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**OWNER/CONTRACTOR
ORGANIZATIONAL CHANGES:
HOW OUTSOURCING KNOWLEDGE WORK AFFECTS
PROJECT PERFORMANCE**

PAMSY HUI

ALISON DAVIS-BLAKE, PH. D.

JOSEPH P. BROCHAK, PH. D.

CENTER FOR CONSTRUCTION INDUSTRY STUDIES

REPORT NO. 10

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A Report of

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The University of Texas at Austin

Under the Guidance of the

Owner/Contractor Organizational Changes Thrust Team

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EXECUTIVE SUMMARY

This document contains the findings of a study based on the data gathered from the first three versions of the Benchmarking and Metrics Survey which is administered to member firms of the Construction Industry Institute (CII). At the present time, 323 individual projects completed since 1994 have been received and analyzed.

The primary focus of this report is to use this data to test the effect of outsourcing on project costs. Research and theory in this area discusses both potential benefits of outsourcing: flexibility, focus, and access to an increased knowledge pool, and also potential drawbacks: lack of coordination, lack of communication, lowered safety standards, and interpersonal conflict.

The report describes and tests the following two hypotheses about the use of outsourcing on major capital facility projects:

1. Moderate outsourcing levels of engineering detailed design and pre-project planning will result in poorer current project outcomes than low or high outsourcing levels.
2. Moderate outsourcing levels of engineering detailed design and pre-project planning will result in poorer future project outcomes than low or high outsourcing levels.

The results of the analysis support the two hypotheses above for the outsourcing of the Pre-Project Planning (PPP) phase of project management. In other words, moderate levels of outsourcing for the PPP phase increases not only the cost of the PPP phase but also the cost of all subsequent project phases. Similar but weaker results were found for the level of outsourcing during the detailed design phase. We discuss these results and their implications for project management.

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CHAPTER 1: INTRODUCTION

1.1 Background

One of the trends in organizational design that has captured the imagination and attention of managers and organization scholars is the increased outsourcing of a variety of functions. Across a wide range of industries and occupations, firms rely on individuals who are under the administrative control of another firm to perform work, at times very critical work, for the focal firm. For example, in the construction of industrial facilities, outsourcing of the pre-project planning function increased by more than 50% between 1994 and 1997 while outsourcing of the detailed engineering design function increased by nearly 25% during the same time period.

In some industries such as offshore oil production (Stinchcombe & Heimer, 1985), residential construction (Eccles, 1981), and garment manufacturing (Uzzi, 1996, 1997), extensive use of subcontractors has become the *de facto* standard form of organization. Production facilities and homes are built and clothes are designed and manufactured not by one integrated firm but through the combined efforts of networks of firms that contract with one another. Indeed, some organizational researchers have argued that the appropriate use of outsourcing is integral to developing competitive advantage (Matusik & Hill, 1998; Quinn, 1999) and to organizational survival (Uzzi, 1996).

Despite the rapid increase in outsourcing of many activities, there have been no empirical studies testing the extent to which firms reap the intended benefits of outsourcing. The purpose of this paper is to determine the extent to which the expected benefits of outsourcing actually occur. For this test, we examined the use and benefits of outsourcing at the project level of analysis. This allows us to attribute the costs and benefits of outsourcing to its intended purpose

rather than being forced to aggregate the effects of outsourcing across multiple projects in the entire firm.

We focus on two previously neglected characteristics of outsourcing that are likely to affect the costs and benefits of outsourcing. First, we focus on the intensity of outsourcing. To date, much of the research and theorizing has focused on a firm's decision to outsource (or not outsource) an activity using arguments similar to those proposed in the transactions costs literature (Williamson, 1975). However, for a specific project, the use of outsourcing is better measured as a continuous variable rather than a dichotomous one. Managers must decide what portions of each project phase to outsource and what portions will be performed internally. More extensive use of outsourcing affects a firm's ability to coordinate and control work. Thus the intensity of outsourcing on a project may affect project performance.

Second, we focus on temporal interdependence among tasks. Temporal interdependence refers to tasks performed at one time that directly influence tasks or activities performed later on. In classic make-or-buy decisions, outsourcing generally only impacts the activity to be outsourced (Williamson, 1975). According to the logic of transaction cost economics, decision makers must determine whether the cost of buying a resource exceeds the cost of producing it. Usually in classic make-or-buy decisions, the impact to future tasks from the current outsourcing decision is not a key concern.

In contrast, critical knowledge work, such as the pre-project planning and detailed design of capital facility construction projects, exhibits a high level of temporal interdependence (Thompson, 1967; Stinchcombe & Heimer, 1987). Pre-project planning, detailed design, and construction of capital facilities are performed independently and in sequence; however, there is also overlap between these phases. Decisions made during the pre-project planning phase of a

project have a large impact on the design and construction phases. Similarly, decisions made during the design phase of a project impact the construction phase. The implication is that performance problems in later phases of capital facility projects may arise from early outsourcing of critical knowledge work. The outsourcing of knowledge work that is highly interdependent with other work in the firm, whether contemporaneously or temporally interdependent, can result in a loss of project control manifested by increased project costs and schedule overruns (See Thompson, 1967 for a discussion of this issue in a typical organizational setting).

First, we will briefly describe the research setting. Second, we will develop our theoretical arguments and present hypotheses about how the intensity of contractor use affects outsourcing performance. Third, we will describe our data, methods, and results. Finally, we will conclude with a discussion of the implications of our findings on the practice of outsourcing knowledge work and the future study of employment externalization.

1.2 Research Setting

This research is conducted in the U.S. major capital construction industry. This includes nonresidential construction commissioned by firms, governments, universities, etc. Thus industry products vary widely. For example, office buildings, manufacturing facilities, research and development facilities, roads, and bridges are all potential industry products. Construction costs are important because they can account for between 15 and 25 percent of final product costs (Federal Facilities Council Report, 1998). The industry is among the largest in the country, employing over 8 million people and contributing 8-10 percent of the annual U.S. GNP.

There are two major classes of participants in this industry: owners (the firms or governmental entities that commission and pay for the constructed product) and contractors

(firms providing a variety of services to owners). Contractors range from small firms that specialize in estimating to very large firms that can handle nearly all phases of a major capital construction project.

A major capital construction project has four basic, distinct phases: (1) pre-project planning, where the scope and feasibility of the project are assessed and where plans for how the project will proceed are developed, (2) detailed design, where the overall plans developed in pre-project planning are translated into detailed drawings of all of facility's major systems (e.g., electrical, hydraulic, mechanical), (3) facility construction, (4) facility start-up, where the facility's systems are tested and adjusted as needed. Historically, owners have completely outsourced the construction phase (which still relies heavily on manual labor) and have retained the pre-project planning and design phases in-house. These phases are composed primarily of knowledge work, some of it extremely specialized (Indeed, there is much knowledge required for the construction phase). However, during the 1980s, owner firms began to outsource pre-project planning and detailed design. We focus here on the impact of outsourcing the knowledge work associated with a major capital construction project (specifically during the pre-project planning and design phases). We should note that given the major differences in the early knowledge work phases of the project and the later construction phases (where physical labor is critical), our results may not generalize outside of knowledge work settings.

CHAPTER 2: THEORY DEVELOPMENT AND HYPOTHESES

2.1 Theory

Existing research and theorizing about outsourcing has identified three potential benefits of outsourcing. First, outsourcing offers the focal firm financial flexibility. Because the focal firm uses the services of an external provider only as required, the focal firm does not have to bear the costs associated with maintaining an in-house workforce that may not be fully utilized at all times. Second, outsourcing provides numerical and functional staffing flexibility for the focal firm (Pfeffer & Baron, 1988; Harrison & Kelley, 1993; Smith, 1998). Outsourcing allows the focal firm to rapidly increase or decrease the amount of human effort applied to a particular task. Through outsourcing, the focal firm can respond to short-term fluctuations in product demand (Mangum, Mayall, & Nelson, 1985; von Hippel, Mangum, Greenberger, Heneman, & Skoglund, 1997) and meet fluctuations in demand for human capital generated by factors such as non-recurring projects (Gordon & Thal-Larsen, 1969; Abraham, 1988, 1990). Outsourcing also allows the focal firm to meet temporary needs for specialized skills and knowledge (Gordon & Thal-Larsen, 1969; Abraham, 1988, 1990; Kochan et al., 1994).

Third, in addition to flexibility benefits, some strategy researchers have argued that outsourcing can be an important source of organizational learning and competency building. Matusik and Hill (1998) suggested that using contractors provides firms with access to ephemeral resources such as public knowledge (e.g., industry best practices) that, when integrated with existing stocks of organizational knowledge, can lead to the creation of new within-firm knowledge. Similarly, Quinn (1999) argued that the outsourcing of knowledge activities (such as advertising, engineering design, and information technology) allows firms to

focus on their own core competencies and realize economic benefits by tapping the focused expertise of outsiders.

These potential benefits of outsourcing follow directly from the two theoretical perspectives that have dominated research on moving work outside of organizational boundaries: transaction costs and social embeddedness. A transaction cost perspective focuses on the cost of acquiring a skill or resource in a market transaction as compared to producing that skill or resource within the firm (Williamson, 1975). When the total transaction cost of producing a resource exceeds the cost of acquiring it in the market, firms are likely to contract out for that particular skill or resource. Thus, according to transaction cost theory, firms can increase flexibility by relying on contractors to provide resources that can only be partially utilized by the firm (Eccles, 1981; Walker & Weber, 1984; Davis-Blake & Uzzi, 1993).

A social embeddedness perspective focuses on the relationship between exchange partners rather than the location of organizational boundaries (Granovetter, 1986). Granovetter argued that economic transactions are embedded in social relationships. Firms engage in recurring or persistent transactions because ongoing relationships produce trust and relationship-specific expertise (Granovetter, 1986). Additionally, recurring exchange relationships between owners and contractors result in lowered relationship costs, the transfer of firm-specific knowledge, and joint problem-solving behaviors (Uzzi, 1997). Thus ongoing relationships increase the probability of the acquisition of external ephemeral resources and improve the process of organizational learning. In addition, these benefits are most likely to accrue when firms are engaged in ongoing exchange relationships with a limited set of exchange partners (Uzzi, 1997; Matusik & Hill, 1998).

In contrast to the potential benefits of outsourcing, there are also potential drawbacks. The use of contractors has been linked to a number of organizational dysfunctions. These include lack of communication and coordination, increased injury and accident rates, and increased interpersonal conflict between employees of the contractor and employees of the focal firm (Kochan, Smith, Wells, & Rebitzer, 1994; Smith, 1994; Rousseau & Libuser, 1997; Broschak & Davis-Blake, 1998). One possible explanation for these potential drawbacks to outsourcing is that managers sometimes use outsourcing inappropriately. Some inappropriate use may be linked to faddish and fashionable adoption of outsourcing (Stinchcombe & Heimer, 1985; Abrahamson, 1996).

Studies linked to the benefits of outsourcing tend to be drawn from industries where tasks can be subdivided into sequential activities. For example, in the home building industry, specialty contractors perform whole tasks that are beyond the expertise of general contractors (Eccles, 1981). In the New York garment industry, garment manufacturers outsource entire tasks such as making patterns, cutting fabric, and sewing (Uzzi, 1997). In these industries, firms outsource entire tasks that are sequentially interdependent with other activities performed both inside and outside the focal firm (Thompson, 1967). In other industries, particularly those involving knowledge work, tasks are not always easily divisible. For instance, in the construction of offshore oil facilities, engineering and design tasks are often too complex to be performed by one firm. These tasks are divided between the focal, “owner” firm and multiple contractor firms. Therefore, they require extensive interaction during the course of pre-project planning, design, and construction. In this industry. Because these outsourced tasks are reciprocally interdependent, we predict that increasing the intensity of contractor use increases

the owner's communication and coordination requirements. This often leads to decreased project performance.

According to organizational theory, an organization's technology, including the degree of interdependence between tasks or activities, suggests an appropriate organizational structure (Woodward, 1958; Thompson, 1967; Fry 1982). For reciprocally interdependent activities, organizational theory recommends joint administration and tightly geographically-bounded locations (Thompson, 1967; Stinchcombe & Heimer, 1985). Failure to tightly couple highly interdependent activities can result in increased coordination costs and/or a loss of control over communication and coordination for these activities.

For activities such as the pre-project planning and detailed design of capital facility construction projects, outsourcing violates this basic principle of organizational design. By assigning parts of the pre-project planning phase and detailed design phase of construction projects to contractors, owners are dividing highly interdependent activities among multiple firms. Information does not pass easily between subcontractors or between the owner and contractor or between subcontractors themselves, and no one has ultimate authority or knowledge to coordinate all the work of these distinct firms (Stinchcombe & Heimer, 1985). As a result, ultimate decision-making authority is diffuse and control and coordination are extremely difficult.

This is not to say that owner firms behave irrationally by outsourcing. The complexity of large capital construction projects often necessitates that outsourcing occur (Stinchcombe & Heimer, 1985). Complex engineering projects often involve numerous technical and environmental contingencies that cannot be anticipated prior to project commencement. To cover all project contingencies would require owner firms to staff personnel at a cost-prohibitive

level. Thus the outsourcing of some engineering work for large capital construction projects becomes the most feasible solution despite the potential loss of coordination and control over project outcomes.

2.2 Hypotheses

But how does the ability of an owner firm to coordinate and control an activity vary with the intensity of contractor use? We predict that when the level of outsourcing is low, the majority of work is performed within the boundaries of the owner firm. In these cases, outsourcing creates few coordination and control problems. Similarly, we predict that when the level of outsourcing is high, the majority of project work is performed outside the boundaries of the owner firm. In these cases, the role of owner personnel is primarily coordination and control of contractor activities. However, when the workload is somewhat balanced between the owner and contractor, owner employees must perform engineering work and act as liaison between the owner and contractor(s). In these cases, communication and coordination of the project will be the most difficult. These arguments lead us to the following hypothesis:

Hypothesis 1: Moderate outsourcing levels of knowledge work will result in poorer contemporaneous project performance than either low or high outsourcing levels of knowledge work.

The intensity of outsourcing knowledge work for capital construction projects is expected to have both a contemporaneous and delayed effect on project performance. For capital construction projects, budgets, schedules, and capital commitments for the entire project are made during the earliest stages of a project based on estimates of project scale, scope, and available technology. After the pre-project planning and detailed design of a capital facility construction project, changes to the project scale or scope and use of alternative technologies, will have repercussions during the later phases of the project. Thus because planning, detailed

design, and construction are temporally interdependent, we would expect that an owner's inability to coordinate and control project work in the earliest phases will result in poor project performance in later phases of the project. We formalize this argument with the following hypothesis:

Hypothesis 2: Moderate outsourcing levels of knowledge work will result in poorer future project performance than either low or high outsourcing levels of knowledge work.

CHAPTER 3: METHODS

3.1 Sample

The sample for this study is drawn from the Benchmarking & Metrics Database (BM&M) maintained by the Construction Industry Institute (CII) at the University of Texas at Austin. The data come from the responses of 35 different American owner firms to three waves of questionnaires regarding 323 construction projects completed after 1994. The three waves were conducted from 1996 to 1998. The first wave includes responses on 87 projects, the second wave 97 projects, and the third wave 139 projects. Though there were slight differences in the questionnaires between successive waves, the items selected for analysis in this study are comparable across the different versions of the questionnaire. Owners answered one questionnaire for each project, providing basic information about their projects, such as the type of facility constructed. Owners also supplied detailed descriptions of contract incentives offered to contractors, the extent of outsourcing for each project phase, and the budget and actual costs for each phase in each project.

The level of analysis is the project. Approximately 26 percent of the projects in the BM&M database are public sector facilities (e.g., roads, public buildings) with the remaining 74 percent being private sector facilities. The data included projects from a variety of industrial sectors including light industry (e.g., food processing), heavy industry (e.g., oil refining), general buildings (e.g., hotels), and infrastructures (e.g., highways).

3.2 Variables

3.2.1 Dependent Variables

Our dependent variable is the *Percentage Cost Overrun* or the percentage by which actual costs exceeded budgeted costs. For projects, or project phases, that were over budget the

value of this variable was positive; for projects that were under budget the value of this variable was negative. We calculated the percentage cost overrun for three project phases (*% PPP Cost Overrun, % Design Cost Overrun, and % Construction Cost Overrun*), as well as for the overall project (*% Total Cost Overrun*). For individual phases as well as total project, the value of these variables can be positive or negative.

3.2.2 Independent Variables

Our two independent variables are the percentages of the critical knowledge functions that were outsourced (*% PPP Outsourced, and % Design Outsourced*). We calculated these percentages from owners' reports of the percentage of the work done by themselves and each contractor in each phase. The percentage outsourced is the amount of work performed by contractors for a phase divided by the total amount of work performed for a phase.

The construction of capital facilities is a complex process, so we controlled for several other factors that might affect cost overruns. First, we controlled for the type of project under construction. *Light Industry, Heavy Industry* and *Infrastructure* are dummy variables representing the different production sectors the projects serve. A fourth category, *General Buildings*, served as the omitted category. Controlling for sectors is important because different sectors require constructions of different complexity. For example, more specialists are involved in the building of an oil refinery than a warehouse, and the complexity of a project can affect the accuracy of cost anticipation. We also controlled for whether the construction was on a new site (*Grassroots*) or a retro-fit of an older facility (*Modernization*) with another set of dummy variables. The omitted category was additions to current facilities usually to increase capacity (*Addition*). Grassroots and modernization involve more complex work, increased uncertainty, and decreased owner ability to accurately estimate costs.

We also controlled for whether projects were *Public Sector* or *Private Sector*, since construction of these projects are handled differently. Owners for public and private sector projects serve different constituencies and thus take different approaches to dealing with budgets and managing projects. The public sector tends to be less sensitive to contingencies due to bureaucracy and thus tends to have more cost overruns.

We also controlled for project size (*Log (Project Budget)*). The larger the budget, the less likely it is to have a large cost overrun percentage because the same absolute value means a smaller percentage if the budget is larger. We used the log transformation because the sample was positively skewed.

We also expect different incentive schemes to have different effects on how well the project follows the budget or the plan it entails. There are four main types of incentive schemes the construction industry uses – *Lump Sum*, *Cost Reimbursement*, *Guaranteed Maximum Price* and *Unit Price*. Cost reimbursement is often used when the scope definition of a project is not clear and many changes are expected. The owners generally pay the costs of any changes plus some fees, which are usually a fixed percentage of the costs. Sometimes, incentives such as a cost savings sharing scheme are included. Guaranteed maximum price is a payment method in which owners guarantee beforehand the maximum amount they are willing to pay. Unit price refers to the value of work done. An incentive scheme that uses the hourly rate paid to the workers is considered cost reimbursement. Lump sum is usually used when the project scope is well defined. A fixed price is set beforehand, and contractors bear the risks of changes. For lump sum contracts, the potential for high profits is great when cost savings are high. Lump sum is the omitted category in our analysis of this variable. Because some of the projects use several

incentive schemes for different contractors we created a dummy variable to indicate whether *Mixed Incentives* are used.

Finally, we controlled for the wave of the survey. As mentioned, the data consists of three waves of responses. We created dummy variables, *Version 2* and *Version 3*, with Version 1 as the omitted category, to control for any period effects that can be attributed to the version of the questionnaire to which owners responded (e.g., different macroeconomic situations), or to any organizational experiential learning that may have occurred over time.

3.3 Analysis

The sample contains a number of owners with multiple projects reported. Firms tend to use similar incentive schemes, build similar facilities, and take similar approaches across different projects. This violates the assumption of independent observations that the Ordinary Least Square (OLS) model builds on. As a result, if we estimate our parameters using OLS, this nonindependence problem can render the estimation inefficient (Liang & Zeger, 1986). As a remedy, we relax the assumption and use maximum likelihood techniques to estimate generalized estimating equations (GEEs). What GEEs do is to take autocorrelation due to nonindependence into account when estimating the parameters. The aim is to obtain more consistent estimators than we would have gotten using OLS (Liang & Zeger, 1986).

3.4 Model Specifications

Initial plots of raw data revealed that the impact of outsourcing on cost overruns was highly nonlinear. Thus, attempting to fit a linear model to the data would obscure important variations in the effects of the independent variables. Thus, as recommended by Greene (1997), we estimate a spline function. A spline function is a function composed of segments of straight lines with different slopes joined together. In this case, we used three segments. The use of the

spline function is particularly recommended when the slope of the regression line is likely to change when distinct milestones are encountered (Greene, 1997). In construction projects, such milestones may occur when outsourcing deviates from minimal levels and reaches levels where the owner can no longer control the day-to-day activities of the contractor. Another milestone may occur when the contractor begins to perform nearly all of the work with the owner assuming a minimal role.

The derivation of the spline function is shown in Appendix 1. It is estimated as an adjustment of the linear model. The regression model we are estimating is:

Percentage Cost Overrun = $\beta_1 + \beta_2 (\text{Percentage of Function Outsourced}) + \delta_1 * p_1 * (\text{Percentage of Function Outsourced} - \alpha_1) + \delta_2 * p_2 * (\text{Percentage of Function Outsourced} - \alpha_2) + \varepsilon$, where $p_1 = 1$ if the percentage of outsourcing for PPP (or detailed design) is at least 20% (10%), 0 otherwise, and $p_2 = 1$ if the percentage of outsourcing for PPP (detailed design) is at least 90% (90%), 0 otherwise. For pre-project planning, α_1 is 20, and α_2 is 90, indicating the two percentage thresholds, or milestones, chosen; the same logic applies for the analysis of detailed design, with α_1 being 10 and α_2 being 90. The outsourcing thresholds were chosen where data tended to be particularly concentrated. The density of data around the threshold helps ensure that changes in slope are not artifacts but accurately represent the data.

With this modification, what we are really estimating are $\beta_1, \beta_2, \delta_1$ and δ_2 . The intercept of the first segment is β_1 , and the slope β_2 , just as in OLS models. The difference with this model is that we also estimate the intercepts and slopes of the second and third segments. The intercepts for the second and third segments are $\beta_1 - \alpha_1 * \delta_1$ and $\beta_1 - \alpha_1 * \delta_1 - \alpha_2 * \delta_2$ respectively and the slopes are $\beta_2 + \delta_1$ and $\beta_2 + \delta_1 + \delta_2$. Thus, if we create dummy variables for the values, $p_1 * (\text{Percentage of Function Outsourced} - \alpha_1)$ and $p_2 * (\text{Percentage of Function Outsourced} -$

α_2) for each function, we are essentially estimating the slope of the first segment, the difference between the slope of the first two segments and the difference between the slopes of the last two segments by estimating β_2 , δ_1 and δ_2 . In other words, the variables representing the percentage of outsourcing of each function indicate the properties of the first segment, and the two dummy variables represent the incremental properties of the second and the third segments. For simplicity, we will label the variables corresponding to the three estimators as *Low PPP (or Design) Outsourcing*, *Medium PPP (or Design) Outsourcing* and *High PPP (or Design) Outsourcing* respectively.

CHAPTER 4: RESULTS

4.1 Results

Table 1 reports means, standard deviations, and correlations for all variables included in this study. More than half of the projects are heavy industrial construction such as refineries and manufacturing facilities. General buildings (the omitted category) such as office buildings and warehouses comprise about a quarter of the projects. Light industry and infrastructure are the two minority groups. The projects are evenly distributed among grassroots projects, modernizations and additions to existing facilities (the omitted category). Only about a quarter of the projects are for public entities. As expected, cost reimbursement is the dominant incentive scheme in the majority of firms followed by fixed lump sum pricing (the omitted category), unit pricing, and guaranteed maximum pricing. About a quarter of the projects use more than one incentive scheme. Note that the average of each cost overrun measure is low with high variance.

Tables 2 and 3 report the GEE models using the spline function. Table 2 shows the impact of outsourcing pre-project planning. The outsourcing of pre-project planning has a very strong impact on total cost overrun. In addition, outsourcing pre-project planning also affects cost overruns in all major stages of the project. Figure 1 graphs the effects of outsourcing (holding control variables at their means or at the largest category in the case of categorical variables). As predicted, as the level of PPP outsourcing rises from none to medium (20%), cost overruns increase. Also, as the level of PPP outsourcing moves from medium to high (90%), cost overruns fall. Surprisingly, as outsourcing of pre-project planning moves from high levels (90%) to total outsourcing, cost overruns rise again. Thus, as predicted, we find that outsourcing pre-project planning affects not only the cost of the PPP phase but also the cost of all subsequent project phases.

Table 1. Descriptive Statistics and Pearson Correlation Coefficients^a

VARIABLE	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1. % Total Cost Overrun	-1.45	13.94	1.00																			
2. % PPP Cost Overrun	1.02	30.73	.02	1.00																		
3. % Design Cost Overrun	1.60	30.71	.29	.05	1.00																	
4. % Construction Cost Overrun	4.45	30.61	.45	-.07	.05	1.00																
5. % of PPP Outsourced	26.57	37.80	-.03	-.02	.08	-.05	1.00															
6. % of Design Outsourced	75.35	38.23	-.06	.08	.15	-.02	.19	1.00														
7. Light Industry	0.11	0.32	.02	.03	.16	-.06	-.08	.03	1.00													
8. Heavy Industry	0.57	0.50	-.09	-.08	-.05	.05	.04	-.11	-.42	1.00												
9. Infrastructure	0.06	0.24	.02	.12	-.09	.09	.04	.08	-.09	-.29	1.00											
10. Grassroots	0.33	0.47	-.05	-.07	.01	-.08	-.02	.11	-.13	-.23	-.06	1.00										
11. Modernization	0.38	0.49	.08	.01	.04	-.01	.11	-.03	.04	.09	.05	-.55	1.00									
12. Public Sector	0.26	0.44	-.11	-.09	-.04	-.06	-.03	-.07	-.21	-.41	-.00	-.18	-.00	1.00								
13. log (Project Budget)	16.66	1.18	-.09	.06	.04	-.04	-.10	.15	.12	.09	-.10	.21	-.24	-.25	1.00							
14. Unit Price	0.11	0.31	.01	-.01	.11	.03	.00	-.04	.02	.04	-.05	.05	.02	-.07	.04	1.00						
15. Cost Reimbursement	0.57	0.50	-.04	-.08	-.02	.08	.15	.09	-.01	.28	.03	-.19	.17	-.38	.11	-.19	1.00					
16. Guaranteed Maximum Price	0.06	0.24	-.02	.06	.01	-.02	-.08	.02	.32	-.21	-.01	.00	.04	-.15	.05	-.04	-.14	1.00				
17. Mixed Incentives	0.24	0.43	-.01	-.07	.01	-.04	.02	.03	.06	-.06	-.08	.07	.06	-.08	.11	.25	.25	.32	1.00			
18. Version 2	0.30	0.46	.07	-.01	.00	.03	.03	.12	.17	-.08	.07	-.02	-.09	-.07	.15	-.06	.05	.19	.19	1.00		
19. Version 3	0.43	0.50	-.03	-.08	-.10	-.03	.10	-.13	-.14	.06	-.08	.00	.11	-.18	-.30	.04	-.08	-.08	.00	-.57	1.00	

^aAll correlations are pairwise. N ranges from 152 to 323. For N=152, correlations greater than .16 are significant at $p \leq .05$.

On average, the firms in this sample outsourced 27% of the planning function and 75% of the design function; however, the variance in outsourcing is also quite high, indicating that the firms in this industry have many different approaches to outsourcing.

Table 2. Cost Effects of the Outsourcing of Pre-Project Planning^a

Variable	Total Cost Overrun	PPP Cost Overrun	Design Cost Overrun	Construction Cost Overrun
1. Low PPP Outsourcing	0.90(.21) ^{***}	1.07(.78) [†]	0.63(.25) ^{**}	0.55(.46)
2. Medium PPP Outsourcing	-1.33 (.29) ^{***}	-1.46(1.04) [†]	-0.76(.33) ^{**}	-0.95(.61) [†]
3. High PPP Outsourcing	1.43(.43) ^{***}	1.27(1.38)	-0.04(.84)	1.85(.66) ^{**}
4. Light Industry	1.30(3.42)	-3.59(13.18)	15.39(11.87)	-18.01(8.46) [*]
5. Heavy Industry	-0.70(2.86)	-10.72(5.81) [†]	10.09(9.70)	-6.34(6.67)
6. Infrastructure	-0.54(4.75)	5.86(21.47)	0.49(9.44)	7.47(19.41)
7. Grassroots	-2.08(2.84)	-11.62(6.76) [†]	10.98(4.83) [*]	-11.14(7.09)
8. Modernization	-1.51(2.40)	2.20(5.56)	8.39(6.20)	-8.29(6.46)
9. Public Sector	3.25(1.65)	-18.90(5.87) ^{**}	5.97(8.08)	-9.24(6.32)
10. log (Project Budget)	-1.33(.85)	2.57(1.54) [†]	-1.39(1.28)	-3.31(2.22)
11. Unit Price	3.25(4.04)	-3.12(6.63)	21.01(7.48) ^{**}	14.02(7.15) [*]
12. Cost Reimbursement	-1.58(2.33)	-7.16(7.95)	4.19(4.57)	9.89(7.08)
13. Guaranteed Maximum Price	-1.51(3.39)	17.82(21.42)	6.98(7.94)	7.59(6.59)
14. Mixed Incentives	2.94(3.11)	-4.54(5.92)	-7.76(6.21)	-4.16(5.88)
15. Version 2	2.87(1.83)	-1.62(6.35)	-6.60(4.50)	5.62(6.33)
16. Version 3	-0.92(2.28)	-5.63(5.52)	-12.77(4.12) ^{**}	2.83(6.60)
Constant	22.66(14.21)	-42.69(26.76)	13.20(21.69)	57.20(35.50) [†]
Model χ^2	1051.15 ^{***}	724.52 ^{***}	1067.27 ^{***}	1054.15 ^{***}
N	199	145	179	182

^a All models are generalized linear models with controls for firm effects. Standard errors are in parentheses. t-tests are one-tailed for hypothesized effects and two-tailed for control variables.

[†] $p \leq .10$, * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

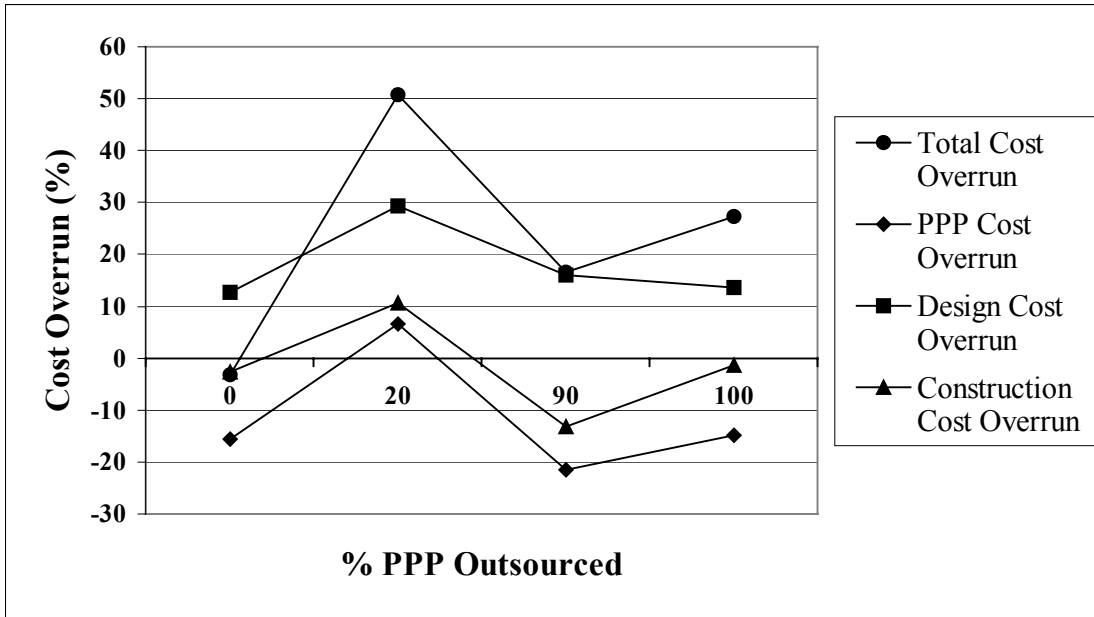


Figure 1 Cost Effects of Pre-Project Planning Outsourcing

While this general pattern of results holds for the pre-project planning, detailed design, and construction phases, and for total cost overruns, the pattern of significance differs across the phases. Specifically, the final increase in costs (as outsourcing exceeds 90%) is not significant in the pre-project planning and detailed design phases. While, in the construction phase, the effect of moving from no outsourcing to moderate outsourcing is not significant.

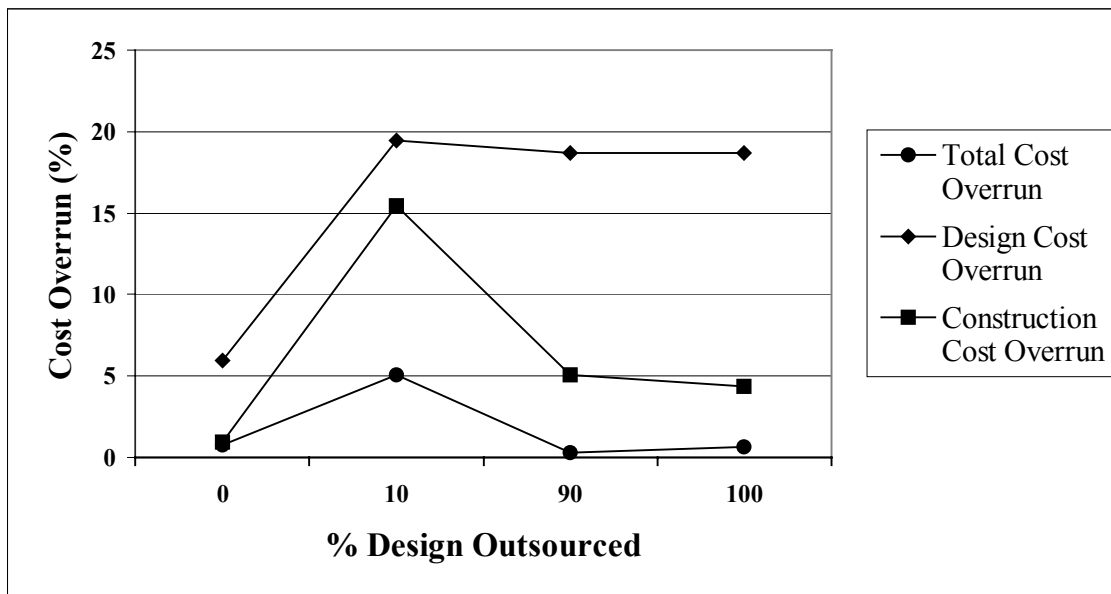


Figure 2 Cost Effects of Detailed Design Outsourcing

Figure 2 and Table 3 report the results for outsourcing detailed design (in the same format as the results for pre-project planning). As predicted, when detailed design outsourcing moves from none to moderate, cost overruns increase. However, as detailed design outsourcing moves from moderate to high levels, cost overruns decline. Surprisingly, when the level of detailed design outsourcing moves from extensive to complete, cost overruns in the detailed design phase rise. This effect is not present in other phases or in total cost overrun. Thus, we find that outsourcing detailed design affects both the cost of the design phase and the cost of subsequent project phases.

Table 3. Cost Effects of the Outsourcing of Detailed Design^a

Variable	Total Cost Overrun	Design Cost Overrun	Construction Cost Overrun
1.Low Design Outsourcing	0.59(.37) [†]	1.97(.99) [*]	1.27(.73) [*]
2.Medium Design Outsourcing	-0.65(.42) [†]	-2.15(1.06) [*]	-1.38(.77) [*]
3.High Design Outsourcing	-0.10(.22)	1.02(.35) ^{**}	-0.18(.51)
4.Light Industry	0.44(2.70)	11.69(9.74)	-7.86(8.45)
5.Heavy Industry	-0.31(2.03)	9.02(6.88)	-1.53(5.70)
6.Infrastructure	0.47(2.34)	-7.22(7.88)	8.41(13.40)
7.Grassroots	0.03(2.58)	5.88(4.36)	-6.24(5.84)
8.Modernization	2.95(2.37)	6.02(4.39)	-5.53(5.39)
9.Public Sector	1.72(2.03)	6.10(5.45)	-3.69(4.88)
10.log (Project Budget)	-1.12(1.01)	0.16(1.02)	-2.03(1.76)
11.Unit Price	1.81(2.31)	17.41(6.36) ^{**}	9.67(4.77) [*]
12.Cost Reimbursement	1.19(2.02)	5.18(4.01)	10.40(5.54) [†]
13.Guaranteed Maximum Price	-1.03(2.32)	7.84(6.96)	6.92(4.40)
14.Mixed Incentives	-0.60(2.52)	-3.83(4.04)	-5.68(4.79)
15.Version 2	2.52(1.49)	-7.55(4.40) [†]	1.45(4.66)
16.Version 3	-1.37(2.39)	-12.71(4.03) ^{**}	-1.49(5.12)
Constant	15.64(16.17)	-16.98(18.02)	31.48(27.74)
Model χ^2	378.98 ^{***}	478.94 ^{***}	382.10 ^{***}
N	281	247	256

^a All models are generalized linear models with controls for firm effects. Standard errors are in parentheses. t-tests are one-tailed for hypothesized effects and two-tailed for control variables.

[†] $p \leq .10$, ^{*} $p \leq .05$, ^{**} $p \leq .01$

CHAPTER 5: DISCUSSION

We hypothesized that owners would be less likely to experience problems of coordination and control on capital facility construction projects when the levels of outsourcing of critical knowledge work (e.g., pre-project planning and detailed design) were either very low or very high. We also predicted that the coordination and control problems resulting from medium outsourcing levels of critical knowledge work would have both a contemporaneous and delayed effect on project performance. Our empirical analysis of 323 capital facility construction projects generally supported our predictions, though there were some surprising findings.

For both pre-project planning and design, we found that outsourcing the function affected the cost overrun associated with the function. Initially, the percentage cost overrun for that function increased with the level of outsourcing but then decreased as outsourcing moved from medium to high levels. This suggests that owners are best able to control the cost of knowledge work when the majority of the work is conducted either by the owner or by the contractor. Getting a little help from contractors (probably from boutique firms that specialize in relatively esoteric tasks) or effectively letting go of the planning and design functions has the smallest impact on the ability of owners to estimate and control costs. However, consistent with theories of organizational design, when pre-project planning is shared by the owner and contractor (e.g., medium levels of outsourcing) owners experience the most problems controlling the project and as a result, percentage cost overruns are highest. As Thompson (1967) predicted, when highly interdependent tasks, such as knowledge work on construction projects, are decoupled, coordination and control can be compromised.

Also consistent with our predictions, we found strong evidence of a delayed effect of loss of coordination and control due to outsourcing. In four of the five cases where we tested for the

delayed effects of outsourcing of pre-project planning or detailed design, cost overruns for subsequent project phases or for the entire project increased between low and medium levels of outsourcing and then decreased between medium and high levels of outsourcing. The only exception was for the delayed effect of pre-project planning outsourcing on construction cost overruns. The effect of moving from low to medium levels of outsourcing was positive as expected but not significant. Still, percentage cost overruns for the construction phase decreased significantly as outsourcing of detailed design increased from medium to high levels.

These results provide strong evidence of the existence of optimal levels of outsourcing of critical knowledge work, or perhaps more accurately, the existence of sub-optimal levels of outsourcing. The benefits that are attributed to outsourcing may not be realized at all levels of outsourcing. Focal firms that are unable to integrate a few contractors into their own processes or that are unable to largely let go and coordinate the work of contractors may find that the financial flexibility associated with outsourcing is offset by poor project performance.

Surprisingly, we found that letting go of critical knowledge work in its entirety did not necessarily benefit owners. For example, increasing the pre-project planning outsourcing from a high level to 100% outsourced increased (a delayed positive effect) both construction phase and total project cost overruns. Similarly, increasing the outsourcing of detailed design from high levels to complete outsourcing increased detailed design cost overruns (a contemporaneous positive effect). One possible explanation for these results is that agency problems occur when outsourcing of detailed design becomes complete (Williamson, 1975). Contractors performing critical knowledge work without some oversight by owners appear to either deviate from the plans and schedules set by owners or make decisions that are not necessarily in the owner's best interest. Clearly, some form of owner involvement in the critical knowledge work of capital

facility construction projects is necessary for owners to maintain coordination and exercise control over complex projects. Another possible explanation is that the contractors are left without owner input and make decisions without the proper information that later lead to cost overruns.

Finally, our results provide some preliminary evidence that the effects of outsourcing knowledge work may differ across types of knowledge work. Specifically, we found that outsourcing pre-project planning had larger and stronger effects on total cost overruns than outsourcing detailed design. The pre-project planning phase is the most cognitively complex project phase, requiring the integration of knowledge about marketing, finance, workforce planning, and governmental regulations and laws with knowledge drawn from many engineering disciplines. The pre-project planning phase also requires the integration of “generic” construction knowledge (e.g., estimating the cost of a certain piping design) with firm-specific knowledge about the owner’s strategy, competitive position, and product lines. It may be that outsourcing knowledge work that is more complex and wide ranging or that requires more integration of firm-specific and generic knowledge may pose greater risks for a firm than outsourcing other types of work.

Outsourcing provides focal firms access to the expertise and resources of contractors that can supplement the owner’s own workforce. But as outsourcing becomes increasingly common, and as firms focus more on core competencies and leave seemingly non-critical activities to external firms, we note that firms should exercise caution in selecting both the type and the level of outsourcing they utilize. Our results suggest that some combinations of outsourcing and in-house work can actually leave firms worse off than they started.

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APPENDIX

Assume that there are three straight line segments, representing the three levels of function outsourcing.

The basic rationale of the spline is that not only do the three segments have different intercepts when they are extended to the y-axis, they also change at different rates as the x value increases. In this case, the y-axis represents the cost overrun percentage, and the x-axis represents the percentage of outsourcing of a function. Recall that different levels of outsourcing are expected to have different impact on the cost overrun percentage. The impact is not fixed within each level, but is changing at a fixed rate.

Thus, the first segment should be expressed as: $Percentage\ Cost\ Overrun = \beta_0 + \beta_2 (Percentage\ of\ Function\ Outsourced) + \varepsilon$

The objective is to express that there is a different intercept as well as a different slope for the second segment. Thus, the second segment is written as:

$$Percentage\ Cost\ Overrun = \beta_0 + \gamma_1 + (\beta_2 + \delta_1) * (Percentage\ of\ Function\ Outsourced) + \varepsilon$$

Likewise, the third segment can be written as:

$$Percentage\ Cost\ Overrun = \beta_0 + \gamma_1 + \gamma_2 + (\beta_2 + \delta_1 + \delta_2) * (Percentage\ of\ Function\ Outsourced) + \varepsilon$$

To represent all three equations in one, dummy variables, p_1 and p_2 are created, and milestones, i.e., where the slope changes, are set arbitrarily at α_1 and α_2 .

$$p_1 = 1 \text{ if Percentage of Function Outsourced} \geq \alpha_1$$

$$p_2 = 1 \text{ if Percentage of Function Outsourced} \geq \alpha_2$$

As a result, we obtain the equation:

$$\begin{aligned}
\text{Percentage Cost Overrun} = & \beta_1 + \beta_2 (\text{Percentage of Function Outsourced}) + \gamma_1 * p_1 + \delta_1 * p_1 \\
& * (\text{Percentage of Function Outsourced}) + \gamma_2 * p_2 + \delta_2 * p_2 * (\text{Percentage of Function} \\
& \text{Outsourced}) + \varepsilon
\end{aligned} \tag{1}$$

To join the three line segments, we must set the constraint such that the values of percentage cost overrun on the first segment and the second segments are equal when the percentage of function outsourced equals α_1 . Similarly, a constraint has to be set such that the values of percentage cost overrun on the second and the third segments are equal when the percentage of function outsourced equals α_2 . Thus,

$$\beta_1 + \beta_2 * \alpha_1 = (\beta_1 + \gamma_1) + (\beta_2 + \delta_1) * \alpha_1$$

$$0 = \gamma_1 + \alpha_1 * \delta_1$$

$$\gamma_1 = -\alpha_1 * \delta_1$$

Similarly,

$$(\beta_1 + \gamma_1) + (\beta_2 + \delta_1) * \alpha_2 = (\beta_1 + \gamma_1 + \gamma_2) + (\beta_2 + \delta_1 + \delta_2) * \alpha_2$$

$$0 = \gamma_2 + \alpha_2 * \delta_2$$

$$\gamma_2 = -\alpha_2 * \delta_2$$

Now, substitute γ_1 and γ_2 into equation (1). We get:

$$\begin{aligned}
\text{Percentage Cost Overrun} = & \beta_1 + \beta_2 (\text{Percentage of Function Outsourced}) + \delta_1 * p_1 * (\text{Percentage} \\
& \text{of Function Outsourced} - \alpha_1) + \delta_2 * p_2 * (\text{Percentage of Function Outsourced} - \alpha_2) + \varepsilon
\end{aligned}$$