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Exploring Techniques for Contingency Setting

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One of the primary areas of concern for a company's project system is the assignment of reliable contingency allowances in project cost estimates. Over the years, various contingency-setting techniques have been developed in an ongoing search for reliable approaches. These techniques vary from simple to extremely complex in their development and use, but all have the objective of improving the accuracy of project estimates. Unfortunately, very little data have been published on how successful industry contingency-setting techniques have been in improving project estimate accuracy. The goal of this paper is to objectively and quantitatively explore the historical performance of the various techniques. In addition, we will also describe a technique successfully used by Independent Project Analysis, Inc. (IPA), but little used in industry, and see how its performance compares with the common industry approaches.

CONTINGENCY VERSUS THE BASE ESTIMATE

Conflicting views exist about what contingency is. For the purpose of this paper, contingency is defined as the amount of money that experience has demonstrated must be added to the base estimate to provide for uncertainties related to (a) project definition and (b) technological uncertainty. Contingency is money that is expected to be spent. The contingency account is not intended to provide for changes in the defined scope of a project (e.g., change in capacity or product slate) or for unforeseeable circumstances beyond management's control (e.g., 100-year storms or strikes against equipment vendors). Contingency should not be viewed as a reserve or slush fund that the project team cannot spend without upper management approval. Likewise, management should not have the expectation that, if a project team does its job well, contingency will not be spent. A competitive approach is to set contingency at an amount that achieves a 50 percent probability of overrun. At a 50 percent probability, the project system, on average, is expected to spend all of its contingency.

The previous discussion assumes that the base estimate is a realistic and competitive estimate of the known scope and also assumes typical site and market conditions. A competitive base estimate is free of excessive allowances and markups for general unknowns. Allowances to cover specific, but uncertain, items are expected within a base estimate. The competitiveness of the base estimate is a key factor to consider in contingency setting.

THE TECHNIQUES

The vast majority of projects set their contingencies using techniques that can be grouped into one of three categories: predetermined percentage, expert's judgment, and risk analysis. We will also explore a fourth technique called regression analysis, or ordinary least squares regression, that IPA and a few others use. The first three categories will be the focus of our historical analysis. Because numerous publications describe the three most common contingency-setting techniques, we will only discuss those methods briefly.

Predetermined Percentage

Many company or site project systems use predetermined or mandated percentages of the base estimate as the project's contingency. We found that many project systems mandate that all projects will include contingency of either 5 or 10 percent of the base estimate. Although the basis for the percentage may seem arbitrary, 5 to 10 percent is a reasonable average for contingency use in the process industries.

The advantages of this technique are its ease of use and consistency. Using a consistent percentage removes subjectivity from the process. Because of the ease with which it is implemented, a fixed contingency percentage is often the technique applied to smaller projects. The disadvantage of the technique is the fact that it removes specificity and subjectivity from the process; it is inflexible to potentially important risk drivers, such as process complexity, use of new technologies, and level of project definition. Because of this, the method tends to underestimate contingency needs for complex and poorly defined projects and to overestimate for simple or well-defined projects. By failing to take project risk drivers into account, the predetermined percentage method produces large variations in the probability of overrun or underrun from project to project.

Expert's Judgment

A more advanced and flexible methodology for determining contingency is to use the educated judgment of experts to assist in setting a contingency level. In this technique, skilled estimators and project team members use their experience and expertise to assign a level of contingency that they believe is appropriate for the project at hand. Unlike the predetermined percentage technique, expert judgment considers specific risk factors and base estimate competitiveness.

The degree of structure to this contingency-setting process varies widely. Typically, the experts must consider bounds or norms (formal or informal) for contingency outcomes. These bounds may be expressed by using an expanded version of the predetermined contingency approach whereby the experts must select from contingencies that are predetermined for discrete risk levels (e.g., 15 percent for high risk, 10 for average, and 5 for low risk). If the process is more highly structured than this, it tends to be classified as a risk analysis approach, which is discussed in the next section.

By using specificity and subjectivity in setting each project's contingency level, a project system is more likely to have more accurate estimates. However, subjectivity is also the main disadvantage of this method in that the skill, knowledge, and motivations of the experts may vary widely. Typically, only a few experts are available whose understanding of project cost risk and estimate competitiveness can be relied on. This expertise is not easily transferable, which makes turnovers a primary concern.

Risk Analysis

Risk analysis techniques examine risk factors in a more structured way than expert judgment and apply specific quantitative methods of translating the assessed risks into contingency values. The quantitative methods are usually probabilistic in nature and allow the statistical confidence level of cost outcomes to be considered.

The most commonly used form of risk analysis employs Monte Carlo simulation as the quantitative method. In this technique, a probability distribution is assigned to each estimate line item or subtotal, and the simulation tool (typically a spreadsheet add-on) randomly selects a possible outcome from each item's distribution and aggregates the item outcomes into a total expected project cost outcome. This process is repeated many times (e.g., 1,000 iterations) to obtain an average total cost. The distribution of the iterative outcomes can then be used to select a contingency value that provides the level of statistical confidence desired. Using Monte Carlo analysis or similar risk analysis techniques allows estimators to examine the risk of individual project cost elements in a highly structured way.

The main advantage of risk analysis techniques is that they are probabilistic in nature. They allow confidence levels to be explicitly considered, and they are also very flexible. Monte Carlo analysis can be applied to any estimate or cost analysis that can be totaled or modeled in a spreadsheet; the spreadsheet model can be as simple or complex as desired. For any given model, the estimator then has almost infinite flexibility in assigning probability distributions to estimate elements

Risk analysis techniques have another advantage if the risk assessment step is done in a group setting wherein the project team reviews the entire estimate from a risk perspective. This is often the only team review of the estimate, and the outcome of the review is almost always an improved base estimate, as well as a probabilistic-based contingency value.

A major disadvantage of risk analysis techniques as typically applied is that the estimate items for which probable outcome distributions are being assigned are not, in themselves, risk drivers. The distributions assigned, therefore, tend to be somewhat meaningless. For example, the typical cost model is a spreadsheet tabulation of estimate elements, such as piping and electrical line items. The estimator is expected to assign a probability distribution (e.g., triangular distribution with +50/-30 percent high-low range) to "piping." However, if the major risk driver is level of project definition, few, if any, estimators will have a really good idea of how project definition (or weather or labor markets, etc.) will affect any particular line item.

Risk analysis also requires more time and resources to implement compared with predetermined percentages or an expert's judgment. The Monte Carlo technique is also deceptively complex. For example, it requires that dependencies be established between elements of the cost model, which is almost always skipped by users because few understand cost item dependencies (e.g., if the electrical cost outcome is on the high end of its range, what is the probability that the piping cost outcome will also be on the high side). The complexity also allows outcomes to be easily manipulated, so the results are often inconsistent. The time and complexity of risk analysis techniques often mean that they are reserved primarily for larger projects or projects of increased business importance.

Regression Analysis

Regression analysis is a statistical technique for estimating the equation that best fits sets of observations of a response variable and multiple explanatory variables in order to make the best estimate of the true underlying relationships between these variables. IPA uses regression analysis to establish contingency requirements. This technique was formulated by collecting detailed histories of projects and identifying key factors that drive differences between project estimates and actual cost outcomes. As with risk analysis techniques, regression analysis is based on quantitative modeling. However, the explanatory variables in the regression model are quantified risk drivers, not estimate line items or subtotals. Regression analysis is empirical and objective, and regression models produce consistent results no matter who applies them.

Similar to risk analysis techniques, regression models are probabilistic in nature and allow the statistical confidence level of cost outcomes to be considered. However, unlike risk analysis techniques, regression analysis is based on actual data, not assumed probability distributions and risk driver-cost outcome relationships. Because regression models are based on historical data, they bring expert knowledge to contingency setting without the need for a skilled expert on every project.

Through regression analysis, we have found several project risk drivers, both controllable and uncontrollable, to be the strongest drivers of project cost deviation or the amount of contingency used. The following is a list of these risk drivers.

Project Definition Level—The objective of project definition or Front-End Loading (FEL) is to gain a detailed understanding of the project and to minimize the number of execution uncertainties. Project definition level is an important driver that can have a direct effect on the level of contingency used by a project. It is one of the most important elements in our model.

Use of New Technology—Projects involving new technology—that is, technology that has no commercial history either within the owner company or elsewhere—have been historically proven to require more contingency. New technology may involve the use of new chemistry, first-of-a-kind major equipment, or existing equipment performing a new service. New technologies are associated with more risk than proven technologies because Industry has little or no experience with a new technology. As a result, the use of new technology increases the amount of contingency required.

Process Complexity—Complexity can be measured in many ways. We define complexity as the number of continuously linked process steps, counted on a block basis, in a facility. Parallel trains are counted only once, and the control system and off-sites are not included. As project complexity increases, the need for increased contingency also increases.

Contracting and Execution Strategy—Projects executed using lump-sum contracts typically require less explicit contingency than other contracting strategies because they move much of a project's risk from the owner to the contractor. Execution strategy affects contingency use because, if a project is cost driven, it is less likely to take actions and make changes that will put cost at risk. If a project is schedule driven (i.e., the project team is willing to spend money to achieve its schedule objective), more risk may be acceptable, and costly changes may be tolerated.

Equipment Percentage—Because the majority of major equipment estimates are based on firm quotes, equipment cost experiences the least cost growth. Even for early estimates using historical data or budget quotes, equipment cost estimates tend to be more accurate than the estimates for other cost accounts. Therefore, projects that have a high equipment percentage typically require less contingency.

Other inputs that should be considered when creating a regression model are company cost culture, estimate inclusiveness, process impurity problems, project management practices, project scope characteristics, and estimate quality.

HISTORICAL PERFORMANCE

The objective of this section is to present the results of our historical analysis of the process industry's contingency data over the last 10 years. Before we discuss our methodology and findings, we need to introduce our dataset of projects.

The Database

The dataset used for this research is a subset of the IPA Downstream Project Evaluation System (PES®) Database. The PES database currently consists of more than 8,000 projects, each with more than 2,000 pieces of information. These data points capture detailed project-specific information, including project definition, technology, project management, cost, schedule, operating performance, and safety. The database contains projects in a wide range of industrial facilities that were executed by more than 200 companies around the world. From this database, we selected a subset of 1,500 projects on which we have detailed information regarding cost, scope, contingency level, and contingency-setting technique. Because we are primarily interested in more recent projects, about half of the selected projects in our dataset were completed after January 2000. Including a wide spectrum of project costs was also important. To that end, projects in the dataset range in size from less than $100,000 to greater than US$1.5 billion. All costs are adjusted to 2002 United States (U.S.) dollars, which allows us to compare projects executed in different years.

Historical Measure of Contingency

In order to quantitatively evaluate the accuracy of each project's contingency, we needed to create some type of measurement, which we called the Contingency Performance Indicator (CPI). The CPI is defined as the absolute value of percent of contingency used minus the percent of contingency estimated. For example, Project A has a base estimate of $8 and a contingency of $4. The actual cost of the project is $10. In this example, the CPI = absolute[(10-8)/8 - (4/8)] = 25 percent. For this project, the estimated contingency (50 percent) is different from the contingency used (25 percent) by 25 percent.

The perfect CPI of 0 percent is a result of the estimated contingency exactly predicting the actual amount used. Because the CPI is an absolute measure, any deviation from the estimated contingency, whether it is an overrun or an underrun, is treated in the same way and results in a positive score. For the purposes of this study, we are concerned only with the accuracy of the predicted contingency, not the direction of deviation.

EVOLUTION OF CONTINGENCY TECHNIQUES

When we examined whether the industry was improving in contingency estimation over the last 10 years, we found that the CPI has, on average, been increasing. Figure 1 indicates that contingency estimates are, on average, getting further from the actual contingency required. This decline in performance is driven by dramatically worse performance for smaller projects. The CPI for large projects has been largely constant over the last 10 years, with a median of about 7 percent. During the same time period, small projects have gotten dramatically worse in contingency estimation, with the CPI measure going from a median of about 6 percent in 1994 to 1995 to a median of about 10 percent in 2002 to 2003. In essence, the average difference between estimated contingency and the actual contingency required on small projects has almost doubled in the last 10 years.

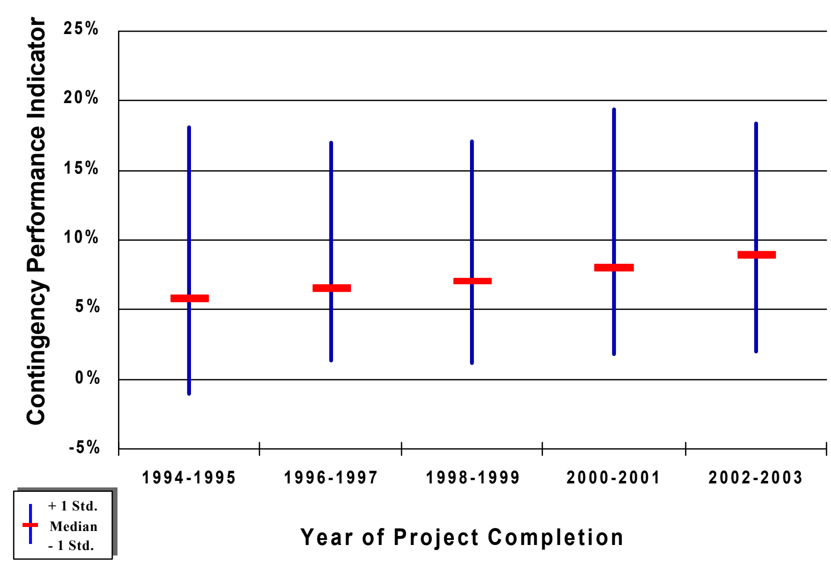

Figure 1—Contingency Performance Over the Last Ten Years

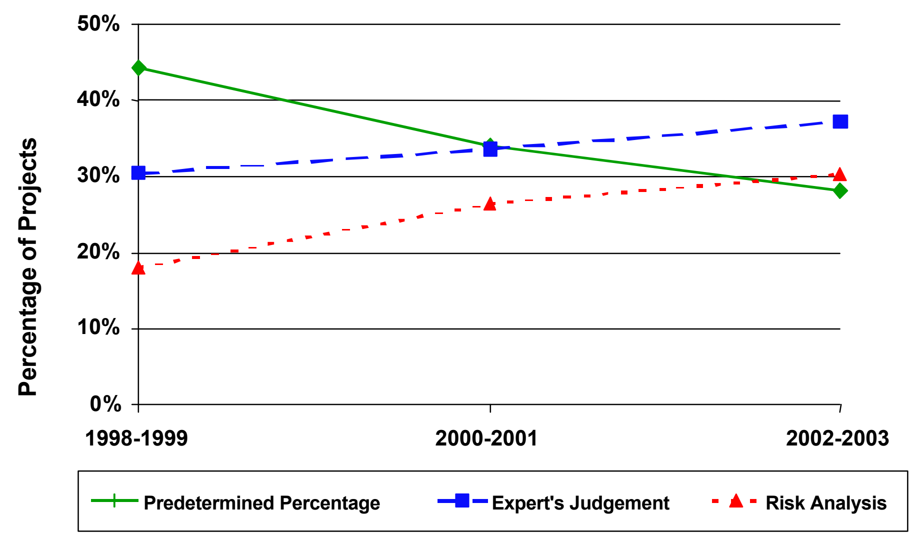

Figure 2—Use of Contingency Techniques

This result is especially surprising considering that the percentage of projects using more sophisticated approaches to contingency setting has been increasing. As shown in Figure 2, about 20 percent of projects used risk analysis techniques prior to the year 2000. In the post-2000 period, project teams' use of risk analysis has increased to more than 30 percent. During the same period, the use of predetermined percentages has dropped from almost 50 percent to 30 percent.

COMPARING THE TECHNIQUES

To better understand the decline in contingency-estimating performance, we evaluated projects executed using the three commonly used estimating methods. The industry belief has been that projects that use a risk analysis technique to estimate contingency will achieve better accuracy (i.e., lower CPI). In fact, all three of the techniques produce results that are essentially the

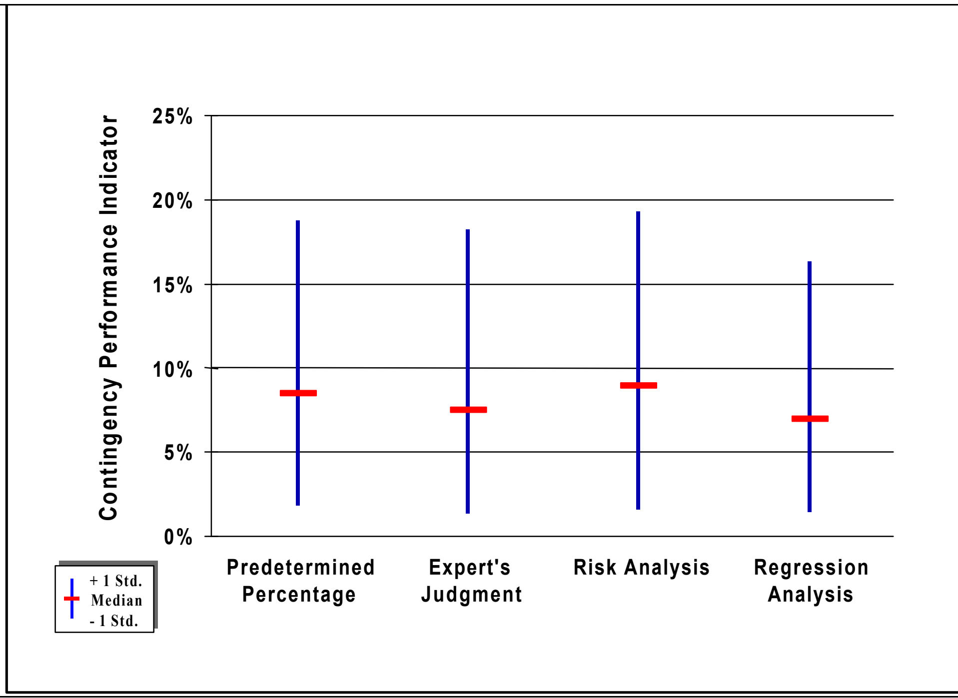

Figure 3—CPI for the Three Contingency Setting Techniques

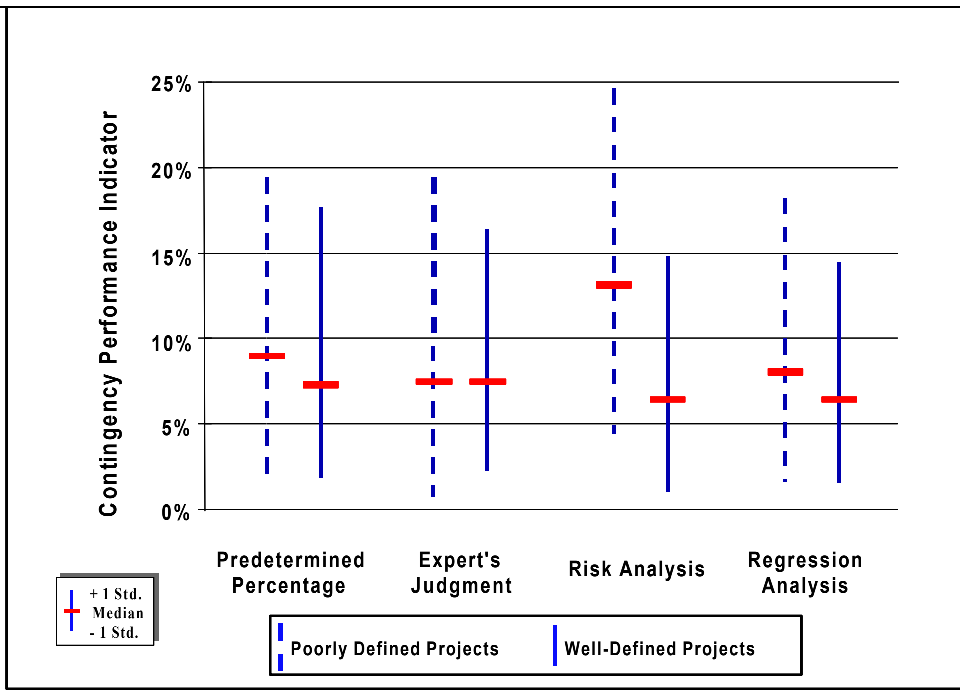

Figure 4—CPI for Well-Defined Projects vs. Poorly Defined Projects

same, as shown in Figure 3. No statistically significant difference exists between the three techniques. This is true for both new technology and off-the-shelf projects and is independent of project size and complexity. As previously stated, Monte Carlo analysis as typically applied, does not explicitly address how risk drivers link to cost outcomes; therefore, there is no reason to believe it would yield better results than the other techniques. As a means of comparison, IPA's regression model produces a median CPI of 7 percent for the same group of projects.

The most important risk driver is the level of project definition at the time of authorization. When we examined CPI by project definition level and contingency estimation technique, the results were dramatic. Figure 4 shows CPI medians for projects, split by level of project definition. For well-defined projects that used either a predetermined percentage or an expert's judgment, the median difference between estimated contingency and actual contingency requirements is almost 7.5 percent. However, when the project team used risk analysis techniques, the median difference is reduced to less than 6.5 percent. When we looked at projects that were poorly defined, using a risk analysis technique is a disaster. The median CPI for risk analysis balloons to 13 percent when used on poorly defined projects. In addition, the variance of CPI results also increases by 50 percent, indicating that risk analysis is inconsistent and unpredictable for these projects. Projects that used either a predetermined percentage or an expert's judgment are indifferent to project definition level, with the median CPI still below 9 percent. We believe that the risk analysis results reflect the fact that teams are attempting to address both the poor quality of the base estimate, as well as other risk factors, and they are overly optimistic. When a technique does not explicitly address risk drivers, too much flexibility does not yield improved contingency setting performance.

Regression analysis yields a similar CPI regardless of the level of project definition. This is due to the fact that regression analysis uses the level of project definition as an explicit factor when estimating contingency requirements.

As we have seen, assigning contingency to capital projects is one of the greatest challenges faced by project teams and estimators. Although the various techniques that are used to assist in that decision are similar, each has strengths and weaknesses. Through our historical analysis, we have found that certain techniques are more reliable under certain project risk conditions. Using an expert's judgment as the basis for setting contingency levels invariably outperforms the use of predetermined percentages. This is true regardless of project size, definition level, or complexity. Both of these techniques are stable enough, however, that they can be used on any type of project without the worry of drastically reduced performance for a given set of risk factors. This is not necessarily true for risk analysis techniques. This research has shown that risk analysis techniques can deliver slightly better contingency accuracy for projects that have good levels of definition prior to authorization. The use of risk analysis techniques on projects that are not well defined produces considerably worse results than other methods. For these projects, using a different contingency estimating method is preferable. Because the difference in performance is so drastic, choosing what technique to use, given differing project risk factors, is an extremely important decision.

Another technique discussed was regression analysis. Regression analysis directly addresses the factors that drive project risk, and these are the factors that drive the consumption of contingency. In order to use this technique, detailed project data, including cost and project drivers, must be collected. These data, taken from actual projects with quantifiable results, form the foundation for regression analysis. Although this technique takes time to develop, the finished product is easy to use and produces consistent and accurate results. This technique, if implemented correctly, can be a viable alternative or an excellent supplement to the traditionally used methods for contingency setting.

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