Project Capital Cost Risks and Contracting Strategies

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A primary consideration for all parties in the construction industry should be the completion of projects as efficiently and cost effectively as possible. Unfortunately, many projects fail to meet their cost, time, and quality objectives. The cause of many of these failures is rooted in poor front-end planning in the early stages of a project.

An owner's influence over the course of a project is greatest in the early stages. At this juncture, certain decisions will significantly affect the cost, schedule, and quality of the project outcomes, as well as risks associated with these outcomes. Among the significant decisions are the type of contract and the contracting strategy under which the project will be executed. Failure to recognize the interaction between the contracting strategy and the project's risks and capital costs will place that venture at a competitive disadvantage. Yet, an evaluation of all of the risks and uncertainties associated with a project is not commonly undertaken, even on the largest of projects. Risk evaluation, in general, is perceived to be costly and typically relies on "expert" opinion and rules-of-thumb, due to a lack of quantitative information about specific risks.

Laufer and Cohenca [1] have noted that uncertainty and its influence on decision-making in organizations has been extensively researched. Much of the research has focused on developing methodologies to evaluate the effects of uncertainty on construction planning in terms of cost and time overruns. Nonetheless, there exists a paucity of quality information on the identification and quantification of specific risks associated with construction contracts. This article presents some results of a study assessing the effects of contract-related uncertainty on project outcomes in the oil and gas industry.

BACKGROUND

The oil and gas industry has the following distinguishing characteristics:

- relatively few owners (project initiators);
- relatively few engineering and contracting organizations (project implementors);
- considerable formal and informal communications;
- no constraints on owner selection of contracting methods; and
- no constraints on the methods by which owners select engineering and construction contractors.

The existence of few owners and few engineering/contracting organizations creates an environment in which a considerable number of formal and informal relationships are formed between the parties. Informal mechanisms, including reputation and trust (alignment) between the contracting parties, are important for both owners and their contractors. These relationships and mutual dependencies affect total project costs and the risks associated with the outcomes of formal contracts.

One decision made very early in most industrial projects is the overlap of engineering design and construction (fast-tracking) to reduce the project duration. Although this results in increased front-end engineering and construction costs, the expectation is that this will result in overall cost savings to the project. However, too much overlap between construction and engineering can cause disruptions and reduced productivity over the duration of the project. Few studies have been performed on this issue.

In a study, the Construction Industry Institute [2] identified projects as having either early or late starts, based on the amount of overlap in engineering design and construction. The overlap was defined as the number of calendar days between the start of construction and the completion of engineering, divided by the total calendar days of the project (from start of engineering to completion of construction). Cost overruns, expressed as the percentage of total change in dollars, were 27 percent greater for the projects in which field construction began early. Projects that started construction late had only an 11 percent cost overrun. The CII sample involved 16 projects with an average value of approximately $80 million.

CII [2] also identified a premium associated with the complexity of the contracting strategy. They found that a design-build or engineer-procure-construct (EPC) approach experienced a lower proportional amount of change, amounting to an average 9 percent cost overrun (based on dollar value), while a design-bid-built approach experienced an average cost overrun of 15 percent.

METHODOLOGY

Data from this study was collected by a quantitative matrix survey and interviews with more than 30 industrial practitioners. Participants in the survey were selected based on experience and reputation in the industry. Respondents had an average of 27 years of project management experience gained on an average of approximately 20 projects and represented owner, engineering contractor, and construction contractor organizations.

The survey proposed two models of projects in the oil and gas industry, differentiated by the size of project ($20 million and $500 million). This article will focus on the findings associated with the $20 million project. The survey models contained four independent variables:

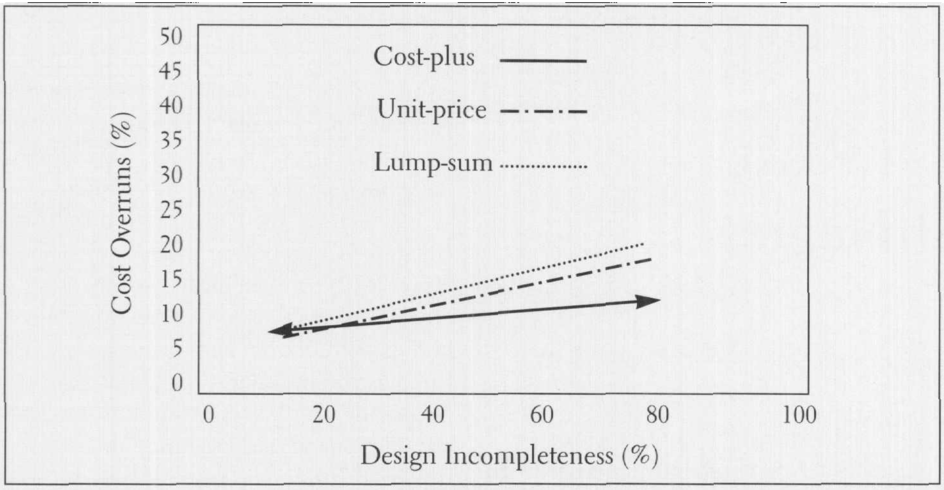

Figure 1—Cost Overruns, Simple Contractual Arrangement, Cost-Plus, Unit-Price, and Lump-Sum

project size, the complexity of contractual arrangements, the level of design completeness, and the contract types. Six dependent variables were considered:

- final contractor workhours;
- expected construction duration;
- growth in materials;
- contractor risk premiums;
- percent change in total cost due to changes; and
- the influence of senior management and direct labor supervision skills on the total project costs.

The dependent variables considered were normalized to facilitate data analysis and comparisons. This article discusses the effects of the four independent variables on the expected construction duration and the percent change in total cost due to design changes.

Based on Laufer and Cohenca's [1] work, all projects under consideration would be considered to be complex. This definition of complexity is based on the number of subcontractors and trades involved. If more than 20 trades and/or 15 subcontractors are involved, the project is considered to be complex. On most industrial projects in the oil and gas industry with a value of $20 million or more, the owner or his or her representatives may be expected to have over 20 trades and more than 15 subcontractors.

In our study, the complexity of the contractual arrangement was qualitatively measured. A simple contractual arrangement was defined as a typical EPC or engineering procurement construction management (EPCM) type of arrangement with minimization in the number of contracts and a high degree of horizontal and vertical integration of contracts. A complex contractual arrangement was one that had a low amount of horizontal and vertical integration of contracts and more contract interfaces than the minimum required. These additional interfaces may be the result of strict local hiring policies, political influence, the need to build skills and a workforce in the area for long-term considerations, or the owner's organization and structuring of the project. All respondents understood and recognized projects within their experience in which the contractual arrangement had been made unnecessarily complex.

Design completeness at the start of field construction was used as a measure of the degree of project fast-tracking, as opposed to CII's [2] use of overlap. Results were determined for three different levels of design completeness when field forces were first mobilized.

Based on a literature review, 10 percent, 50 percent, and 80 percent levels of design incompleteness measures were selected. At 10 percent design incompleteness (or 90 percent design completeness), a design is essentially complete, with only minor details such as shop drawing submittals outstanding. At 50- percent, approximately half of the detailed design has been completed. At 80 percent design incompleteness, only a small amount of the detailed design was completed. Respondents were asked to assume that the processing and transmission of engineering drawings and information proceeded in an orderly manner.

Three forms of contract types were considered. These are commonly referred to as cost-plus, lump-sum, and unit-price contracts. Although numerous subcategories of each type of basic contract form exist, the study was restricted to the three basic contract types.

DATA ANALYSIS

Cost overrun (total project cost charges) and construction schedule data for the $20 million project were initially analyzed using a linear multiple regression analysis in which three independent variables—contract complexity, design incompleteness (completeness), and contract type—were regressed. Design completeness was identified as the most significant explanatory variable.

RESULTS

Changes in Project Costs

Total project cost changes (overruns) are significantly affected by overlapping engineering design and construction (fast-tracking) for all contractual types and arrangements. However, the different contract types and arrangements behave differently at different levels of design completeness.

Simple Contractual Arrangements With Differing Levels of Design Completeness

Figure 1 presents the cost overruns associated with simple contractual arrangements at various levels of design incompleteness. At 10 percent incompleteness, lump-sum and unit-price contracts produced the least changes (6 percent), while cost-plus produced the greatest change (8 percent). However, it is also important to consider the risks associated with each of these expected outcomes as measured by standard deviation (see table 1). The cost-plus contract was subject to the greatest range of opinion, as measured by a single standard deviation (6 percent). Lump-sum and unit-price contracts were more consistently evaluated by respondents, at 6 and 5 percent, respectively.

Table 1—Standard Deviations of Results

Contractual Arrangement	Contract Type	Design Completeness	One Standard Deviation
Simple	Lump-sum	90	4.6
		50	7.9
		20	11.9
	Unit-price	90	5.0
		50	8.1
		20	11.5
	Cost-plus	90	6.2
		50	9.5
		20	15.6
Complex	Lump-sum	90	5.6
		50	8.7
		20	14.1
	Unit-price	90	5.9
		50	8.0
		20	12.0
	Cost-plus	90	7.0
		50	10.4
		20	16.3

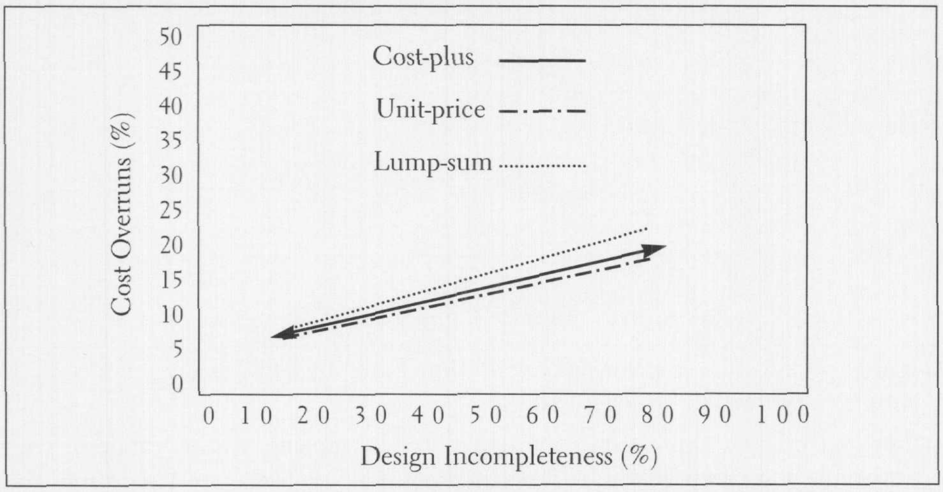

Figure 2—Cost Overruns, Complex Contractual Arrangements, Cost-Plus, Unit-Price, and Lump-Sum

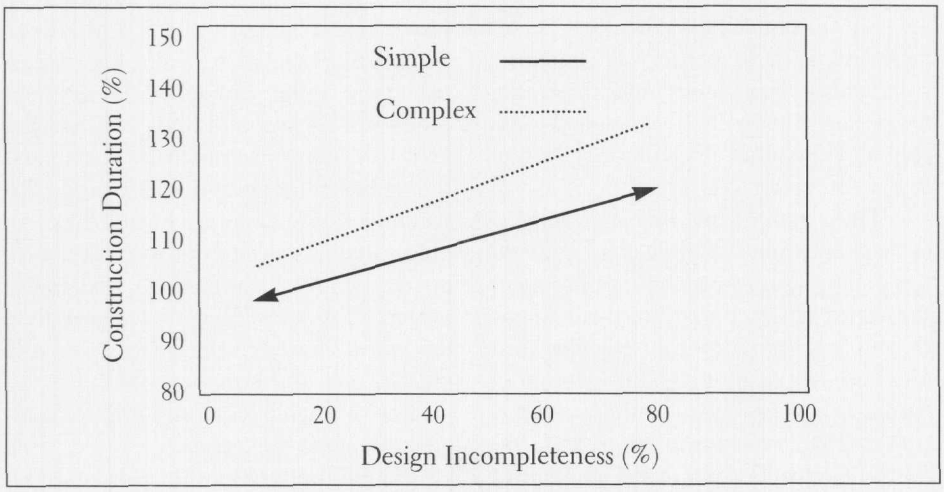

Figure 3—Construction Duration Versus Design Incompleteness

At 20 percent design completeness, cost-plus contracts had the least amount of total cost overruns (15 percent) and lump-sum the greatest amount (22 percent). The unit-price contract experienced significant total change (20 percent). The cost-plus contract was subject to the greatest volatility as measured by a single standard deviation (16 percent) from the expected value (see table 1). The unit-price experienced the least volatility (12 percent), and the lump-sum contract was intermediate (14 percent).

Complex Contractual Arrangements With Differing Levels of Design Completeness

Figure 2 presents the cost overruns associated with complex contractual arrangements at 10 percent, 50 percent, and 80 percent levels of incompleteness. At 10 percent design incompleteness, unit-price contracts have the lowest expected total change in cost (8 percent). The lump-sum and cost-plus contracts had expected total changes of 9.0 percent each. The volatility of the lump-sum, unit-price, and cost-plus contracts from the expected total change was approximately 6 percent each (see table 1).

At 80 percent design incompleteness, unit-price contracts had the lowest expected total change in cost (22 percent). The lump-sum contracts had the greatest expected change in total costs (27 percent), while cost-plus contracts were expected to have a 23 percent increase in cost over the bid price. The volatility in the expected values was least for unit-price contracts (12 percent) and greatest for cost-plus contracts (16 percent). The lump-sum contracts' volatility from expected values was 14 percent.

Changes in Construction Schedule

The construction schedule is significantly affected by the level of design completeness and the complexity of the contractual arrangement.

Figure 3 indicates the schedule overruns resulting from simple contractual arrangements at different levels of design completeness. The construction duration increased by 23.5 percent at a 80 percent level of design incompleteness over the anticipated duration at 10 percent design incompleteness.

The construction duration of a complex project increased by 6.5 percent over a simple project at a design incompleteness level of 10 percent. For a complex contractual arrangement, the construction duration increased by 27 percent when the design incompleteness was 80 percent over the expected duration of a 10 percent design incompleteness project.

The Effect of Fast-Tracking on Total Project Costs

Figures 4 and 5 illustrate the effects of fast-tracking on total project costs for various contract types and contractual arrangements. A project requiring 8 months of engineering and 8 months of construction in a simple contractual arrangement at 10 percent design incompleteness was selected for analysis.

In simple contractual arrangements, the lump-sum contracts produced the lowest and cost-plus the greatest expected project costs when overall project time was reduced by 8 percent or less. When the overall time-reduction by fast-tracking was greater than 8 percent, cost-plus contracts produced the lowest overall cost.

In complex contractual arrangements, lump-sum, unit-price, and cost-plus contracts produced similar total project costs when the overall project schedule was reduced by less than 3 or 4 percent. However, when the overall project schedule was greater than 3 or 4 percent, the unit-price contracts produced the lowest overall total project costs and lump-sum contracts the greatest.

In the early stages of a project, the owner or his or her representatives make choices regarding contract complexity, contract types, and the level of design completeness at the start of field construction. These choices significantly affect the project's capital costs, construction schedule, and the associated risks. An owner must consider these effects in the early stages of a project. The premiums and risks associated with the choices made must be carefully weighed against the potential economic benefits.

The contracts described as lump-sum, unit-price, and cost-plus represent a locus of responsibility for project uncertainty and risk. The lump-sum contract, in principle, represents substantial risk allocation to the contractor. Cost-plus contracts represent substantial risk allocation to the owner. Unit-price contracts represent an intermediate allocation of the total risk to both parties. The quantity risk, within boundaries and depending upon clauses, is generally allocated to the owner, while other risks may be allocated to the contractor.

The apparent risk allocation appears to be valid when the project is highly defined. The lump-sum contract produced the lowest expected cost and the least cost risks in or with both the simple and complex contractual arrangements. Unit-price contracts also produced similar costs, but with a slight increase in the risks to the owner. Cost-plus contracts produced the highest expected costs and the greatest risk to the owner.

The apparent risk allocation by contract type appears invalid when the project is less defined and the results are significantly affected by contractual complexity. In simple contractual arrangements, the cost-plus contracts produced the lowest expected costs but the highest risk to the owner. The unit-price contract produced the second-lowest cost and the least risk. Lump-sum contracts produced the greatest expected costs and the second-largest risk to the owner. In complex situations, unit-price contracts produced the lowest cost and least risk to the owner. The cost-plus contract produced the second-lowest expected cost but the greatest risk, and lump-sum contracts the greatest expected cost and the second-greatest risk to the owner.

There is a relationship between contractual complexity and construction duration. Increasing contractual complexity

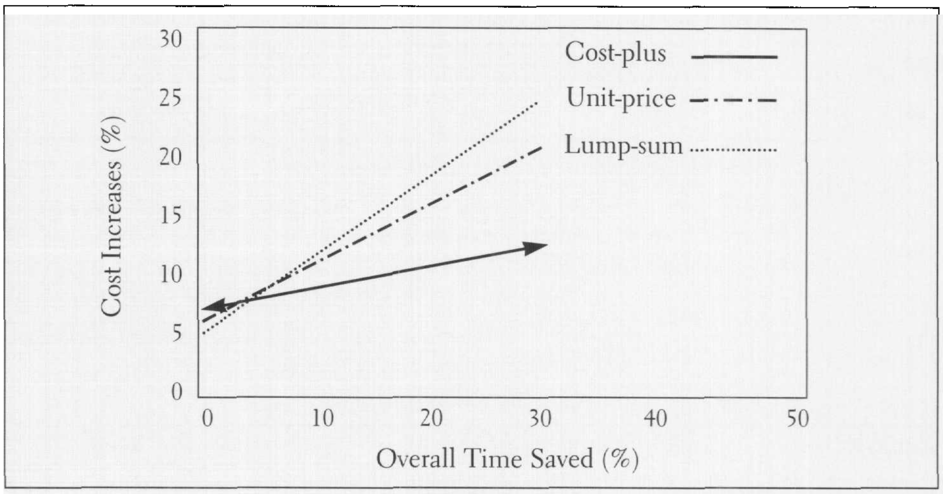

Figure 4—Cost Increases Versus Overall Time Saved by Fast-Tracking in a Simple Contractual Arrangement

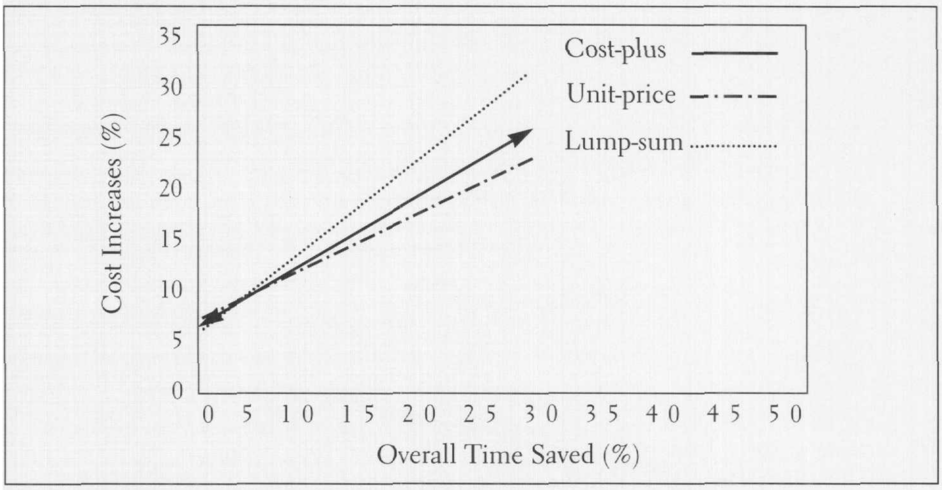

Figure 5—Cost Increases Versus Overall Time Saved by Fast-Tracking in a Complex Contractual Arrangement

increases the expected construction duration.

A preliminary review of the risk-project size relationship indicates similar and proportional patterns for both $20 million and $500 million projects. This leads us to the preliminary conclusion that there is no significant difference between the proportional amount of change in small and large projects. This finding is similar to that observed by CII [2].

These conclusions lead us to the following recommendations.

- To minimize total project cost and schedule duration, the owner should strive for a high degree of project definition. In highly defined situations, the owner should allocate, when reasonable and within the capacity of its contractors, a substantial proportion of the project risk.
- Fast-tracking produces less project definition at the start of construction and reduces the total project (schedule) duration. The reduced project duration increases total project costs and risks.
- The additional cost (premium) for fast-tracking paid by the owner must be carefully weighed against the financial benefits derived from earlier start-up and completion of a project.
- The premium paid and the associated risks (both cost and schedule) for fast-tracking are related to the types of contracts and the contractual structure selected by the owner.
- There is a premium—both in time and cost—associated with contractual complexity. Arrangements that can reduce the contractual complexity will reduce overall project costs and construction duration.
- In simple contractual arrangements, the lowest-expected cost but the highest owner risk are obtained with cost-plus contracts. The lowest risk is obtained with unit-price contracts. This assumes that the level of cost control imposed on the project is the same for all types of contractual structures.
- In complex contractual arrangements, the lowest-expected costs and least risk are obtained with unit-price contracts. However, as the level of complexity increases, there is an increasing need for alignment of interests and risk-sharing to minimize the total project costs and risks.

Additional research is currently being undertaken as part of this study to evaluate the interaction of contract types and arrangements, workhours, cost control, management and direct labor supervision skills, expected project costs, and the associated risks.

REFERENCES

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