The Engineering Economist, 49:327–337, 2004
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ISSN: 0013-791X print / 1547-2701 online
DOI: 10.1080/00137910490888075

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AN ANALYSIS OF CONTRACT COST PHASING ON ENGINEERING AND CONSTRUCTION PROJECTS

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The development and implementation of engineering and construction projects for new manufacturing facilities in the oil, gas, and petrochemical industry is largely contracted out. Progress and cost control by the owner is an intrinsic part of these projects. The results of an empirical analysis of payment and progress schedules for different contract types are presented, indicating a practice of advance payments on lump sum/fixed price contracts. The Value of Work Done concept and a normalized approximation function for progress control are discussed. The results provide guidance for progress management and contract cost phasing on engineering and construction projects.

The (capital-intensive) oil, gas, and petrochemical industry forms one of the world's largest areas of economic activity. Engineering and construction projects for new manufacturing facilities are an essential part of the business process of owners (operators) in the industry. Generally, these projects are large and complex with technology/engineering aspects playing an important part. The capital associated with a project for a single processing plant will in many cases be hundreds of millions of U.S. dollars. The time required for (technical) development and implementation of (major) projects is long; typically, 2–3 years and 3–4 years, respectively. Most of the work associated with project development and implementation is contracted out. A crucial element in developing the

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contracting strategy and tactics is the allocation of risk between the owner and main contractor.

Projects in the oil, gas, and petrochemical industry are inherently risky business ventures due to their size, complexity, and geographical location. However, the most important parameter is time. Circumstances change with time and so do the risks associated with a project. This is particularly relevant for projects with a long development and implementation time. "Most prone to escalation are the so-called 'long-haul' projects that require huge investment and yield no revenue until the work is finished. Long-haul projects are potentially fraught because: time = risk. Time changes the nature of risk" [4].

In this article we look at contracting strategies and contract cost phasing on engineering and construction projects for manufacturing facilities. We pay particular attention to "time-related" risks and we present the results of an empirical analysis of payment and progress schedules. The projects pertain to oil, gas, and petrochemical manufacturing facilities and cover a wide geographical area. In 70% of the cases the owner was a joint venture in which the Royal Dutch/Shell Group of Companies (Shell) participated as a shareholder; in the other 30% of the cases, Shell was the sole owner. The results do not only have relevance for the oil, gas, and petrochemicals industry but also for other capital-intensive industries and public sector projects with a long development and implementation schedule.

CONTRACTING STRATEGIES

During the last 10–15 years most owners have reduced their in-house project and engineering organizations and replaced these with external resources from engineering and construction contractors. The latter are currently engaged by owners for project definition (technical scope and certain other project dimensions) during development as well as for the implementation of projects. During implementation, some 20% of Total Installed Cost (TIC) is directly related to main contractor involvement; i.e., detailed design and engineering and project management. The remainder pertains to procurement of materials and equipment and (sub) contracts for construction work. See Figure 1.

On many projects, implementation is carried out under a Lump Sum/Fixed Price (LSFP) contract. With such a contract, the main contractor is paid a fixed contract sum for all engineering, procurement, and construction (EPC) work up to the moment of handover to the owner. The risk of the actual cost exceeding the contract sum is borne by the main contractor. If the actual cost of the work exceeds the contract

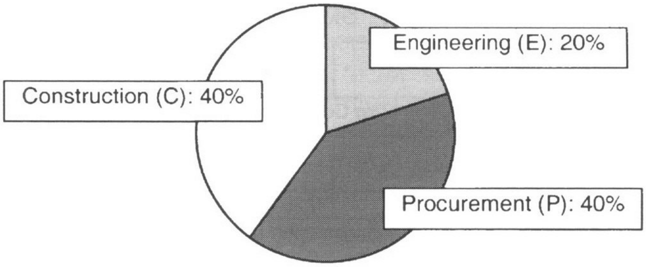

FIGURE 1. Typical work breakdown oil, gas, and petrochemical manufacturing facilities.

sum, the contractor has to accept a reduced profit or even a loss (or try to increase the contract sum through the contract provisions regarding changes in the work). This provides an incentive for efficient execution of the work. Also, LSFP contracts usually contain "liquidated damages" for performance shortfall and delay in completing the work, in discharge of the actual damages suffered by the owner. Liquidated damages have to be a reasonable forecast of the actual damages to the owner and are typically capped to limit the liability of the main contractor [3]. The premium associated with the main contractor carrying the implementation (capital cost) risk is inherently included in the contract sum. The size of this risk premium is dependent on the main contractors' assessment of the risks and on market conditions (i.e. competitive pressure).

Alternatively, the owner can employ a main contractor during implementation on the basis of a Cost Plus Fee (CPF) contract for engineering and project management. In addition to this CPF contract the owner has separate contracts with suppliers and construction subcontractors; the main contractor may enter into these contracts "for and on behalf of" the owner. See Figure 2. The main contractor is reimbursed for all his costs plus a certain fee; this may be fixed or a percentage of TIC. Contracts with suppliers and subcontractors are awarded at the appropriate time during project implementation; e.g., when the design and engineering have progressed sufficiently. This holds true for a CPF contract as well as an LSFP contract. The difference lies in the time at which the risk is "priced." With an LSFP contract, the main contractor is required to provide an ex ante guarantee with respect to TIC; i.e., the main contractor is acting as a "quasi-insurer" [7]. With a CPF contract the owner initially carries the overall project (capital) cost risk and in the course of project implementation this is (gradually) transferred to suppliers and construction contractors.

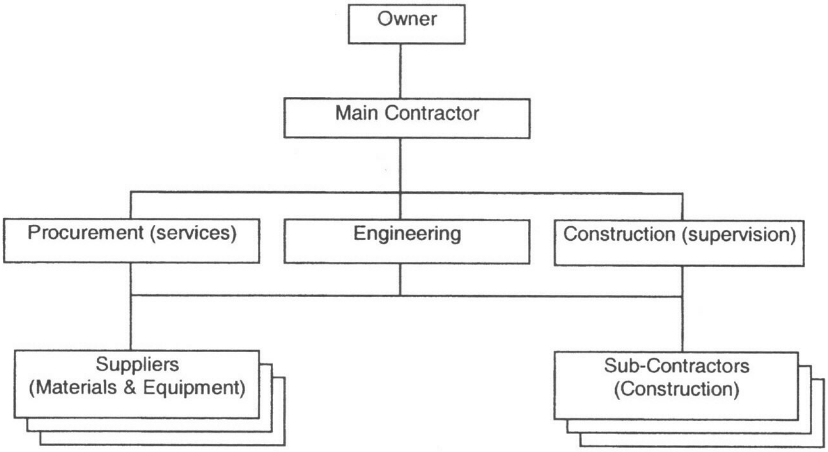

FIGURE 2. Typical project management organization.

Many owners (and third-party financiers) have a preference for LSFP contracts over a CPF contract, provided the scope definition is sufficient. On engineering and construction projects with a long project implementation time, however, a large number of different (and changing) risks exist and contracts can never be "complete," no matter how much ex ante effort has gone into project development. In this context, a contract is said to be complete when all parameters that are (or may become) relevant are taken into account [5]. Hence, the fixed price under an LSFP contract may prove to be illusory if risks materialize and lead to change orders and claims. Also, many LSFP contracts currently contain exclusions or limitations of the contractor's liabilities, particularly with respect to risks that are outside its control (e.g., wage increases) to limit the risk premium included in the contract sum.

Under an LSFP contract, there is an asymmetric information situation with the owner having only limited information about the actual cost. Furthermore, the owner is in a "hostage situation" as any disruptions such as delays are very costly (e.g., due to feedstock and/or product supply commitments) despite any provisions regarding liquidated damages. This is reflected in the common wisdom of project managers that "after the investment decision has been taken, every project becomes time driven" and "the owner has the money, the main contractor the time."

On CPF contracts, the asymmetric information situation does not exist, as (in theory) both owner and contractor are fully informed. The

Contractor's incentive to pursue change orders and claims is much weaker than under an LSFP contract; unfortunately, so is the (cost) performance incentive. In response to the latter, Cost Plus Incentive Fee (CPIF) contracts have been developed whereby the contractor's fee (profit) is subject to performance against a number of ex ante criteria, including overall project cost [1]. Whether or not the owner is indeed fully informed depends to a large extent on its project management capability. With a CPF contract, more active participation of the owner is required, particularly during the early phases of implementation when most of the contracting and procurement activities take place. With an LSFP contract the owner's contract management role is essentially limited to monitoring the main contractor's performance and pertains largely to change management.

These days, many projects are financed and third party financiers generally require securities, including the support of export credit agencies that have an impact on the overall contractual arrangement. These include direct agreements with the owner and the main contractor (and key suppliers and subcontractors as the case may be) and certain obligations with respect to the provision of information and restrictions related to changes in the contractual arrangements. The financiers' interests pertain to repayment of the loan and not to the overall (long-term) success of the project (including aspects such as realizing the project at the lowest TIC). Consequently, they are risk averse and look for risk minimization (e.g., through insurance), even if this results in cost that the owner considers to be uneconomic [6]. The financiers' requirements may restrict the owner's flexibility with respect to adopting a contracting strategy to minimise overall project cost.

It is noted that in addition to LSFP and CPF type contracts, a large number of "hybrids" are used, particularly with respect to contracts with suppliers and construction contractors (e.g., unit rate contracts). Also, the type of contract with the main contractor may change during project implementation, e.g., a CPF contract may be converted into an LSFP contract by mutual agreement.

COST PHASING

Irrespective of the contracting strategy, project management inherently involves progress monitoring/control of a wide range of different activities. This can be done through the concept of Value Of Work Done (VOWD): an assessment of the goods actually received at site and the services physically completed, all expressed in monetary terms. Other essential control elements are: (a) quality of work, (b) the value of goods and services that have been committed but not yet received, (c) the (estimated) value of uncommitted work, and (d) payments.

Contracts usually contain a payment schedule based on: (a) milestones and/or (b) progress. Milestones payments are here defined as those pertaining to (a) time (e.g., monthly payments) and (b) the achievement of certain events (e.g., main equipment delivered on site). With progress payments, the schedule is linked to actual (physical) progress of the work, as for instance measured by the VOWD.

A disadvantage of a milestones payment schedule lies in the fact that it is established ex ante; i.e., schedule risk considerations are incorporated in the payment schedule. On the other hand, establishing (actual) progress/VOWD accurately requires considerable effort and is often difficult, particularly on LSFP contracts where the information available to the owner is limited (see also Contracting Strategy above). Therefore, LSFP contracts usually contain a milestones payment schedule with certain rights for the owner to withhold payments, or part thereof, in the event of large differences between the milestone payments and actual progress. CPF contracts, by their very nature, always contain progress payment schedules.

We have conducted an analysis of 10 milestones payments and 10 VOWD schedules, derived from 17 different (major) oil, gas, and petrochemical projects. The main characteristics of the projects are as follows:

TIC Range:	approx. 50–2,500 [USD million]
TIC Mean:	approx. 1,000 [USD million]
Location:	Western Europe: 30%; Africa: 20%;
	Middle East: 20%; Asia: 30%;
Milestones Schedules:	LSFP contracts
VOWD Schedules:	LSFP contracts and CPIF contracts

The 20 data sets are shown in Figure 3. The implementation time (i.e., elapsed time) and capital cost phasing of all projects were normalized to facilitate a comparison between the various projects. Typically, project implementation has a (relatively) slow start followed by a period of steady progress leveling off in a gradual completion of the project. Graphically, this results in the characteristic S-curve.

A mean VOWD schedule was calculated on the basis of the 10 VOWD schedules in the data set and a mean milestone schedule was calculated on the basis of the 10 milestones schedules in the data set (see Figure 3 above). Subsequently,the following normalized functions of the mean

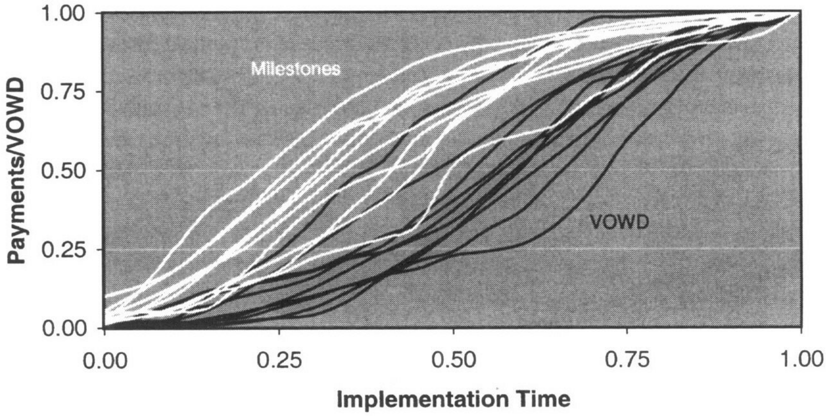

FIGURE 3. Cumulative milestones/VOWD schedules.

VOWD schedule and the mean milestones payments schedule were calculated through regression analysis:

$$\text{VOWD:} \quad y(x = -3.32x^4 + 4.60x^3 - 0.61x^2 + 0.32x \quad (1)$$

$$\text{Milestones:} \quad y(x) = 3.64x^4 - 8.45x^3 + 5.49x^2 + 0.28x + 0.04 \quad (2)$$

where x-normalized, elapsed implementation time.[1]

The fourth-order polynomial functions were selected in view of the characteristic S-curve. The functions were validated through a comparison with the cash outflow on LSFP and CPF contracts given by Camps on the basis of 4 major oil and petrochemical projects [2]. Camps reports his findings in the form of two series of discrete values during the implementation time. One series gives the average cash requirements of two projects executed on a LSFP basis and the other the average of the cash requirements on two projects executed on a CPF basis. By definition, the CPF data points represent actual cash requirements. The cash flow on a LSFP contract on the other hand reflects the commercial arrangement that has been agreed. Figure 4 shows the data points of Camps together with functions (1) and (2) of our research. Data analysis shows a very good correlation with the coefficient of determination R^2 for the VOWD/CPF case being 0.999 and for the milestones/LSFP case being 0.997.

[1]For $0.0 < x < 0.1$ and $0.9 < x < 1.0$ the values are very project specific and consequently the accuracy of the approximation functions (1) and (2) is strongly reduced in these areas.

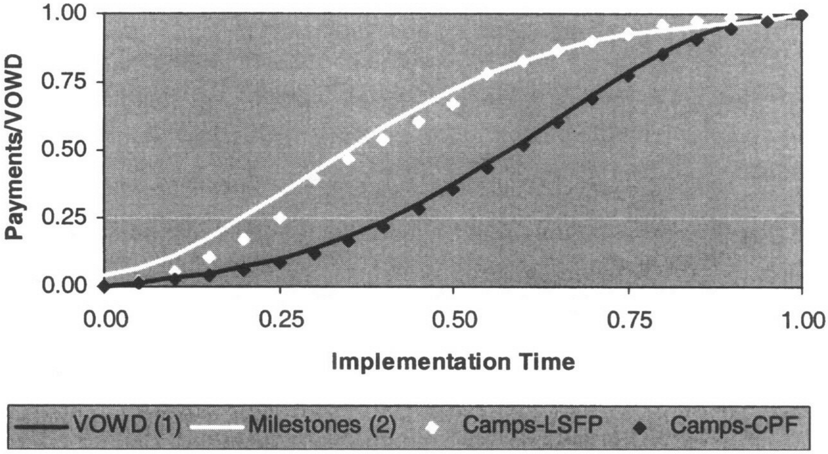

FIGURE 4. VOWD function (1) and milestones function (2) together with independent data points by Camps [2].

The results suggest that:

(1) VOWD as defined above, provides a fair representation of the actual 'cash flow' requirements of a project.
(2) Function (1) provides a generic approximation of VOWD schedules and function (2) is typical for the milestones payment schedules used on LSFP contracts.
(3) A practice seems to exist of advanced payment (vis-à-vis the VOWD) through the milestones schedules used on LSFP contracts.

The cost of advance payments under a milestone schedule (vis-à-vis the actual cash requirements as represented by the VOWD schedule) depends on: (a) the level of advanced payment, (b) the composite escalation (interest) rate used to establish the time value of money, and (c) the project implementation time. For example, using the mean VOWD and milestone schedules of functions (1) and (2) and assuming a composite escalation rate of 10% per annum and an implementation time of 3.5 years, the additional cost of advanced payment on the basis of a Net Present Value (NPV) calculation equals some 6% of TIC. For major projects this constitutes a significant amount of money.

VOWD as defined above, is not dependent on invoicing and payments. Some work elements are classified as VOWD before payment of the work takes place. On other elements payment occurs (partly) before the work item is classified as VOWD; this particularly relates to equipment items with a long delivery time (e.g., large gas compressors) where the purchase price is largely paid before delivery on site. A sensitivity analysis has been made of the effect payment timing on the VOWD. This analysis (not included in this article) confirms that, on balance, VOWD provides a good measure of the cash flow requirements on a project.

A certain level of advanced payment on LSFP contracts may be beneficial. The owner's cost of capital is generally lower than that of the contractor and an advanced payment schedule may enable a contractor to offer a lower contract price. To capture these potential benefits, the milestones payments schedule has to be part of the bidding and evaluation process and the owner has to indicate this clearly in the invitation to bid.

It should also be recognized that high levels of advanced payment have a number of drawbacks. At 50% of the implementation time, the mean cumulative VOWD value is approximately 38%, whereas the mean cumulative milestones payments are approximately 72%. This has a negative impact on the contractor's motivation. Also, advanced payment constitutes for the owner an increased risk with respect to contractor insolvency during the execution of the work. If a (major) capital investment project is carried out by a joint venture of contractors, this can (partly) be mitigated by "parent company guarantees" and "joint and several liability" provisions in the contract. Finally, the generally accepted accounting principles (GAAP) and other accounting standards include the principle of accruals/matching; i.e., costs have to be matched with the associated benefits. If a certain capital investment project constitutes a major part of the overall capital expenditure of an owner, the impact of (advanced) payment schedules with respect to GAAP has to be taken into account.

CONCLUSIONS

Engineering and construction projects with a long development and implementation time are risky business ventures. Most of the work is contracted out. While there are many different factors that have to be taken into account when determining the optimal contracting strategy for a specific project, a key consideration is the allocation of risk between owner and (main) contractor. Many of these risks are time related.

In this article we have looked at some of the generic considerations with respect to risk allocation under LSFP and CPF contracts for engineering and construction projects. The main difference between the two approaches lies in the time at which the project risk is priced. Owners with the required project management capability as well as the ability and willingness to accept financial risks can realize projects through a CPF contract at lower TIC than through the traditionally preferred LSFP contract. Indeed, increasingly owners are forced to accept more risk (both in LSFP as well as in CPF contracts); drivers include: the size, complexity, and geographical location of new manufacturing plants and the (lack of) financial strength of contractors. This requires more involvement of the owner with respect to project management.

On projects with a long development and implementation schedule, the contract cost phasing can have a significant effect on the TIC (based on an NPV calculation). Our analysis suggests that (a) VOWD provides a good measure of project cash flow requirements, (b) projects typically follow the same generic VOWD curve, and (c) advance payment appears to be common practice on LSFP contracts. Advanced payments may reduce the TIC to the owner under an LSFP contract, provided the (advanced payment) milestones schedule is timely incorporated in the tendering process. Other aspects that have to be taken into account are contractor motivation, the risk of the contractor going bankrupt, and GAAP. Both owners and contractors will benefit from making contract cost phasing an integral part of the bidding and contracting process, rather than an afterthought.

ACKNOWLEDGEMENTS

The authors thank Shell Global Solutions International for its assistance in conducting this research and its permission to publish the results.

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BIOGRAPHICAL SKETCHES

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