Making Sense of Your Project Cost Estimate

Using different estimation levels, determined throughout the engineering phase of a project, can save time and avoid surprises when it comes to bid

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Your estimate for a project's capital cost is too high or too low, incomplete or wrong, a poorly developed scope is the likely cause. In almost all cases, project cost estimating is more accurate than the scope used to develop the estimate. (To develop a good project scope, please refer to "Get Your Scope Straight for Project Success," C.E., February, pp. 36–38.) Yet good scope definition is only part of the answer.

What happens in estimating?
A project estimate is a series of activities building on each other.

1. Scope development, defining what will be done, by means of specific engineering documents
2. Estimating or generating data and applying algorithms to determine costs based on engineering factors
3. Applying risk-management methods to better define a basis for major impacts
4. Developing a contingency based on the above

Each step depends on the prior steps. In practice, project estimating becomes more accurate than scope development because, if you can think of something, you can usually place an accurate value on it based on experience. Most inaccurate estimates are caused by things we forget to include, things we decide to leave out, wishful thinking, and things in the realm of "known unknowns."

Zeroing in on the uncertainty
A study undertaken in 2000 [1] looked at 94 variables and 54 contractors and determined that the following seven factors are relevant to producing a good project cost estimate. In order from most to least influential, they are:

- Project complexity
- Technological requirements
- Project information
- Project team requirements
- Contract requirements
- Project duration
- Market requirements

Even small projects can be very complex. In some cases, a project may have multiple stakeholders, each with a differing view of the project result. Managing multiple stakeholders complicates a project.

Technology requirements create complexity. Consider new technology that may not be familiar to you, such as continuous emission monitors (CEMs) for air, or technology for reducing NOx emissions or sulfur in fuels. Smaller companies without an environmental knowledge-base can be frustrated getting up to speed on these technologies, and that increases your project's complexity.

The next item of importance is project information. A good part of this requirement lies in scope definition, discussed in the article referred to above. A good estimate is not possible without good input, and a bad scope document cannot reasonably lead to a good project.

Project-team requirements may or may not influence your estimate much. Is your team local, or are you relying on distant team members with infrequent meetings? In your team committed, or are you sharing members with

- the timing of the project and the possibility that costs might rise before purchase orders are placed or before labor is expended (escalation)
- site preparation requirements (hours and direct labor hours, hours on-site and hours at the job site)
- installation costs (hours and direct labor hours, hours on-site and hours at the job site)
- construction costs (the first cost of equipment, material, temporary facilities, small tools, and so on)
- Engineering cost (engineering)
- Management team (management)
- "Known unknowns," such as bad weather, labor problems or material shortages (contingency)
- Permits, legal costs and other overhead (overhead)
- Non-direct field labor
- Insurance

To assist in getting a good estimate, you must understand how risky each of these line items is to your particular project.

Risk management
You understand the Pareto principle, which states that 20% of causes account for 80% of the outcome, or that 20% of your project activities will account for roughly 80% of the potential risk. The trick is to identify the few items that

Table 1. A Matrix for Estimating Deliverables

<table>
<thead>
<tr>
<th>Estimate classes:</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Order of magnitude estimate</td>
<td>Preliminary estimate</td>
<td>Budget estimate</td>
<td>Detailed estimate</td>
</tr>
<tr>
<td>Also called:</td>
<td>Approximate cost estimate</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
<tr>
<td>Typical purpose:</td>
<td>Early cost estimation</td>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
<tr>
<td>Method of preparation:</td>
<td>Cost curves, published data, or experienced estimator</td>
<td>Estimator, with experience in the project area</td>
<td>Estimator, with experience in the project area</td>
<td>Estimator, with experience in the project area</td>
</tr>
</tbody>
</table>

Note: An estimator must be used only on projects with above-normal risk or for the last two levels of accuracy as a project nears completion.

<table>
<thead>
<tr>
<th>Normal accuracy range</th>
<th>+10% to -10%</th>
<th>+15% to -10%</th>
<th>+20% to -15%</th>
<th>+25% to -15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point estimate</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>When and where plant will be built</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Equipment layout</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Process flow diagram (PFD)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Piping layout</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Project sequence plan</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Equipment list</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Jobs and other site data</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Process equipment</td>
<td>V</td>
<td>IV</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Equipment data sheets</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Equipment piping</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Equipment setting manual</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Electrical V</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrical equipment layout</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrical equipment piping</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrical equipment drawings</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrical bulk Piping</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

(Continues on p. 56)
A single large reactor or two smaller ones will be built, and not having a solid estima
ting basis for how the larger one can be shipped, transported to the site and set in place.
In many cases instrumentation and electrical work are the biggest risk factors in a project.
Instrumentation/ electrical work (IEW) is often the last thing to be engineered. It can represent 30% or more of the total project cost. In addition, it isn’t well understood by the average person, so it often doesn’t draw the attention it needs at early project stages. Finding out after you bid on a project that you will have to add a large electrical substation, motor-control center (MCC), process-control-computer components, new underground conduit or new cable racks in tight racks can add cost quickly. Do some homework here and it will be time well spent.

Pipe racks represent another early risk item, especially if a lot of big-bore pipe is required and racks are nearly fully closed. Contamination remediation for lead paint, asbestos and contaminated soils can drive up costs if not anticipated. Don’t forget permits. You will need permits to have contaminated mate
rials handled and disposed of legally, and remediation companies may do the actual work at hourly rates above your local labor rates.

New flares and process-discharge points will require a lot of preliminary effort to secure state and federal per
dmits. Don’t forget required analyses for point sources, such as CDMS for flares.

Your project-cost estimator can show you the line items that might be prob
lematic. These are cost risks that you can mitigate by doing more targeted engineering work, such as: getting a better idea of field electrical capacity,
checking for additional breaker space in the MCC, getting a better look at that 24-in. valve capacity; getting your annual temperature profile for your cooling tower; or obtaining your cooling-water-pump curves to see if you can really make capacity in sum
ter. By identifying such major risk items and further working to define them, you reduce your estimate risk.

A good practice when watching any single items 40% of your total estimate. On a $100 million project, these items exceed $30,000. A 20% uncertainty on such an item’s cost is $100,000 at risk! Of the thousands of line items that make up an estimate—about 50% will be at this level. You can surely justify some engineering time to miti
gate a $100,000 risk.

Contingency

Contingency is the last item you will determine for your estimate. Contingency represents “unknown unknowns”. Contingency must be protected and used properly. For example, contingency is not used for the following:

• Additions to the project scope; these are handled as scope changes, and are estimated separately for cost and schedule impacts using project
dependent

• Handling last-minute changes to governing standards or regulations; these should be handled as scope changes as in the point above.

• Making up for time lost to avoid

• Labor strikes

• Vendor problems, such as bankrup
ty

• High labor turnover due to market forces creating high labor demand and high wages

Known items are things we tried our best to estimate, but upon which we need to hedge our bet: Examples in
clude price adders for expensive equip

ment that must be fully engineered before you can get a locked-in cost; or things you are negotiating for, such as rights of way.

Known-unknowns are items that can happen, but you aren’t sure will happen, such as bad weather, labor shortages and labor turnover.

Unknowns are things with a very

low probability of occurring, but that are very expensive when they do. Ord
arily we use insurance as much as possible to cover the likelihood that these occur, but we do not budget con

tingency money in the estimate for these items. Acts of God (fire, ma

jute) fall into this category.

Look for Monte Carlo methods on the Internet that can assist you to de

termine contingency. Entering “project contingency” into a search engine is a good start.

A last contingency issue is the use of hidden contingency to fatten an esti

mate. Each line item cost must have an auditable basis, such as feet of pipe (dollars per linear foot) or labor hours ($/hour), so that management can review the estimate and make rational judg

ments on its validity. So do not use hidden contingency; keep it as a single line item.

What estimate level to request

Preparing an estimate costs time and money. Not only do you have the costs of preparing the estimate, reviewing it and finalizing it, but you also have the costs of all the engineering work required to prepare the estimate de

deliverables. Ask yourself why you need a project estimate, and whom it will be presented to. This is a good way to de

terminate the accuracy level you will re

quire. The matrix provided in Table 2 shows how your estimate should be normally required for each level of estimate, al

though this distinction is subjective and is somewhat relative by estimator and company job. Estimates typically fall into standardized ranges (percent

age over/percentage under estimated) based on what they will be used for, as shown in Table 2. These estimate lev

els are defined below:

Order-of-magnitude estimate (+100% to -30%) For an order of magni
dude estimate, very little is required except for the desired plant capacity and the location of where the plant will be built. The estimate validity will be based on how closely this project follows past similar projects.

Engineering Practice

When an order-of-magnitude estimate is called for, cost-capacity esti

mation, being based on a new process and pilot plant data, is produced daily. But they can also
be produced by factoring from the cost of a known unit of a given cost, installation date, capacity, and location. For example, you might say, "a similar project back in 1990 that was half of this capacity and was built in the Northwest instead of Gulf Coast cost us $48 million, so this one is about: 

\[ 48,000,000 \times f_e \times f_i \times (2.0)^{0.6} = 76,000,000 \]

where:

- \( f_e \) = factor for 15 years of escalation (in this example, \( f_e = 1.1 \))
- \( f_i \) = factor for location adjustment (in this example, \( f_i = 0.949 \) because its cheaper to build in the new region)

\( (2.0)^{0.6} = \) capacity factor to the 0.6 power (0.6 is a commonly assumed exponent for total plants. Tables can be found for various equipment types.)

The estimate mean value is $76 million with a range of +50% (or $38 million) and -30% (or $22.8 million). Pay particular attention to the +50% side of the number; this is the upper 95% confidence limit. There is only a 5% chance of exceeding $114 million, but there is a 50% chance of going over $76 million. This is because the value is the mean, not the most frequent value. The project will only exceed $76 million.

**Preliminary estimate (+35% to 25%)**:
A preliminary estimate is used to compare competing project options. In a gated-project process, alternatives are compared using project-economic indicators, such as net-present value (NPV). NPV requires installed cost and annual operating/maintenance costs for its evaluation.

A few engineering deliverables, typically by process engineers and piping designers, are sufficient for this level of estimate. A plot plan, PFDs, sized-equipment list, and a preliminary motor H.P./electrical-load list are enough.

**Budget estimate (+25% to 15%)**:
An estimate of this level is often used for detailed studies or for project funding authorization. This level estimate requires significant preliminary engineering by all disciplines. Refer to the cost estimate matrix (Table 1) for details of engineering deliverables required. For our $76 million example project, we might expect to spend 2% to 5% of the total engineering for the estimate deliverables.

Everything is estimated from this information using a conceptual estimating program, and there are many good software programs available. We may have a good idea of site preparation costs, labor rates and engineering costs, and use these in place of software-produced results. The contingency at this level of estimate will be high to cover things we know of but could not include, such as underground obstructions or enough insulation and tracing. Typically defined at the end of a project, they simply are not known at this point and we will use factors to create a dollar value for these things. With a good software program, if we tell it that a new DCS or substation is needed, it will estimate the things based on the motor and other power loads and the instrumentation required. If we proceed to authorize the project with this estimate, we would find that while we are only likely to exceed the upper limit 2.5% of the time (5%/2), we have a 50% chance of exceeding the midpoint.

**Definitive estimate (+10% to 5%)**:
The definitive bid is used for lump-sum bids and funding authorization. As the estimate matrix shows, a lot of engineering is required to produce this quality of estimate. Figure on being 75% to 90% complete with engineering in order to have the information required. You are essentially complete with engineering at this stage.

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**What estimate level to pay for?**
I can’t answer this question for you. I can, though, give you some opinions to help orient you. In general, the estimate mean value will not change very much if your scope is good. The estimate bands, or uncertainty, will improve however, as the engineering is closer to complete.

- It is my opinion that a good +25% to 15% estimate can be a useful authorization estimate. If you are certain

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**Final thoughts on contingency**
Contingency, as discussed above, is a list of "knowns and known unknowns" that you are aware of, don’t expect to happen, but could happen. You estimated that local productivity is 80% or 60% but it can be as low as 70%. You will then cover the contingency in the budget. If you build in the Gulf Coast area during hurricane season, you might want to add the cost of battening down the hatches, and paying for 3 to 4 days of your contingency allowance. If there is a pending labor strike, add some contingency for loss of time, possible extra security, and so on. Contingency is not the sum of all "knowns and unknowns", but a percentage to cover the statistical likelihood that some on the list will come true. Many Monte Carlo packages exist to help you determine an appropriate contingency percentage based on your analysis of how good your scope is in most areas.

**Edited by Gerald Ondrey**

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**References**

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