Improving Construction Cost and Schedule Performance Through Risk-based Estimating and Contracting

By Kish Khemani, Neal Walters and John Wolff, A.T. Kearney

Despite the recent buzz surrounding nuclear power generation, project owners and financiers are reticent to invest billions in projects that run a high risk of being well over budget and coming online significantly late. While some degree of cost and schedule uncertainty is inevitable with highly complex, multi-year projects that deploy new technology, the question becomes how can the industry predict financial and schedule impacts of these uncertainties and employ mitigation strategies to limit their impact.

The industry’s poor track record of construction budget and schedule performance fuels this anxiety, to the extent that the potential for continued poor performance may very well jeopardize the anticipated nuclear renaissance. Figure 1 shows recent examples that illustrate a pervasive pattern of poor performance across a variety of factors:

- Geography—With the notable exception of some new capacity in China, cost and schedule over-runs have been pervasive in all regions
- Technology—No major technology provider has been immune
- Project Type—Both new construction and major refurbishment projects have been impacted.

We believe that through better characterization, segmentation and management of risks, project owners can stem this tide and achieve greater predictability and improved performance.

Nuclear power generation facilities are comprised of a combination of several complex systems and subsystems that span the spectrum of technical complexities, design maturities, supply market characteristics and regulatory requirements. While some of these risk drivers are largely a product of the environment in which the nuclear industry operates (for example, regulatory and supply market risk), many are inherent within the facility and are under control of project teams.
owners (for example, technical risk and design immaturity).

Attempting to manage across this spectrum with a single approach will result in challenges and issues that are unwieldy and poorly understood. Yet, project owners often attempt to manage projects at the “macro” level with broad-brush approaches. Instead, breaking down projects into systems and subsystems (“building blocks” or “modules”), characterizing their unique risks and developing tailored management approaches can enable project managers to more effectively manage a project’s budget and schedule.

A critical piece of the puzzle is to ensure that three key elements of project planning—risk identification, cost/schedule estimation and contracting—are fully coordinated and aligned to achieve common goals:

- Increase predictability of cost and schedule
- Minimize project risks to reduce their likelihood and mitigate the magnitude of consequence
- Offload risk the supply base, where appropriate.

If well executed at the onset of project planning, coordinating these three elements can significantly improve project performance.

**ESTIMATING, RISK AND CONTRACTING**

Cost and schedule estimation, risk identification and risk management can play complementary roles in laying the foundation for cost-effective project management. Initial cost and schedule estimates highlight potential bottlenecks and high cost items.

Risk identification can inform contracting decisions and provide input into creating risk-adjusted or “probabilistic” cost and schedule estimates. Smart contracting can reduce the cost of the project, assign risk to partners that can control it and drive desired behaviors to mitigate potential cost and schedule uncertainties throughout project execution. Too frequently these three functions are managed with little or no coordination and their complementary power is never realized.

**Breaking it down into manageable pieces:** Nearly all major capital projects are comprised of several complex systems and subsystems. These “modules” span the spectrum of technical complexities, design maturities and supply market characteristics. Despite this reality, project planning often remains at the project-wide “macro” level; but contracting approaches developed at a macro level can’t adequately address
specific risks. Further, over-bundling of project contracts often results in unnecessarily narrowing the supply base to just a few suppliers that can provide a turnkey solution, thus limit bargaining power. Cost and schedule projections developed with cost estimating factors at the macro level (for example, cost per installed kilowatt) may provide directional estimates, but do little to highlight areas of potential concern or opportunity. Finally, risk identification at the macro level ignores that it is often a “butterfly effect” of seemingly small-scale risks that cripples project budget and schedule performance.

In short, attempting to manage large projects with a broad brush at a high level usually results in significant high-level problems that are too large and poorly understood to manage once they surface. A better approach is to break down projects into a set of manageable systems and subsystems. Existing work breakdown structure constructs that project owners use to track budgets and cost across project systems constructs are logical starting points, but many neglect to appreciate that project phases such as construction or testing are effectively unique project “building blocks” that can have adverse cost and schedule impacts.

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Probabilistic Cost Modeling: Major capital projects are susceptible to a long list of risks and uncertainties. These uncertainties may include risks to the revenue a project may generate (through either price or demand volatility), geopolitical and regulatory developments, project technical issues, supply base performance and raw material price volatility, to name a few. The challenge becomes how these risks and uncertainties can be quantified to understand potential impacts on project cost and schedule.

To be successful, project owners must identify all material potential risks to cost and schedule for each project building block. A number of internal and external sources may contribute to initial risk identification, including engineers, supply chain managers, suppliers themselves, market analysts and regulators. Each risk must be mapped to potential impacts (that is, cost or schedule).

Many approaches and statistical constructs for probabilistic cost modeling exist, each with the same basic premise: Quantify project risks by estimating three different elements for each risk factor:

1. Probability that the risk materializes (that is, the chance that something goes wrong)
2. Magnitude of consequence (that is, how much will it cost if it goes wrong)
3. Interdependencies with other risks (that is, how the risk probability is impacted by other risk factors).

Two nuances with the above steps are often overlooked. First, risks may have either a binary probability and consequence (either they happen or they don’t) or they have consequences with some sort of distribution (for example, 10 percent chance of consequence A, 20 percent chance of consequence B, 30 percent chance of consequence C and so on). Construction commodity price volatility is a good example of a risk with a distribution of consequences.

A second nuance is that interdependencies of risks are often understated. Risks may be interdependent through a causal relationship (for example, if Risk A occurs, Risk B is more or less likely to occur as a result) or risks may be impacted by the same root cause (for example, if copper prices go up, aluminum prices are likely to go up as well). A lack of understanding of these two nuances can lead to catastrophic errors in developing total project estimates. The recent Gulf Oil disaster, in which it appears that a number of individual risk factors led to a
catastrophic outcome, is a good example of these concepts.

Once finalized, all risk probabilities, consequences and interdependencies can be fed into a simulation tool to derive a probabilistic view of project costs and schedule. Again, there are various statistical tools and approaches that support this step.

The utility of probabilistic cost modeling is two-fold: First, a project-wide “S” curve (Fig. 4a) provides a view to expected costs and confidence levels. That is, the confidence that a project will be completed at or below a given cost. The same view can be created for schedule expectations. Second, by capturing risks and quantifying their impacts at the building-block level, a “heat map” (Fig. 4b) can be created that identifies what building blocks pose the greatest risk to the overall project.

“Green” building blocks are those deemed to pose little or no cost risk, while “Red” building blocks could exceed cost targets by 25 percent or more (with “blue”, “yellow” and “orange” building blocks somewhere in between. A well structured and maintained heat map can highlight for project managers where investment and attention should be focused in the “red”, “orange” and “yellow” areas to manage overall project performance.

Developing a risk-based contracting strategy: Risk profiles and supply market characteristics will almost certainly vary widely across project building blocks. One block may have a mature design, little technical and regulatory risk and a competitive supply market. The design for another block may still be evolving, involve critical parts within the pressure boundary and have few supplier options. Another block may be low cost, but pose considerable schedule risk to the overall project. Combinations of risk factors and their magnitude are likely numerous across any one project. Accordingly, a one-size-fits-all contracting approach is virtually assured of being misaligned with the project risks that will make or break the project’s economics.

The oil and gas industry was an early adapter of a risk-based approach to contracting for multi-billion-dollar exploration and production projects. Faced with narrowing supply base options, increasingly complex systems and urgency to deliver projects within razor-thin margins of error in budget and schedule performance, companies were forced to re-think the one-size-fits all contracting approach. The benefits of doing so have been significant, for example:

- A deepwater oil field project in Angola achieved a 10 percent cost savings and on-time budget performance by unbundling contracts across major subsystems and deferring payment until project completion
- An alliance of partners for an oil platform project in the North Sea achieved 22 percent cost savings and a 17 percent schedule underrun by structuring a combination of fixed price and cost reimbursable contracts, and establishing specific profit incentives for cost management
- A major oil and gas exploration and production company achieved a greater than 15 percent procurement cost savings by unbundling the contracting for the topside and hull subsystems for a floating production storage and offloading vessel, effectively expanding the supply base and increasing competition while minimizing interface risk
- Another major exploration and production company has cited improved contracting strategies as the primary driver for a 5 to 7 percent total cost reduction on all major projects.

“Improving cost estimation, risk management and contracting are hardly new objectives for project owners. However, by increasing coordination of these three functions, significant value can be captured early and protected throughout the project.”
A true “risk-based” contracting approach takes into account a number of risks and supply market characteristics when making contracting decisions. Among critical supply market characteristics are these:

- Competitiveness of the supply base—how many suppliers are legitimate options to bid on the work?
- Current availability of suppliers—given the current landscape, how many suppliers have capacity to bid on the work?
- Relative bargaining power across project building blocks—is the bargaining power for one building block much greater or less than for another (if so, better to unbundle to avoid paying monopolistic pricing for both building blocks, all else equal)
- Owner capabilities—what project services can the project owner keep in-house?

Among possible risk characteristics are the following:

- Interface between systems—how complex are the interfaces between different building blocks?
- Cost—how large a portion of the total project cost is represented by a building block? What is the worst case scenario vs. the projected cost?
- Schedule criticality—what happens to the total project schedule if a building block incurs delays?
- Need for control over technology—for security, intellectual property or other reasons, what control and/or ownership over a building block are required?
- Design maturity—how far along is the design for a given technology?
- Familiarity with suppliers—do suppliers have a (positive) track record?
- Regulatory risk—what building blocks required the greatest attention to meeting regulatory requirements.

By collecting perspectives on each of these characteristics, many contracting questions can be posed and a risk-based contracting structure can be applied.

A common argument against developing risk-based contracts is the added ad-
investments when it appears that selected risks are beginning to veer outside the bounds of acceptability.

Improving cost estimation, risk management and contracting are hardly new objectives for project owners. However, by increasing coordination of these three functions, significant value can be captured early and protected throughout the project. Leaders in other industries are successfully using risk-based approaches to improve project cost and schedule performance and are achieving reductions of up to 20 percent in total project cost by doing so. Adopting similar practices in the nuclear industry could go a long way towards ensuring the nuclear renaissance leads to significant addition of new generation capacity that is both clean and economic.

Administrative costs required. While it is true that additional resources and expertise may be required, any associated costs are dwarfed by the potential cost and schedule implications of getting it right.

**BRINGING IT TOGETHER**

Interactions across estimating, risk identification and contracting are sequential:

- Initial cost and schedule estimates prioritize risk identification and then risk identification fuels probabilistic modeling of improved cost and schedule estimates.
- Initial estimates also inform contracting decisions…and the contracting structure then works to reduce costs.
- Risk identification informs the contracting strategy and then the contracting strategy reduces or offloads project risks through incentives or contractual provisions.

Beyond the increased predictability and better provisioning for risks that result from coordination of risk, estimation and contracting, another critical output is the increased transparency to risks that is created. By identifying risks at the building-block level and developing tailored contracting strategies, a virtual spotlight is shined on each potential problem area. Project owners know early what risks can break a project’s financial plan. They are then able to closely monitor the right areas and make targeted investments.

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**FIGURE 5 Contracting Decisions and Potential Dimensions of a Risk-Based Structure**

<table>
<thead>
<tr>
<th>Key Contracting Decisions</th>
<th>Risk-based Approach May Include:</th>
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<tbody>
<tr>
<td>Where to bundle vs. unbundle hardware and services?</td>
<td>Contracts bundled across phases and/or building blocks, where appropriate</td>
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<tr>
<td>What type of suppliers to use (EPC, hardware vendors, etc.)?</td>
<td>Contracts unbundled to maximize bargaining power, where appropriate</td>
</tr>
<tr>
<td>When should suppliers be engaged in the project lifecycle?</td>
<td>Combination of EPC and hardware suppliers</td>
</tr>
<tr>
<td>How should suppliers be selected?</td>
<td>Mix of in-house/outourcing decisions</td>
</tr>
<tr>
<td>How should payment be structured?</td>
<td>Multiple contracts with single suppliers, to align incentives with specific risks</td>
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<tr>
<td>What level of coordination is required?</td>
<td>Tailored contracting clauses to assign risk</td>
</tr>
<tr>
<td>What contractual incentives are needed to drive the desired behaviors and priorities?</td>
<td>Varying levels of incentives and penalties</td>
</tr>
<tr>
<td>How to assign risk management to risk owners via contractual clauses?</td>
<td>Multiple supplier selection processes</td>
</tr>
</tbody>
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Risk-based Approach May Include:

- Contracts bundled across phases and/or building blocks, where appropriate
- Contracts unbundled to maximize bargaining power, where appropriate
- Combination of EPC and hardware suppliers
- Mix of in-house/outourcing decisions
- Multiple contracts with single suppliers, to align incentives with specific risks
- Tailored contracting clauses to assign risk
- Varying levels of incentives and penalties
- Multiple supplier selection processes
- Mix of fixed price and cost-type remuneration structures

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“Smart contracting can reduce the cost of the project, assign risk to partners that can control it and drive desired behaviors to mitigate potential cost and schedule uncertainties throughout project execution.”

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