Risk	0.58		0.58	0.37		0.37									
Scope	0.65		0.65	0.29		0.29									
Project Outcomes		0.62	0.62		0.30	0.30	0.20		0.20	0.42		0.42	0.38		0.38

Notes: DE = Direct effect, IE = Indirect effect, and TE = Total effect.

Outcomes are consistent with prior studies of the project-execution phase [15], [16], [39] and the overall project life cycle [3], [22], [23]. The present study extends the state of knowledge of how project stimulants affect project capacity and, hence, project outcomes. Specifically, previous studies [9], [13], [14], [17], [18] focus on describing project performance and the input characteristics that affect the performance. Few investigate how communication and team performance (project stimulants) affects innovation,

risk, and scope performance (project capacity) in the initiation and planning phases, which in return influences project outcomes in the closing phase. In the initiating and planning phases of a capital project, for example (see the TE column in Table 5), a 1% performance increase in Communication results in 0.67%, 0.58%, and 0.65% performance increase in Innovation, Risk, and Scope, respectively, producing a 0.62% increase in Project Outcomes in the closing phase. Likewise, a 1% performance increase in Team results in 0.21%, 0.37%, and 0.29% performance increase in Innovation, Risk, and Scope, respectively, generating a 0.30% increase in Project Outcomes.
Further, a 1% performance increase in Innovation, Risk, and Scope creates 0.20%, 0.42%, and 0.38% increase in Project Outcomes, respectively, where Risk has the highest direct effect among the variables. In particular, Communication possesses the highest total effect of 0.62, despite having no direct effect on Project Outcomes. This suggests that the project-performance chain may generate synergistic interaction effects that magnify the overall effects on the outcome variables.

Tests of hypotheses 1a and 3 reveal that team and innovation have mildly significant impacts on innovation performance and project outcomes, respectively. These results are somewhat unexpected, because the general perception in the reviewed literature suggests that people-management performance affects innovation performance, and project outcomes are significantly subject to innovation performance. One possible explanation of team performance's mildly significant effect on innovation is that item scales ultimately retained for the Team construct are more relative to team-unity perspective, such as degree of cohesiveness and degree of team-building. In addition, previous project-performance studies ask survey respondents to directly indicate on Likert scales to which performance levels of project cost and time are in the closing phase. Thus, one possible explanation of innovation's mildly significant effect on project outcomes is that a perception gap exists between how respondents feel the levels of cost and time performance are versus which levels of cost and time performance actually are. Another explanation may be that although innovation is an important factor of project performance for new product development (NPD) and research and development (R&D) projects, it might be less critical to conventional industries, such as the capital projects industry. Nonetheless, more research is needed to further clarify the mildly significant impacts of team and innovation on innovation and project outcomes, respectively, although some possible explanations are provided.

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