Designing a Solution
to Grandma's Puzzle

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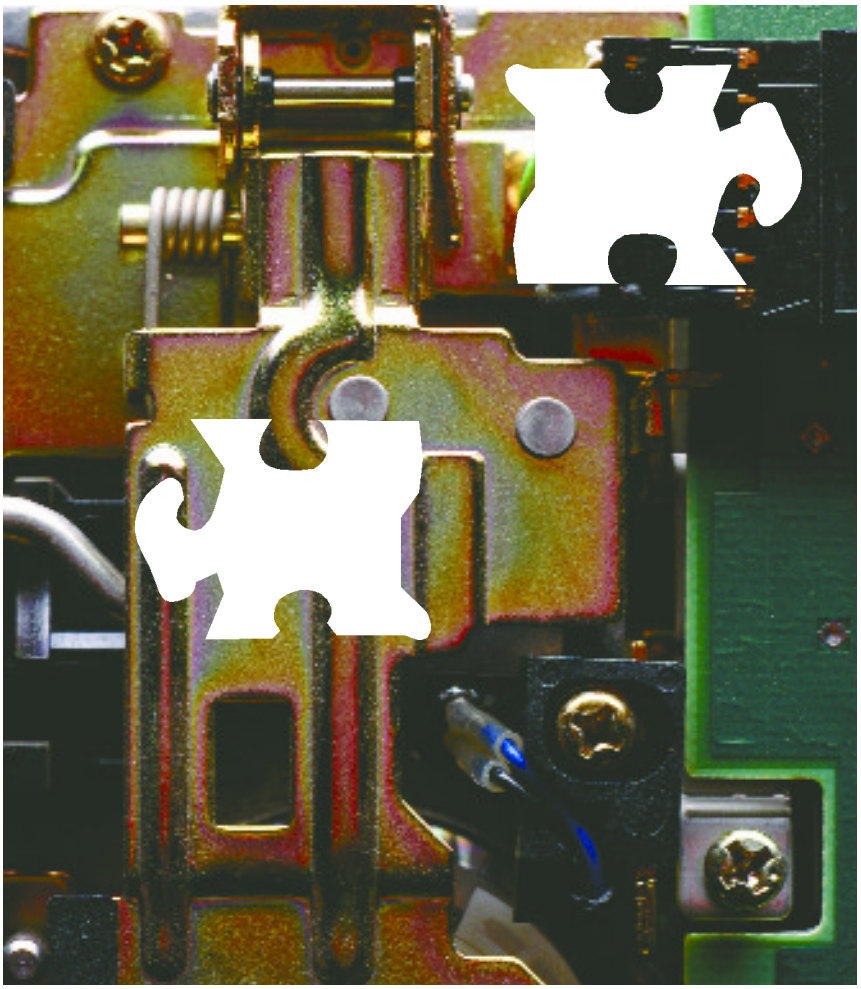

Depressed oil prices and the desire of shareholders to maximize returns on their investment are fueling an ongoing quest for cost reduction in the offshore oil and gas business.

These investments are usually discrete field development projects, that can be quite complex, particularly when they are located in deep water which now can be in excess of a mile.

Two such projects rarely are alike due to the specific circumstances of reservoir and environmental conditions, and the water depth and other unique circumstances mean that often such a development is of a prototype nature involving unusual technical challenges.

Additionally, the drive for cost reduction and the increasing complexity of the projects are counter to each other, and make selection of the most successful approach to project execution more difficult.

Departing From the Traditional Approach

The traditional approach to a complex exploration or development project is to have a designer develop the technical solution, and define this in considerable detail in the form of drawings and specifications. This then forms the basis for procurement of materials and the contracting of construction of the project by other parties.

This traditional approach has sometimes led to higher costs, when the design gave insufficient consideration to the available construction equipment and methods.

One solution has been to develop new contracting models that attempt to combine the design and construction responsibility, aimed at improving

and facilitating construction, thus gaining cost efficiencies through the optimal use of construction knowledge and expertise in the early phases of a project.

In addition, the juxtaposition of design and construction responsibility eliminates interfaces between engineering, procurement and construction (at least from the owner's perspective), concentrates liability, and often is expected to reduce the time schedule.

Initiating An EPC Project

These turn-key projects, known as Engineer-Procure-Construct (EPC) projects, are generally initiated in one of two ways. In one approach, a conceptual design done by the owner or his consultant is turned over for detailed design and construction to an EPC contractor or consortium selected after a competitive bidding round.

Alternatively, competing construction consortia may be asked to participate in a design competition which includes the conceptual design phase, and is intended to result in firm competitive price proposals.

This second approach, however, has led to a number of projects that ended up with large budget overruns, were late in being completed, and ended up in a loss for the construction contractor.

Understanding What Went Wrong

Since failure was obviously not the intent, we must try to find the reasons for it, and what can be done to prevent it. To answer this, we must understand the nature of the projects we are talking about, which can be described as follows:

- Many of these projects are "one-shot" undertakings. They can be compared to a prototype development in other industries, except that the design will certainly not be mass-produced.
- Due to this prototype character, projects must often be developed from a very limited basis, using known technologies in other applications where possible. This makes the estimation of the realization process difficult in terms of schedule and cost.
- Since this prototype is not mass-produced, the "development budget" is normally low, usually less than 5 percent of the project cost. This compares to multiples of 1000 or more of unit cost for commercial products where trial and error is often an integral part of the development process.
- These projects are always client specific in that they must provide a solution to a client specific problem. The culture and prior experience of the client organization tends to lead to specific demands that require unique rather than generic solutions.

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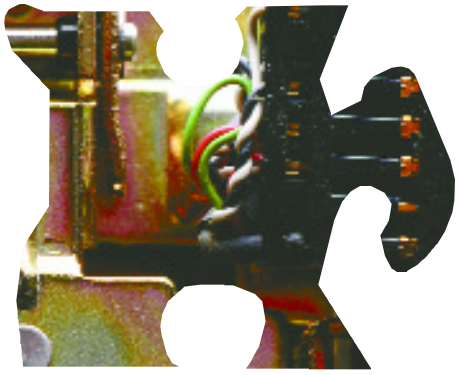
This is an unwise, but frequently



used approach. The fallacy of this thinking can be illustrated by the following parable.

Grandma's Puzzle

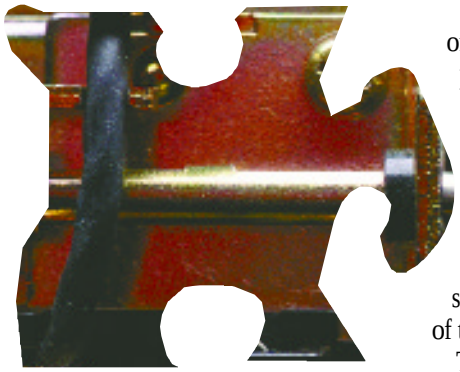
A man would like to give his grandmother a jigsaw puzzle for her birthday. Since she is too old to do one herself, he identifies her favorite puzzle and decides not only will he make it up, but he'll mount and wrap it as her gift.

But he's a busy man, and the day before Grandma's birthday party, he realizes he must buy the puzzle that evening and then engage a third party to produce it by next evening.

He contacts two providers, telling both service companies that the puzzle consists of about 500 pieces, that it has to be solved, pasted on a board, cut in four pieces, and wrapped for delivery within six hours so he can hand it to Grandma at her birthday party.

Both companies give him a price after quickly developing a work plan consisting of the following steps:

1. Make up the puzzle on a board
2. Put a second board on the completed puzzle
3. Flip the whole thing



4. Remove the first board
5. Spread glue on the back of the puzzle
6. Place the board back on the puzzle
7. Wait five minutes
8. Cut the edges
9. Cut the puzzle assembly in four
10. Wrap the pieces
11. Deliver to the client before he goes off to Grandma's party

The plan has two main phases, one is to complete the puzzle, the other is to do the "real" fabricating work of mounting, trimming, cutting and wrapping.

The Job Begins

One contractor gives a satisfactory fixed price and gets the job. He figures that the puzzle can be solved in three hours. He anticipates three more hours for the "real job" of pasting, trimming and packaging.

The most experienced paster in the company is appointed project manager and he in turn selects specialists in pasting, cutting, packaging and puzzling.

The project manager is familiar with good production rules: organize according to discipline, more people mean more progress, time pressure works, competition is desirable, and use proven methods only (no trial and error).

The puzzler launches into the job with vigor. But soon, reality rears its head: after three hours only 20 percent of the puzzle is ready! Now the initial production schedule is off.

Worse, the pasters and cutters, who are experienced doers, become restless when it's time for them to perform and their product isn't ready. Convinced that they know how to get the puzzle solved, they keep getting in the way of the puzzler.

They move pieces around and get upset because the puzzler is trying to match pieces rather than forcing them into their "obvious" place. Of course, the completed 20 percent consists of the edges and the pieces with easily recognizable patterns.

At this point, the project manager sees the large number of unsolved blue sky and green grass pieces and calls for more puzzlers. An hour later, 30 percent of the puzzle is done.

But with only two hours left until deadline, the pasters insist that they start their work; they cannot wait any longer and meet the deadline.

They take away the edges and some small clusters and paste these on the board. As they work, they find that the puzzlers put some of the pieces in the wrong place, so these now need to be reworked with great care.

By this time everybody is in each other's way, and nerves are getting frayed.

With two hours left, the project controller determines that there are 600 pieces instead of 500. The project manager throws a tantrum, grabs 100 pieces and throws them in the waste basket, exclaiming that he contracted for pasting 500 pieces, and no more!

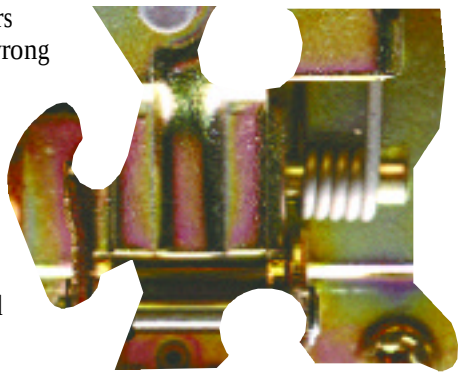
After an hour of trial and error, reality again is manifested: the dispatched 100 pieces are, of course, essential to finishing the puzzle. They are retrieved by the project manager himself and cleaned of coffee stains.

Now, virtually on deadline, the project manager goes and asks the client for more time and money. The client sees what is going on, and approves another hour, but no more money since the contract stated "about 500 pieces."

The deadline comes and goes, with the project team grimly back on track but now disheartened. After 12 hours, a 100 percent increase over the contracted time, the puzzle is ready to be shipped.

Of course, Grandma's birthday party is over, but the puzzle, beautifully solved, mounted and wrapped, is presented to the client, who

One solution has been to develop new contracting models that attempt to combine the design and construction responsibility, aimed at improving and facilitating construction, thus gaining cost efficiencies through the optimal use of construction knowledge and expertise in the early phases of a project.



must deal with his tardiness in his own fashion.

Later, the contractor seeks additional compensation, but is rejected. In arbitration, a partial award of extra funds is made, at which time all have lost money and gained a bad experience.

The Lesson Learned

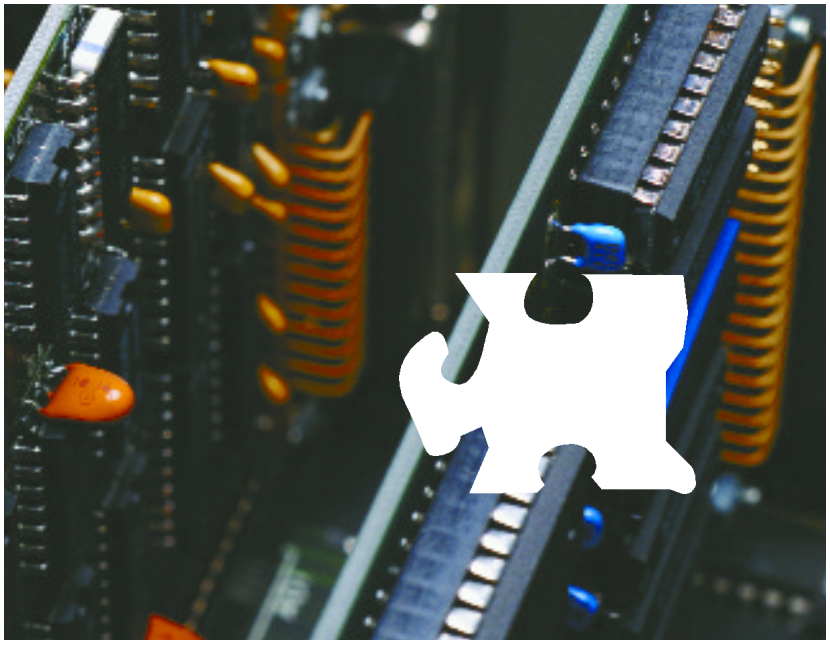
So what is the lesson? First, the client could have thought earlier of his grandmother's party, realized he needed additional resources, and engaged an outside party to assist him at that time.

His first charge would be to a designer – the puzzler – who could be assigned to solve the puzzle at a more reasonable pace and a more reasonable cost.

Then the puzzler could mark the pieces and note their position on a drawing. All of this would be possible at lower cost and without an army of pasters and cutters hanging around creating diversions.

When the drawing was supplied to the contractors bidding on the pasting-cutting-shipping job, it would have allowed them to know exactly how many pieces would be involved, and where to put them.

The actual work would easily have been accomplished in the available time, and the bid prices would probably have been lower.



Under the circumstances, the time allowed for puzzling was too short. Marshaling more puzzlers might have helped, but only if a clear puzzling process had been defined so that added puzzlers could work without getting in each other's way.

A lack of time and resources devoted to initial planning resulted in a botched job with time and cost overruns that hurt everyone involved.

The EPC Analogy

The above story is analogous to an EPC contract where the general performance objectives are defined (about 500 pieces to be pasted on a board which then must be cut and shipped), but where the details of the work are left to be determined.

The contractor taking on a complex project could make ample allowance for unknowns and increase his price and delivery schedule accordingly (even though he thereby increases his risks of losing the bid.)

Now, virtually on deadline, the project manager goes and asks the client for more time and money.

Another alternative for the contractor would be to spend his own time and money to define very clearly what needed to be done at each step of the way so his cost and timing estimate is accurate (for which he has no time and budget). This approach leads to another observation about this type of projects.

Owner companies would like to pass the responsibility for the successful completion of a project to someone else, which is the essence of an EPC contract model. However, until the price is established, and the project sanctioned, there is no budget for a thorough engineering effort to define the work to be done in detail; in fact, the EPC model assumes that economies can be achieved by having the constructor responsible for the design, so he can adapt it to his preferred construction methods which is presumed to reduce cost.

In reality, the constructor is often not well equipped to do the front end engineering work, and tends to want to get into "just doing the job" (forget the puzzlers, start pasting). This has been the cause of significant cost overruns and completion delays on large projects amounting to the loss of hundreds of millions of dollars.

The root problem with these failures

is that inevitable risk and uncertainty are incorrectly assessed and/or poorly managed.

Project Stages

A complex offshore development project goes through a number of stages that can be defined as concept development, design and implementation. The factors contributing to the success of such a project were the subject of a doctoral thesis by Dr. H.A.J. de Ridder at Delft University of Technology in 1994[1].

His conclusions included the following. During the concept development stage, the level of uncertainty with regard to the nature and cost of the final solution is high, and diminishes as the project progresses through subsequent stages.

The relative level of effort and cost is lowest at the early stage of the project, since this consists of mostly brainpower, increases slowly during the design stage, and rises rapidly when the implementation takes place.

These trends are illustrated in Figure 1. It shows how the estimate of actual effort needed to complete a project increases through the various phases from the initial estimate to the final actual effort, as uncertainties due to inaccurate problem definition and incorrect perception of the end result are gradually resolved. This increase in effort is usually covered by a contingency added to the initial estimate, but even this additional allowance will normally not be correct.

The figure also illustrates how the design phase is the most effective place to reduce uncertainty in determining the final effort, so that there is little uncertainty left at the start of the implementation phase.

It follows that when a project is contracted on an EPC basis, with only the concept development completed, the contractor has to assume a high level of risk.

As the project becomes better defined during the design process, the total estimated effort (cost and time) to complete the project increases.

If costs exceed the allowance the EPC contractor made in the bid price, and assuming he wants to stay in business, either he must increase his productivity (getting the work done with less effort) or the goals need to be adjusted (getting less done).

The EPC contractor may have the ability to affect his productivity, but adjusting the goal is not within the control of the designer or implementer – it is the prerogative of the owner.

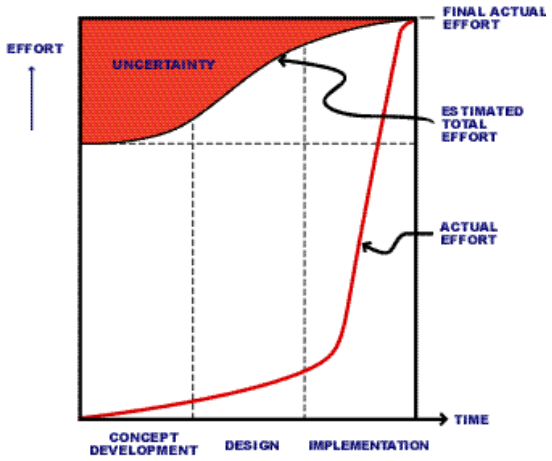
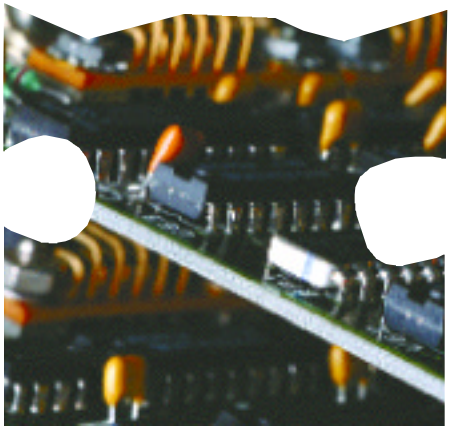


FIGURE 1

Design Competition Drawbacks

As mentioned previously, a design competition, where several potential EPC contractors are asked to develop concepts and price these, is based on the assumption that the winning contractor will produce the lowest cost solution because he will optimize the use of his equipment.



However, this means effectively that he starts the work during the concept development phase, where the level of uncertainty is higher. It also tends to result in a number of concepts that are quite varied and difficult to compare in terms of ultimate effectiveness in meeting project requirements.

Frequently, good ideas are generated by the various bidders, but only those of the successful bidder can be applied if fair contracting is practiced.

The reasons why there is uncertainty regarding the efforts required to complete a project stems from the difficulty in stating the problem to begin with.

Defining The Problem

If we define a project as the implementation of a solution to a problem, then the first thing that needs to be clearly defined is the problem, that is the actual and the desired final state. As an example, let us assume that oil has been discovered in 5,000 feet of water off the west coast of India, where little prior oil development has taken place.

Based on seismic surveys and three exploratory wells, the geologists estimate a field exists that contains 300 million barrels of recoverable oil

(this is a guess, and they may be off). The production per well is projected at 8,000 barrels per day, based on the perceived permeability of the oil-bearing rock.

The oil properties are determined from tests on oil samples recovered during drilling, but the accuracy thereof is influenced by the way the samples were obtained, the degree of contamination of the samples, and how they were protected during transport.

The ocean floor is thought to be rather smooth and from borings done during drilling some preliminary soil properties have been determined. There is no reason to believe that there is any significant ocean current. This, then is the actual state.

It is obvious, however, that there are a lot of uncertainties resulting from estimates, guesses and untested assumptions, which means we can only speak of a "perceived actual state" which may well be different from the actual state, and which we may not learn until later.

The oil company believes there is sufficient justification to develop this oil field and produce and export 80,000 barrels per day for 15 years. The facilities required to accomplish this represent the desired state.

The discrepancy between the perceived actual state and the desired state is the problem to be solved. This situation is illustrated in Figure 2.

There also may be a difference between what the project goal is stated to be, and the actual outcome. Further delineation drilling, detailed seabed surveys and other data gathering after the start of the preliminary engineering work may indicate that the production levels per well ca not be achieved without pressur maintenance, or a change in the legislative climate may require that a given percentage of the project facilities are manufactured locally where efficiency is lower.

While the differences between the actual and desired future states may be the responsibility of the owner, the solution developed by the problem solver needs to be able to accommodate the resulting changes, further complicating the problem solving game.

Thus, the design process of a frontier type project is a difficult one, not only due to poor definition of the problem (current state and future state subject to inaccuracy and change), but because many of the project requirements are conflicting, and the solution is complex, consisting of many elements with non-simple interactions.

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Timing and Pricing

Creating an efficient design becomes an iterative search process to harmonize the intangibles within the project. The successful outcome of this process is reached when problem and solution are in harmony, and the design is fixed through specifications, drawings and quantities.

Such should be the situation at the end of the design phase. It is important that the designed solution can be implemented efficiently, meaning that methods and equipment needed to successfully achieve the implementation of the project

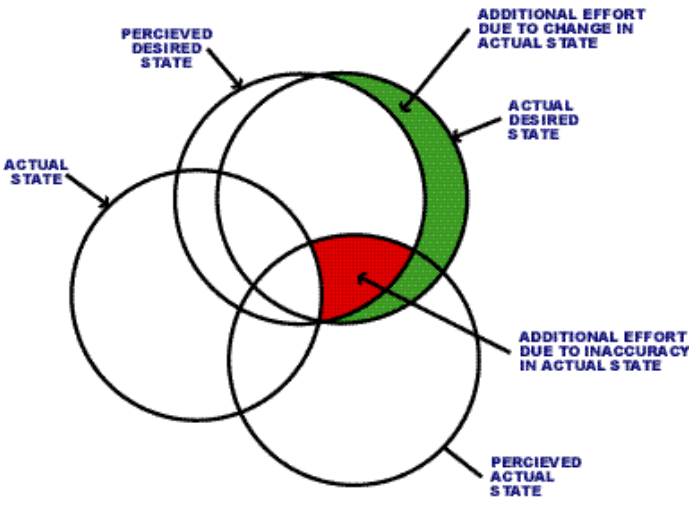
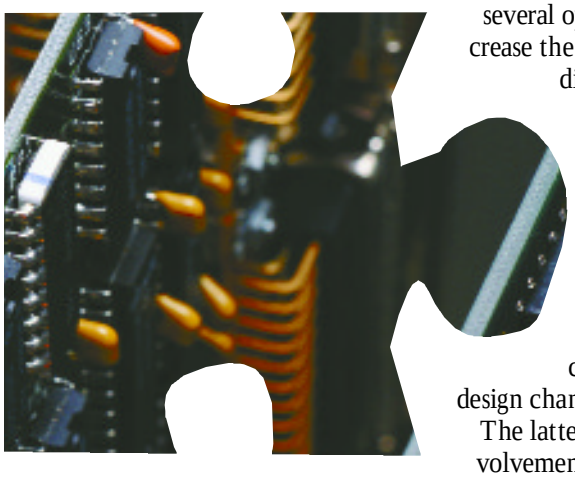


FIGURE 2



are taken into account. At this point the level of uncertainty is reduced to a minimum, and the implementation phase can start with clear objectives and resource requirements (read: lump sum fixed price).

The practical meaning of the above is that the end of the concept development phase is not a good time to expect firm lump sum price proposals; there is simply too much uncertainty. A contract will need to have provisions for adjustments depending on the changes in estimated total effort.

While it may be argued that a contractor can make a contingency provision in his bid price, for a complex project this is not in the interest of either the owner or the contractor. It is either estimated too high, in which case the owner pays too much, or it is too low so that the contractor loses.

Dealing With Overruns

If the estimated total effort were to rise beyond an agreed level, there are several options. One is to increase the efforts, i.e. approve additional budget. In case the owner rejects such extra costs, he may either accept a less than 100 percent solution, or alternatively the productivity may be increased by working more efficiently, or by making design changes.

The latter case requires the involvement of the implementation contractor and designer, and it makes sense to have a contractual arrangement that provides incentives for these parties to be creative.

Another conclusion relates to the relative accuracy of total estimated effort throughout the project life. Since concept development leads to limited reduction of risk and uncertainly (it only defines the general solution), it is unrealistic to expect a cost estimate at the end of a conceptual design phase of plus or minus 10 to 15 percent, although sometimes this is precisely what is expected.

The only solace for the concept developer is that there is no absolute verification of that figure until much later.

If a contractor who enters into an EPC contract at the completion of the concept development looks at this as a construction project, as is often the case, he will overlook the uncertainty left in the total estimated effort, and bid too low.

Such a misperception will start with an underestimation of the required design effort (time and cost), leading to an underestimation of the total effort required for project implementation.

The contractor will tend to treat the result of the conceptual phase as if these were drawings and specifications, the normal input to the construction phase, rather than a statement of desired performance of the completed system.

The consequences of this gap in perception depend on the type of contract. In case of a fixed-price contract, it will lead to an excessive overrun in effort, which will lead to claims and inevitable acrimony.

To minimize potential overruns in effort, some sort of incentive model is preferable for EPC contracts. It could be a fixed fee type, which would allow recovery of additional direct costs only beyond a target cost; or an incentive contract with a risk-reward element where the contractor receives part of the savings when he comes in under budget, but may lose his fee or profit in case of overruns.

The key to a successful model is the selection of the target cost at such a level that there is a realistic chance for being below budget in order for the incentive to have meaning.

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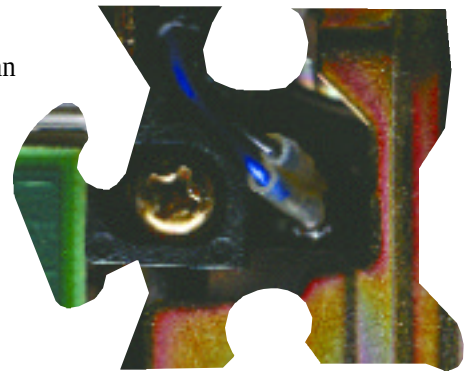
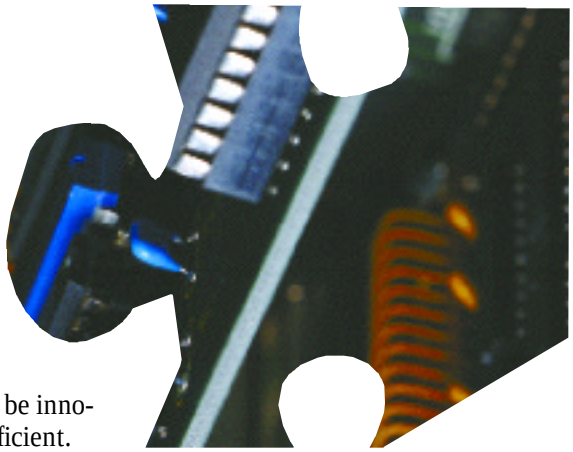


For a successful project, one can stick to the traditional approach of developing complete project definition through design before contracting for implementation.



Conclusion

At the start of a complex offshore oil and gas project the estimated effort required for its complete implementation is inherently uncertain. This uncertainty gradually is reduced throughout the project life, but most of this reduction happens in the design phase.

EPC contracts are typically awarded before the design phase, after only concept development has taken place. The resulting uncertainty in total required effort stems from the inaccuracies in definition of the actual state (design conditions) and the desired final state. Resolving these inaccuracies and other conflicting project requirements normally occurs during the design phase, but only if this is given sufficient attention.

Construction companies often tend to view the concept definition as the design and underestimate the engineering effort remaining. This leads to further changes and additional costs.

For a successful project, one can stick to the traditional approach of developing complete project definition through design before contracting for implementation.

Alternatively, an EPC model can be used provided that the EPC contractor is encouraged and given the opportunity to complete a thorough design effort, using the assistance of an experienced designer where needed.

In any event, it should be recognized that skimping on budget during the concept development phase is false economy, since the more information can be provided to the EPC contractor, the better his bid will be in terms of price and quality of solution. The contract should include incentives for the contractor and his team to be innovative, effective and efficient.

With this approach Grandma will get her puzzle solved and delivered on time for the agreed price. ■

[1] Ridder, H.A.J.de; Design and Construct of Complex Civil Engineering Systems; Delft University Press 1994.

Mr. Timmermans has more than 27 years experience in the oil and gas industry specializing in offshore engineering and construction disciplines. He is a recognized authority on design and installation techniques for offshore pipelines and design of pipeline construction equipment with emphasis on extreme water depths and arctic conditions. He has written and presented numerous technical papers and holds several patents. Prior to the formation of INTEC Engineering, Inc., Mr. Timmermans worked for a consulting firm specializing in offshore pipelines for twelve years. He worked initially in The Netherlands for this employer and played a major role in lay barge design activities. He was subsequently appointed Chief Engineer with responsibility for engineering offshore pipelines, risers, structures and pipelaying systems. In 1975, he established the Houston engineering office and managed this office until early 1984. Prior to this period, he worked as a Project Engineer for Bechtel and as a technical assistant at the Civil Engineering faculty of the Technische Hogeschool, Delft. Mr. Timmermans has actively participated as Project Sponsor in many of INTEC's projects, with responsibility for quality assurance and compliance with client requirements. This has included projects in deep water such as the Vancouver Island Pipeline Project and several other deep water and arctic projects. He has also taught courses in marine pipeline engineering and construction methodology to engineers and scientists of national and international oil companies.