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This article presents the general principles of what contingency and estimate accuracy are in order to remove common misconceptions about their composition and use.

Use and Misuse of Capital Cost Estimate Contingency – Why Deleting it Makes Projects More Expensive, Not Less

by Gordon R. Lawrence

Introduction

Investment of capital in new production or research facilities is a regular part of daily life for all major pharmaceutical firms. Before a decision to invest is made, an estimate of the costs to design, engineer, and construct the new facility must be made. Any estimate, by definition is imprecise and carries financial risks. The cost implications of that imprecision and those risks are reflected in the application of contingency to an estimate and in assigning an accuracy range to that estimate.

There is a great deal of confusion among business sponsors, end-users, and finance managers outside of the project/engineering group as to exactly what contingency is, what it is for, and how it differs from an estimate accuracy range. This lack of common understanding was exposed in an article by Baccarini,[1] in which he described the results of a brief *vox populi* on the subject of contingency, held at a project management conference. One possible reason for this confusion and lack of understanding is the fact that although there are many published articles discussing in great detail how to calculate contingency and estimate accuracy,[2] these articles (of necessity) contain a considerable amount of statistical terminology. This terminology can be off-putting to the layman. Another reason may be due to the fact that many people conflate design allowance and management reserve with project contingency.

There also is a tendency among finance and business groups to view contingency as evidence that the project team is inflating or "padding" the estimate to give itself an easy life. In an effort to remove this padding and ensure the project is built for a competitive cost, these groups very often decree that the contingency should be limited to a specific percentage of the estimate cost or even in extreme cases deleted from the estimate altogether.

This article presents the general principles of what contingency and estimate accuracy are in order to remove common misconceptions about their composition and use. It uses simple graphical descriptions in order to assist the reader in visualizing the concepts. It avoids as much statistical detail as possible, sticking to simple statistical terms that should be familiar to all (i.e., median and mode). The article also differentiates between design allowance, contingency, and management reserve.

The article then goes on to show that contingency is not the same as estimate accuracy, that it is an essential part of any estimate, that it

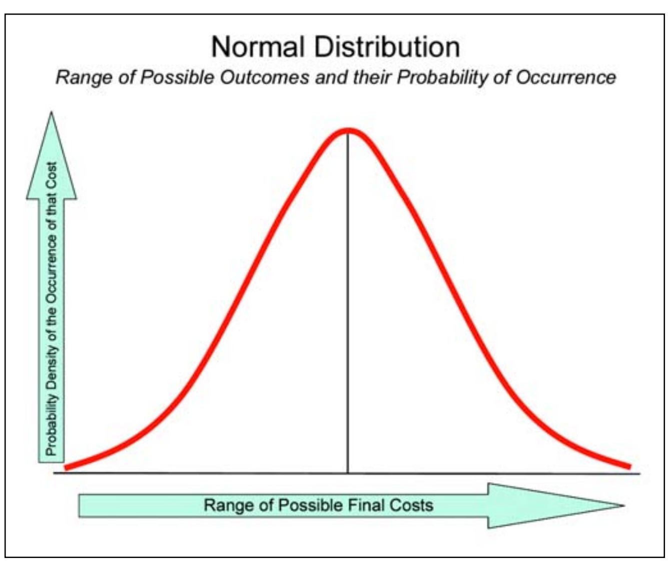

Figure 1. "Normal" distribution curve of possible cost outcomes.

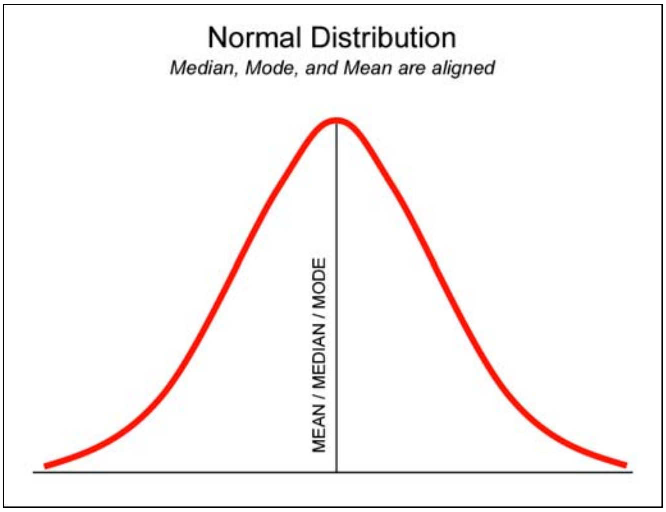

Figure 2. "Normal" distribution curve, showing mean, median, and mode.

should be expected that contingency will be totally consumed during the course of the project, that it does not include design allowances, and that contingency is not to be used for scope changes.

In addition, the article will address the issue of imposing artificial constraints on how much contingency a project team is allowed to retain in an estimate, in the belief that this will ensure that the final project cost will be competitive. The article will explain why taking such action can be counterproductive and result in projects becoming less cost competitive instead of more competitive.

Readers of this article should come away with a greater appreciation of the need for contingency and its difference from estimate accuracy. Those readers who then wish to take the next step and consider the practicalities behind calculating contingency and estimate accuracy for a specific project can use the list of references at the end of this article as a starting point.

Estimate Range

Why is an Estimate Range Necessary?

A cost estimate is a prediction of what the final cost will be at some time in the future. Since it is impossible to accurately predict the future, any estimate has some risk and surrounding uncertainty. The range around an estimate reflects that uncertainty.

What is an Estimate Range?

The Estimator and the "Most Likely" Outcome

In single-point estimating, the estimator assigns a single cost value to the estimate. But picking a single point or in effect stating "the project will cost this much; no more; no less," clearly does not take into account that this is an estimate with surrounding uncertainty. So what is this single point value? As Querns[3] and Yeo[4] both confirm, it is generally recognized that estimators tend to pick the "most likely" value when asked to choose a single point.

Three-point estimating takes more account than single point estimating does of the fact that there is some uncertainty around the estimated cost. It asks the estimator to specify a minimum and a maximum cost based on his/her experience, as well as the "most likely" cost.

Armed with this information and by taking a view (a) on the potential monetary effect of a risk on the cost, coupled with (b) the likelihood of the occurrence of that risk, a probability distribution curve of the range of cost outcomes can be developed. If the range of possible outcomes is normally distributed, it will look like the example in Figure 1.

At this point, we introduce our first statistical term, the "most likely" (or the most popular) outcome is the mode of the set.

Choosing the 50/50 Outcome

As noted by Hackney,[5] Healy,[6] and others, it is generally agreed that the best all-purpose estimate for project management and control purposes is the even-chance or 50/50 outcome value. (i.e., the value at which there is a 50% chance of overrunning or underrunning the estimate figure).

The reason why management should choose to ask project teams to control to the 50/50 outcome becomes clear if one considers that management is concerned with not just one, but a portfolio of projects. If a corporation has multiple projects ongoing, controlling each project to greater than the 50/50 point means that management will have more funds committed to projects than (on average) the projects will ultimately need. Hence, funds are tied up unnecessarily and the overall number of projects that could be tackled is reduced. Conversely, controlling to less than the 50/50 point means that, on average, most projects will overrun their budgets, making portfolio budget management difficult as demand for funds fluctuates. In addition, more projects may be authorized than there are ultimately funds for because an optimistic view has been taken of the amount of funds each project requires.

The "Most Likely" and the 50/50 Outcome

To put the 50/50 outcome another way, it is the point where there are an equal number of possible outcomes on either side of the estimate value. Hence, in basic statistical terms, the 50/50 outcome is the median.

If the data set of possible cost outcomes for the overall cost estimate of the project is normally distributed, then as seen in Figure 2, the mode or the "most likely" value, as developed by the estimator, and the median or the 50/50 outcome, as desired by management, are both at the same point on the curve (along with the mean, or the average cost).

Estimate Accuracy Ranges

If someone says an estimate has a ±10% accuracy, what does this mean?

Any discussion of the percentage accuracy must be related to a specified confidence interval. To use Figure 3 as an example, the median/mean/mode cost is $100 million. The 80% confidence interval in this example (i.e., the confidence that the actual cost will fall within this range 80 times out of 100) corresponds to costs between $90 and $110 million (i.e.,

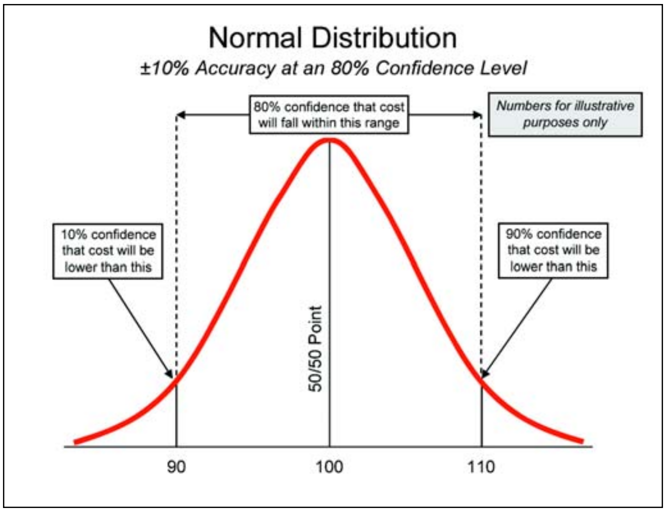

Figure 3. "Normal" distribution curve with example numbers (for illustration purposes only).

the actual cost will turn out to be below $90 million only 10 times out of 100 and above $110 million only 10 times out of 100).

The difference between $100 million and $90 million or between $100 million and $110 million is in each case 10% Hence, this (illustrative) example estimate has a +10% and –10% accuracy with 80% confidence.

An 80% confidence interval is used purely for illustrative purposes. Project teams may choose the 90% confidence interval, or some other interval that suits the corporation's attitude to risk. (Engineering and cost estimating personnel tend to use confidence intervals, such as the 80% confidence interval. However, statisticians and economists sometimes prefer to refer to a standard deviation range. In which case, the 80% confidence range is equal to ±1.28 standard deviations).

Cost Contingency

Having described cost estimate accuracy ranges, the following discussion will focus on cost contingency to see how this differs from an estimate range.

What is Contingency?

Written Definitions of Contingency

Baccarini noted a lack of understanding of contingency; however, although there is a lack of common understanding on the *detail* of what contingency means, Baccarini also noted that there is general agreement that contingency is a sum of money added to a capital cost estimate to cover certain uncertainties and risks in a capital cost estimate. Taking this point further, consider the de-facto industry standard for project management in the USA (and to some extent globally); the *Project Management Body of Knowledge*.[7] This reference book describes contingency as: *"A provision in the project management plan to mitigate cost risk."* The Association for the Advancement of Cost Engineering International (AACE-I) performs a similar role for cost engineering in that its recommended practices also are de-facto USA (and global) industry standards. The AACE-I recommended practice covering cost engineering terminology[8] defines contingency as: *"An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence and/or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs."* In this article, we are following the consensus then if we describe contingency as: *"An amount of money for goods and services which at the current state of project definition cannot be accurately quantified, but which history and experience show will be necessary to achieve the given project scope."*[9]

Several authors, including Karlsen and Lereim[10] note that many sources use terminology that does not make sufficient distinction between design allowances (for items that experience has found to be systematically required[11]), contingency, and management reserve. In this discussion, a clear distinction will be made between the three elements.

In order to provide some detail around that general definition, the following discussion will focus on a graphical description of contingency.

Project Contingency – Why the Most Likely Cost is not the 50/50 outcome

In the previous discussion of estimate accuracy ranges, a normal distribution of possible outcomes was assumed; therefore, the most likely cost (the mode) was the same as the 50/50 outcome (the median). However, as with many things where the cost cannot be less than zero, but the upper limit is less well-defined, the range of possible outcomes for an estimated cost is right skewed - *Figure 4*.

This being the case, the mode, median, and mean are no longer in alignment. In fact, the median is now a larger cost outcome than the mode. (In addition, it is now clear that when describing an estimate range, it is rare that the plus and minus percentages will be the same.)

Since the estimator has produced a base estimate that corresponds to the mode and it is assumed that the estimate is required to have a 50/50 outcome (the median), there is a gap (the median value minus the mode value) that needs to

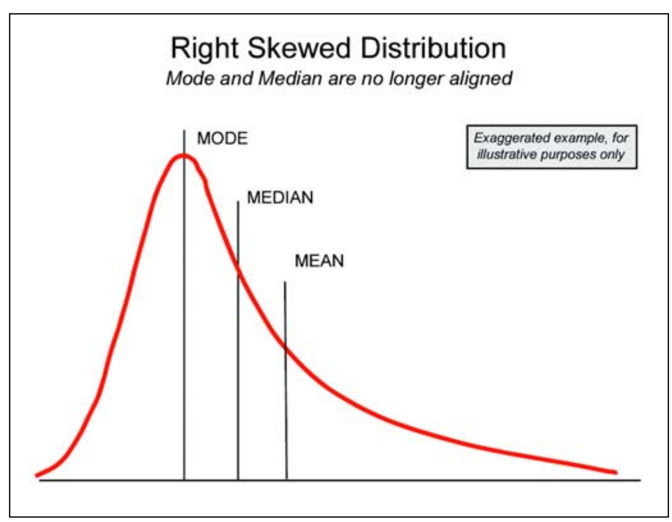

Figure 4. "Right Skewed" distribution, showing how mean, median, and mode no longer align.

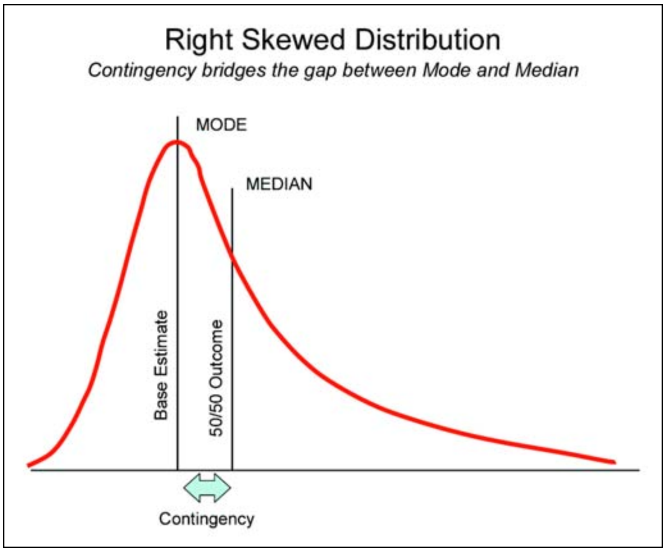

Figure 5. "Right Skewed" distribution, showing how contingency bridges the gap between mode and median.

be filled. As shown in Figure 5, it is to fill this gap that ***project contingency*** money is applied to the estimate.

The question may arise, why doesn't the estimator pick the median value instead of the "most likely," or mode value for each item; or in other words, isn't the need for contingency simply the result of poor estimating on the part of the estimator. The answer to this is an emphatic "no." The estimator can add a design allowance to an individual estimate line item if history shows that an allowance is systematically required for that item. However, contingency is to cover additions that cannot be systematically assigned to any one line item in an estimate, but which, based on historical evidence, can, as noted in the AACE-I definition quoted earlier, be seen to be required "*in aggregate,*" over the entire estimate. Consequently, the act of including the correct amount of contingency is a sign of good, not poor estimating.

It now becomes clear that:

- When calculating the "most likely" outcome, the estimator will already include design allowances for items that have been found to be systematically required. Hence, *design allowances are a part of the estimator's base estimate* (his "most likely" estimate) and are not part of contingency.
- Since the distribution curve reflects only the project scope, contingency is only for the scope as defined in the estimate. *It is not intended to cover scope changes*.
- Contingency is not the same as estimate accuracy
- Contingency is required if the estimate is to reflect a 50/50 likelihood of over or underrun.
- Since contingency is required in order to reach the 50/50 point, *contingency should be expected to be consumed as a normal part of a project* (since 50% of the time all contingency will be consumed).

Management Reserve – Achieving Predictability

The question then arises, what if the organization values cost predictability and wishes to know not just the 50/50 probable outcome, but an outcome with a greater than 50% probability of being underrun; for example, the 90/10 outcome (i.e., a 90% chance of being less than the specified cost). In this case, the estimate value should be the one that lies at the maximum of the 80% confidence interval. A management reserve would then be needed on top of the project contingency to cover the difference between the 50/50 outcome and the 90/10 outcome, ensuring a 90% probability of underrunning - *Figure 6*.

It is important to note here that this management reserve, just like the project contingency, is based on the specific project scope. Hence, just like contingency, it is a reserve to ensure predictability. *Management reserve is not a fund for scope changes.* A further question then arises; why isn't management reserve just included with contingency? The answer to this lies in two parts.

First, as mentioned earlier, it makes cost efficient sense to control estimates to the 50/50 point. Sometimes an individual project will have a higher cost, sometimes lower. But nevertheless, on average, the projects within the portfolio will come in on budget; therefore, no more or less money is assigned than is necessary. Consequently, for the sake of the overall portfolio of projects, there is value in asking the project manager to control to that point (with the proviso that he is not automatically censured for overrunning since 50% of the time he will overrun.)

Second, whereas there is a 50% chance of contingency being completely consumed, there is a less than 50% chance of the management reserve being consumed. Since this is the case, it makes sense to keep those funds out of the control of the project team and only release them to the team on an as required basis.

How Much Contingency is Needed?

Methods of Calculating Contingency Requirements

Although contingency and estimate accuracy can be graphically illustrated by the use of a distribution curve and the

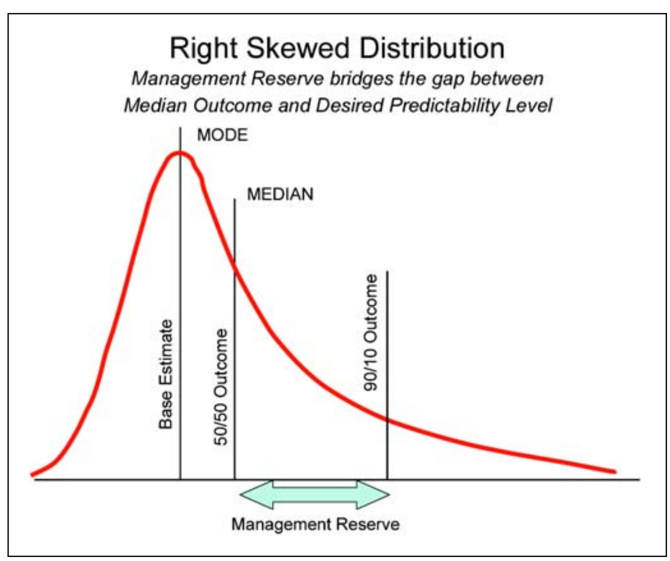

Figure 6. "Right Skewed" distribution, showing how management reserve bridges the gap between the 50/50 outcome and the desired level of predictability.

mode and median, it should be obvious by now that the calculation of the shape of that distribution curve takes considerable estimating experience (in order to form an opinion on possible risk drivers, outcomes, and probabilities) and statistical knowledge (to calculate the curve from that information). It is in calculating this curve and the probability ranges around the estimate that techniques such as risk analysis and Monte-Carlo simulation are brought into play.

However, such analysis and simulation requires specialist knowledge and effort, as well as time to perform the calculations. This may not always be available. Consequently, although a full statistical analysis of risk probability might be the obvious route to take, in practice, there are at least two other common methods. These are:

- Setting a predetermined percentage – Some companies mandate that all estimates will include a pre-determined percentage of the base estimate (such as 5 or 10%) as contingency.
- Expert Judgment – Where skilled and experienced estimators and project team members assign a level of contingency that they believe to be appropriate, based on their experience.

An interesting article by Burroughs and Juntima[12] examines all three methods and compares them to a fourth method; calculation of contingency using a statistical model based on regression analysis of past project results. They found that predetermined percentages and expert judgment methods worked with approximately the same level of efficiency as each other and were impervious to the level of project definition. Risk analysis methods provided a slightly better median performance than predetermined percentages or expert judgment, when project definition was good, but markedly worse performance when project definition was poor. The obvious lesson being that risk analysis is only as good as the base data fed to it.

The fourth method that Burroughs and Juntima propose, that of a regression model, appears to offer as good if not better results than the other methods, but it does require collection and collation of project data over a considerable period of time. (Although one could argue that this is merely putting into systematic form the "experience gathering" of the expert judgment method.)

A recent article by Hollman[13] examines these issues further. He discusses the drawbacks of Monte-Carlo simulations, as currently practiced, and ways in which regression models can be incorporated into the risk analysis and contingency calculation process.

Methods of Reducing Contingency Requirements

Knowing that project contingency is the difference between the mode and the median, it now becomes clear that different levels of project contingency (and management reserve) will be required for different shapes of risk distribution curves. The less risk and uncertainty there is around a project, the more the range of probabilities can be reduced, the "sharpness" of the distribution curve increased, and the gap between the median and the mode reduced - *Figure 7*.

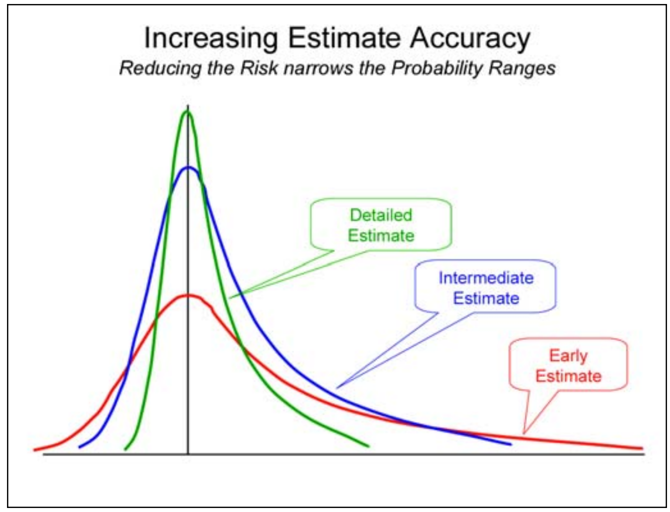

Figure 7. Reducing risk reduces the range and the contingency requirement.

The question then arises, how can risk and uncertainty be reduced? As discussed by Hollmann, project risk and uncertainty arises from several distinct elements, including systemic risks and project-specific risks.

Project Systemic Risks

Systemic risks are those that result from characteristics of the project or process "system." Two of the systemic risks are of paramount importance because they are often the predominate drivers of cost growth. These two elements are:

1. the level of completeness of the project front end definition
2. the project type

(This two element aspect of cost uncertainty has been discussed in numerous studies, including Merrow and Yarossi[14] and Burroughs and Juntima). Of these two elements, project front end definition is clearly within the control of the project team, while project type is largely outside the control of the team.

1. Project Front End Definition

A cost estimator prepares an estimate based on the scope of work documents supplied to him/her. Therefore, any items omitted from that scope of work will not be picked up by the estimator and will remain as potential risks to the project cost outcome. Similarly, any ill-defined items will carry greater risk than clearly defined items.

This point is most obvious in the fact that estimate accuracy ranges are universally understood to narrow as the project design, engineering, and construction proceeds. The more that the design, engineering and construction is complete, the more is definitively known and the less risk and uncertainty there is in the estimate. Ultimately, once the project is complete, the final costs are known and there is no risk and uncertainty left. Several organizations, including the AACE-I have produced documents classifying estimate types, and describing the approximate estimate accuracy range to expect, based on the level of front end development of the design package[15].

The point also is made indirectly in the two industry standards for assessing project front end definition, the Construction Industry Institute (CII) Project Definition Rating Index (PDRI)[16] and the Independent Project Analysis (IPA) Front End Loading (FEL) Index.[17] Both of these indices look at how well developed a project front end design package is at the time of developing the estimate. The point being that if the package development can be improved, this will reduce risk on the project; therefore, reducing the estimate accuracy range, reducing the amount of contingency needed, and increasing the probability of having a competitive, predictable project.

2. Project Type

A project that is using new technology carries greater design and execution risks than a project to build a facility that contains no new process technology and that uses processes and equipment that are tried and tested. Similarly, a project with greater complexity (for example, more unit operations) will carry greater design and execution risks than a simple project. These types of projects will require greater levels of contingency, as has been shown in the statistical models described by Merrow and Yarossi and Burroughs and Juntima.

Project-Specific Risks

Project-specific risks are those drivers that are unique to a given project's scope or strategy (e.g., the weather, labor markets, etc.). In some cases, these risk drivers may be predominant, and they can only be identified through risk analysis. By the time an authorization estimate is prepared, it is hoped that the impact of project-specific risks will have been largely mitigated through effective front-end planning (which also reduces the systemic risks).

The Effect of Limiting or Deleting Contingency

Project contingency is a necessary requirement for an estimate with a 50/50 probability of over or underrun. Consequently, it is clearly not "padding" and in addition, it should be clear that 50% of the time it will be completely consumed during the course of the project. Also, the amount of contingency required is a function of the risk associated with both the project characteristics and the level of scope definition.

Therefore, what happens if the contingency is artificially fixed at a value lower than that which is required? (e.g., if the company has a blanket rule that contingency will only be 5% on all project estimates, but the project team has calculated that a contingency of 15% is required on their project). Or what if the contingency listed by the project team in their estimate is subsequently reduced or removed by financial management staff in the belief that contingency is unnecessary "padding" and that removing it will ensure that the project cost remains competitive?

The first point to note is that by reducing/removing contingency, the financial management team is sending a very clear message to the project team that it is not trusted to estimate costs accurately. The second point to note is that if the estimate has been prepared correctly then by deleting contingency, the project is immediately condemned to having a greater than 50% probability of overrunning.

The next situation to consider is what if this organization also is the type of organization that values cost predictability and punishes overruns? This means that in order to provide greater certainty of avoiding an overrun, both contingency and reserve are required. But the project team knows that any contingency or reserve clearly labeled as such will be removed. Consequently, the team has *only one rational course of action*. That is to include contingency and reserve in the estimate, but hide it among the estimate line items.

Hiding contingency and reserve in the estimate has three effects. First, it sets the stage for a culture of weakened and less accurate estimating. Second, it weakens project control because control budgets will no longer reflect the expected requirements for hours or cost. Consequently, change management is likely to be performed in a less disciplined way. Third, human nature being what it is, the reserve money is no longer at a less than 50% likelihood of being spent. Since it is hidden in the budget it is more likely to be spent, leading to a trend of less cost competitive projects within the portfolio.

In addition, such a situation is typically accompanied by a lack of independent checks on the estimate (otherwise, the hidden contingency would be discovered and questioned). Consequently, the natural temptation within the project team is to hide not just sufficient contingency and reserve money to ensure a 90/10 probability of underrun, but a 95/5 probability or even higher. As already mentioned, once funds are hidden in an estimate in this way, they almost inevitably get spent.

Thus, by removing contingency in order to try and ensure that "padding" is removed from the budget, financial teams actually encourage "padding" to be put in; which was exactly the opposite of their intention. This "padding" is hidden, which will contribute to degraded control of the project overall (which adds greater risk) and since it is hidden, it is more likely to be spent. All of this tends to lead to less cost competitive project outcomes.

Conclusion

Cost estimates are by their nature predictions of a future outcome. As with any prediction, they carry risks and uncertainties. Using experience as to the cost effect of a project risk and its likelihood of occurrence, coupled with risk probability mechanisms such as Monte-Carlo simulations to combine risk effects, a range of possible cost outcomes can be developed.

Estimate accuracy is a function of that range of possible outcomes and should always be expressed with reference to a level of desired probability (e.g., this is a ±10% estimate, within an 80% probability range).

When managing a portfolio of projects, the logical estimate control point for individual projects is the 50/50 outcome since although 50% of projects will overrun, 50% will underrun and the overall average is neutral and neither too many or too few funds are committed overall.

The need for project cost contingency arises because the set of possible cost outcomes is not normally distributed. Contingency bridges the gap between the base estimate calculation (the "most likely" point, or the mode) and the outcome probability point that the project team is expected to control to (usually the 50/50 outcome point, or the median).

Thus, it becomes clear that:

- Design allowances are not part of contingency.
- Contingency is required in order to ensure a 50/50 likelihood of over or underrun.
- Contingency is not the same as estimate accuracy.
- Contingency should be expected to be consumed since 50% of the time it will be totally consumed.
- Contingency is not a fund for scope changes since it is related purely to the project scope as estimated.

If management requires greater cost predictability than a 50% chance of underrunning, it needs to retain a management reserve representing the difference between the 50/50 probability point that the project team is controlling to and the outcome probability point that management desires. Management reserve also is not a fund for scope changes since it too is related purely to the project scope as estimated.

Improving the project definition level can reduce the amount of contingency monies required, but projects that by their very nature are risky (e.g., new technology projects) will inevitably require more contingency than more straightforward projects.

A rational human desire to meet targets and avoid censure due to overruns means that artificially reducing or deleting contingency in cost estimates in the hope that this will reduce cost "padding" and encourage competitive final costs tends to have exactly the opposite effect.

A better way to ensure competitive cost outcomes is to encourage open and honest cost estimating with full declaration of contingency monies (calculated on the basis of risk analysis) and to encourage very good front end definition before development of the authorization estimate.

In summary, the advice for finance managers is:

- Trust your project teams to produce transparent estimates.
- Allow them to clearly show contingency (which is based on analysis of the risks).
- To reduce and control costs, focus on ensuring good design definition during the front end and on effective change and contingency management during execution. Do not focus on cutting contingency.

The advice for business sponsors and end users is:

- Don't use contingency to fund scope changes.
- If the need for scope changes occurs, accept that these are outside the project budget and must be estimated separately.
- Spend your effort on the front end design definition, making sure that the scope definition is agreed and as complete as possible before the estimate is completed.

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17. The Front End Loading (FEL) Index is a weighted checklist of project scope definition and project planning elements developed by Independent Project Analysis (IPA). It is designed to facilitate assessment of a project during pre-project planning. Several different versions of the tool exist - including versions for different types of industrial (process) facilities, offshore oil and gas exploration, production facilities, buildings and laboratories, pipeline projects, and Information Technology (IT) projects. See the Web site: http://www.ipaglobal.com/index.asp for more information.

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