Selecting Contingency Amounts When Developing Budgets and Cost Estimates on Mega-Infrastructure Projects

By Joe O’ Carroll P.E, Parsons Brinckerhoff, San Diego

The main purpose of a construction cost estimate is twofold: first, to determine if a project’s identified scope and schedule are in line with the business case underpinning its viability, and second, it also supports the project owner’s objectives while meeting the business case financial analysis. Although producing a reliable project estimate is much more challenging for a mega-project, it is the bottom line against which both stakeholder and public trust — and confidence — will be measured. Another major challenge of the mega-project is preparing for the unexpected. Given the complexity of these projects, it is impossible to predict all the variables that may be encountered, but expecting all project aspects to proceed as originally planned is not realistic.

The solution to meeting these unknown challenges is to build, through a disciplined risk management process, an analysis-based contingency into areas of a project estimate that demonstrate uncertainty and creating a budget range, rather than a budget number, to describe costs. Seeing the budget as a range enables a project owner to understand the effect that risk has on their project estimates and also provides the basis for determining contingency that can be associated with a confidence (or comfort) level for achieving the desired target. Effectively managed and not overstated, such a contingency can help ensure that cost adjustments associated with risk can be covered without having to seek additional or new funding. Using a budget range in association with a risk-based contingency provides decision makers with a more accurate assessment of ultimate project cost and a realistic confidence level in achieving that target. This, however, begs the question “How much contingency should be budgeted for a mega-project?”

Examples of the contingency levels applied to projects by other agencies

There is no “right” or “definitive” answer to this question. Much of it depends on a number of different circumstances — the level of geotechnical investigations and engineering to be performed for the project, complexity of the project, owner budgeting and budget authorization requirements, environmental constraints, the project delivery method, and current economic conditions but ultimately it is the project owner’s appetite for, or limitations on, risk that encompasses each of these items. However, it is possible to look at what risk levels (and thus contingency) other providers of large infrastructure projects are willing to take and apply to their projects and what confidence level they are willing to accept in their budgets at various stages in a project lifecycle.

One way to manage risk is through control of the costs and schedule. In recent years Agencies, Authorities and Federal Administrations have used risk management and risk analysis in the setting of and management of infrastructure budgets. Risk management is however not new to our industry. Those involved with planning, locating, designing and constructing infrastructure have managed their projects using risk based approaches for some time now. Historically
though, the risk process has more commonly been used to evaluate projects less for decision making on cost and schedule delivery and more for health and safety, socio-economic, ecological impact and regional benefit perspectives.

Transit and transportation sectors in the United States are more advanced in cost risk and contingency management than other sectors of the construction industry and thus provide some of the best reference data. Below are just a few examples of the contingency levels applied to projects by other agencies and/or their funding partners, and some detail on how these contingencies were established and risk management processes applied to control their expenditures:

- Federal Transit Authority (FTA) – A contingency between the 30\textsuperscript{th} and 50\textsuperscript{th} percentiles, based upon a “top-down” parametric risk analysis model of an adjusted base cost estimate stripped of all contingencies. This range allows for an evaluation based not only on the robustness of the cost estimate, but also recognizes the risk associated with project requirements, design, construction, and testing and commissioning.

- Washington State Department of Transportation (WSDOT) – A contingency equivalent to the difference between the base cost estimate and the 60-percent confidence level on the cost risk assessment results based upon application of WSDOT’s Cost Estimate Validation Process (CEVP). As the project approaches construction, and the design is better defined, the 80-percent confidence level will be selected.

- California Department of Transportation (Caltrans) - A contingency equivalent to the difference between the base cost estimate and the 60-percent confidence level, as determined by Caltrans’ internal risk assessment process and procedures at the project outset. As a project evolves through design and toward construction, a contingency is selected that supports a higher confidence level in the total project cost.

- UK Department for Transport (DfT) – A contingency at the 80\textsuperscript{th} percentile, which corresponds to a risk of cost overrun of 20 percent, is the level of risk that the DfT is typically willing to accept for large investments in local transportation infrastructure, based upon an appropriate forecast from a set of reference class projects.

Other agencies with mega-infrastructure projects, such as the Metropolitan Transit Agency in New York, chose to assess their budget contingencies based upon the difference between their base cost estimates and the cost estimates that produced an 80-percent confidence level when subject to a cost and schedule risk analysis. At the pre-award phase of a project, this is compared to the final cost estimate plus 5 percent contingency for change orders and adjusted if necessary. The Utah Transit Authority (UTA), on the other hand, chose to set its budgets on the addition of 50 percent contingency from project risk analysis of its Frontlines 2015 Program, but internally set its target budgets at base cost plus 5 percent risk contingency for each individual project in the program, with the remaining 45 percent being held in a program management reserve.

For some agencies or less informed owners a less rigorous either formal or informal approach to setting contingency is used whereby the owner may set the contingency based on a percentage of the estimated base construction cost, prior change order experience, have an inflated construction cost estimate or carry no contingency at all (sometimes precluded by law). Still others have an unallocated budget, that is not held at the project level, essentially a “management reserve” that may require Director of Board approval for use of the funds.

Why do mega-projects require such large contingencies?
Well thought out and managed programs generally manage 70\% to 80\% of their risks through detailed studies, engineering and contracting. Contingencies are needed for those uncertainties in the design and construction process.
including requirements risk, unknown conditions, property acquisitions and easements, urban impacts, innovative designs and new technologies, timing of procurement, market fluctuations, etc. Other major issues on mega projects include bonding, insurance, warranty, etc which are often managed through creative procurements.

On large infrastructure projects, the contingency amount needed to support high confidence levels usually involves hundreds of millions (in some cases, billions) of dollars over and above the base cost estimate. Some industry experts would suggest that construction costs are affected by numerous factors, such as rising oil prices, natural disasters, possibly a booming construction market in another part of the world, and other macro-economic pressures. The fact is, base cost estimates are generally driven to their lowest possible level assuming the most optimistic scope and most favorable market conditions. This is to get past an often equally unrealistic cost-effectiveness ratio that fails to take into account long-term socioeconomic benefits, development generation, and perhaps, most importantly, fails to acknowledge increases in property value. The other major reason for estimate increase is uncontrolled scope growth driven by political changes at all levels. Mega-projects are highly political and no one wants to argue down stakeholder or other political aspirations. This allows scope growth, specification enhancements and other factors to grow unchecked. These factors include schedule compression, where a project start is delayed, but the policy completion date remains unchanged. Quite often, estimates do not anticipate the massive pre-construction schedule delays that typically occur on mega-projects due to political changes. A budget given at the alternative analysis or environmental studies stage can increase significantly by the time construction begins because either the schedule has moved years out and/or the schedule has subsequently been compressed to comply with a changing political environment.

Another source of risk and thus, a requirement for contingency on a mega-project, is optimism bias. Studies have documented human judgment to be generally optimistic due to overconfidence and insufficient with regard to distributional information. Typically, people will underestimate the costs, completion times and risks of planned actions, but they will overestimate the benefits of the same actions.

Bent Flyvbjerg(1), a leading international expert on major program management and planning, presents an approach to mitigating such risk based on theories of decision-making under uncertainty. This approach won the 2002 Nobel Prize in economics. Flyvbjerg explains inaccuracy in terms of optimism bias and strategic misrepresentation and presents a method called “reference class forecasting,” which achieves accuracy by basing forecasts on actual performance in a reference class of comparable projects, and thereby bypassing both optimism bias and strategic misrepresentation.

Flyvbjerger’s studies focused on three project categories: rail, roads and fixed links (bridges and tunnels). Figure 1 shows that although 10 percent of fixed link study projects came in 10 percent under budget, 90 percent of study projects showed a maximum cost overrun of 80 percent when compared to their budget.

Based on the probability distributions outlined above, the uplift (contingency) required to establish the most likely outcome for a specific project is described by Flyvbjerg in Figure 2. The 80-percent confidence level in the budget—corresponding to a risk of cost overrun of 20 percent — is the level of risk that the UK DfT is typically willing to accept for large investments in local transportation infrastructure. In other words, if a group of project managers were preparing the business case for a fixed link (such as a tunnel project), and if they or their client had decided with 80-percent certainty that they wanted to stay within budget, they would use an uplift on capital costs of 50 percent. An initial capital expenditure budget of $1 billion would then become a budget of $1.5 billion. If the project managers or their client required only 50-percent certainty that they would stay within budget, that would equate to a 20% required uplift (Figure 1) for a budget of $1.2 billion.
It follows from Flyvbjerg’s analysis that the 50-percent confidence level should only be used in instances where investors are willing to take a high degree of risk that cost overrun will occur and/or in situations where investors are funding a large number of projects, and cost savings (underruns) from one project may be used to cover the costs of overruns on other projects. The upper percentiles (80–90th) should be used when investors want a high degree of certainty that cost overrun will not occur, for instance, stand-alone projects with no access to additional funds beyond the approved budget. The established uplifts for optimism bias are applied to estimated budgets when the decision to build a project is made. In the U.K., the approval point for a large transportation project is equivalent to the time of presenting the business case for the project to the DfT with a view to obtaining the go-no go decision. In the U.S., this would most likely be equivalent to the process needed for obtaining a Record of Decision (ROD).

Source: Flyvbjerg database on large-scale infrastructure projects.

Figure 1: Probability distribution for cost overruns for fixed links
Establishing Contingency on Federally Funded Transit Projects

Historically, projects funded through the FTA’s New Starts program have faced criticism for overpromising on costs and benefits. A 1989 report by the U.S. Department of Transportation’s Transportation Systems Center found that project cost estimates prepared in alternatives analysis were significantly below actual costs when the project was implemented. It also found that user benefit forecasts developed in alternatives analyses were generally well above the actual ridership after implementation. In response to this, the FTA has made concerted efforts over the past 20 years to ensure that its discretionary funding decisions are based on credible information on costs and benefits.

In 2005, the Transit Cooperative Research Program (TCRP) commissioned a major report to analyze how past projects had performed and where and why they had seen cost and time increases over their delivery cycles. The report showed how cost certainty grew from alternatives analysis, during preliminary engineering and final design, and through construction. Similar in nature to the reference class forecasting described by Flyvbjerg, this report became a key reference source for developing factors that, when applied to cost estimates and schedules, would generate a sensible maximum ceiling.

Based upon the historical information in the TCRP report, the FTA developed a model that took the most optimistic cost estimate (free of contingency, with a 10-percent likelihood of success) and the most pessimistic estimate (termed the 90th percentile), to which a log-normal distribution curve was applied. This resulted in a cumulative density function (or S curve) of likely project cost ranges versus probability. The intention was to produce more accurate and realistic true end-cost forecasts based on past trends. The multiplication factors between the 10th percentile and the 90th percentile became known as the beta risk factors (BRF). The BRF was to represent all risk exposure on a project and applied to each aspect of the work.

From this process, the FTA developed a contingency profile representing requirements risk; progressive risk reduction; and assignment of BRF values going through design, procurement, and all construction stages, commissioning and testing. The FTA’s goal was to ensure that project protection began with an adequate contingency provision, should
subsequent financial difficulties occur, by establishing a pre-developed plan to mitigate and replenish contingency to a minimum-required level based on the targets.

Establishing and Managing Contingencies

Contingencies have been used effectively to budget for uncertainty, despite some pundits’ belief that contingencies create a self-fulfilling prophecy, with project cost automatically growing to consume all set-aside funds. This may be based on a concern that a cushion results in a more relaxed management approach to cost containment, inevitably leading to unnecessary cost increases, or in the case of some publicly funded agency projects, the “spend it or lose it” philosophy, with little or no credit given for handing money back. However, setting of appropriate contingencies recognizes that unspecified but legitimate costs will arise during the life of a project. These additional costs must be covered by the project’s budget.

The process of using a budget range, rather than a budget number, to describe costs provides a greater sense of cost reliability for completing mega projects or programs. A well planned risk assessment process provides a higher degree of confidence in the allocated budget, and that risks for the project or program have been identified and quantified and can be managed throughout its duration. Following this up with a well developed risk and contingency management plan, project or program managers can be provided with a leaner budget to complete their projects, but with the understanding that they would need to be diligent in reducing and eliminating risks to complete construction within this budget.

It should be emphasized that the risk management is an iterative and ongoing process. Once risks have been assessed, analyzed and managed, the remaining risks will be reassessed, reanalyzed, and continually managed. It is an ongoing process for the life of the project because at different points, some risks will become irrelevant while others, unanticipated at the outset, will appear. Additionally, existing risks must be reassessed for both probability and impact as the project proceeds.

Recommended Approach for Mega-Projects

Traditionally, agencies or other providers of infrastructure projects will do a “quantities x unit” price cost estimate and add a nominal 30-percent contingency at the preliminary engineering phase, reducing this to 10–15 percent toward the end of final design. Often, after contracts are awarded, the contingency is reduced to between 5–10 percent of contract value. When a low bid is accepted, the agency inevitably takes on more risk. When the contingency is tied to a percentage of the contract value, it is not surprising that the agency’s project manager has difficulty bringing the project in within budget.

Changing this traditional philosophy and linking contingency to the amount of risk and uncertainty associated with the project is the right way forward. The author’s recommended approach would be to strip out the entire contingency embedded in the project’s estimate and replace it with a "risk contingency," which encapsulates both the uncertainty in quantities and design development, as well as any discrete risks that the project is unable to mitigate at that point in time. Added to this would be a time-related cost contingency that reflects the potential additional cost associated with the schedule risk analysis, i.e., the risk of the project starting later and taking longer than anticipated. Based upon an integrated cost and schedule risk analysis, the contingency amount held by the Owner can then reflect its appetite for risk. If funding is the biggest constraint, the Owner can choose the confidence level they want to accept in meeting that target and carry the appropriate level of contingency. This approach gives the Owner or infrastructure provider the comfort of knowing that it has made an informed decision, with contingency being properly managed and regularly updated through design development and into construction. At the end of final design (assuming design-bid-build), the
risk contingency carries an element of design change, but mostly market risk, construction risk and commissioning risk. The process would provide a budget contingency ($ value) and a schedule contingency or ‘buffer’ that protects the critical path and near-critical path activities at key milestones in the project lifecycle.

The next step would be to develop a risk and contingency management plan to avoid established contingencies for each project phase being used up too early in the project. This should begin by examining how much risk is associated with the various project elements and when these activities occur. For example, one could assess how much risk is associated with commissioning of the project. Is there a lot of new technology being used that carries a higher risk? How much risk is being carried with the project components being constructed or installed at the back end of the schedule? Look at key milestones — end of final design, all contracts awarded, 50 percent, 75 percent and 90 percent through construction, start of testing & commissioning and establish the minimum contingencies needed at each of these milestones; formulate a plan to mitigate and replenish contingency to a minimum-required level based on the established target.

Once the minimum contingencies are established, provide a suitable buffer to protect these contingencies. If actual project contingencies drop below this buffer zone during project delivery, it would raise a “red flag,” indicating that the project may not have sufficient contingency for completion within the original budget. This signals the need to make some tough decisions that may require either finding additional funding sources or look at where scope in the remaining elements of the project could be cut, if needed, through design refinements.

Conclusions
There is no right or definitive answer to the question of “How much contingency should be budgeted for on a mega project?” The answer depends on a number of different circumstances, particularly the project owner’s appetite for, or limitations on, risk. Typically, providers of large infrastructure projects require a contingency that will provide them with 60-to 80-percent confidence levels that the budget will not be exceeded. Depending on the project, this could require a contingency in the order of 30−50 percent of the base cost estimate. Funding a mega-project to higher levels of confidence (90 percent or greater) is unrealistic, given the many years required for construction and the major challenges and risks it faces. For most projects, it would also be unaffordable.

The solution is to build, through a disciplined risk management process, an analysis-based contingency into areas of a project estimate that demonstrate uncertainty and risk, creating a budget range, rather than a budget number, to describe costs. Effectively managed and not overstated, such a contingency can help to ensure that costs adjustments associated with risk can be covered without having to seek additional or new funding. The use of a risk-based contingency range will also provide decision makers a more accurate assessment of ultimate project costs.

Once the risk-based budget is established, an effective risk and contingency management program must be put in place. The risk management program must be an iterative and ongoing procedure. Once risks have been assessed, analyzed and managed, the remaining risks will be reassessed, reanalyzed and continually managed. This is an ongoing process for the life of the project.

A target contingency profile should be established, representing requirements risk and progressive risk reduction through design, procurement, all construction stages, and into testing and commissioning. Contingencies at each stage in the project lifecycle should be protected with a pre-developed plan to mitigate and replenish contingency to a minimum-required level based on the established target.
References:


(3) Risk Supplementary Report Whole Life model for water services on Belfast Sewer Study, August 2000

(4) Risky Business on Utah Transit Authority’s Frontlines, American Public Transportation Association Proceedings, Goeres, O’Carroll, Grodner and Berry; November 2008.


(7) PB is Raising the Bar and Setting New Standards in Project Risk Management, Economic Forecasting review, Vol. 3 Issue 1 May 2009. O’Carroll