White Paper 2015-10

8 Best Practices for Project Cost Risk Calculations Using the Monte Carlo Method

In this White Paper we will describe some key fundamental practices that need to be implemented when running Monte Carlo simulations of Project Cost with the aim to determine and/or justify a contingency amount. It is important to realize that as any simplified representation of reality, Monte Carlo simulations must obey certain basic rules consistent with its mathematical fundamentals to be representative of the Project situation, and that the method also has significant limitations.

Monte Carlo methods are used to calculate contingency levels for Project cost. The project Estimate to Complete (ETC) Cost is split in a number of lines, to which a probability spread is associated. In addition, discrete risks can be added in the model; these are risks that occur with a certain percentage probability. The statistical spread of the resulting total cost is then calculated. The contingency is generally taken as the P80 cost[1] minus the deterministic cost, although different organizations might have slightly different standards in that respect.

When Monte Carlo is used as the method to calculate the risk contingency it is important to check that the basics are covered to ensure reliability and repeatability.

Technical Best Practices

1: Check that the model has converged

Before dwelling into the details of the method, it is important when running a Monte Carlo model to check that the model has effectively converged before interpreting the results.
In the case of Project contingency models, it is not rare to require up to 10,000 iterations to have a converging Monte-Carlo model. This remains a quick calculation on modern computers. Still too often we observe that conclusions are being drawn from results that have not been checked for model convergence. When trying to reproduce the results, different values are then obtained which is very confusing.

2: Limit the number of lines

The Monte Carlo method has an annoying characteristic: it is mathematically inconsistent. If you add lines to the model for the same project, the contingency will diminish approximately like the square root of the number of lines. Thus it is essential to have a standard regarding the approximate complication of cost models used for Monte Carlo across all projects in the same portfolio. We recommend simple models of approximately 40 lines even for large and complex projects.

3: Remove low probability, high consequence risks

The Monte Carlo method is not geared to cover probabilities in the range 0-20% or 80-100%, and even less in the range 0-10% or 90-100%. Adding such events in a Monte Carlo simulation will create strange results and will make the model very difficult to converge mathematically.
It is not recommended to include those events in the Monte-Carlo model. Very high probability events should be part of the base case (typically as allowances). Very low probability events should be excluded and managed separately once identified using Industrial Risk methods specifically designed for that purpose.

4: Make sure the built up of the Monte Carlo model is adequate in terms of line aggregates

Because the model needs to have a limited number of lines, how the cost data is aggregated into ~40 lines is very important. It should not just be a roll-up of the project cost model into a standard breakdown: certain types of cost might warrant more detail than others. Cost lines should be aggregated by type (internal manpower, procurement, subcontracts…) that reflect the type of risk exposure. Very low risk components should be segregated from very high risk components. Finally, the value of each line should be grossly consistent throughout the cost model. This cost model setup requires some experience and can evolve through the project in particular as parts of the cost is spent.

Process best practices

5: Run a Model sanity check with the Project Manager

It is a good practice to run through the model with senior Project Management to ensure that there is a consistent understanding of the Opportunities and Risks faced by the Project. The Risk Engineer will have collected data from various sources and Project team members, and it can be useful to run through the entire model with representatives of the Project Management Team (ideally, the Project Manager) that have a good overview of the Project in its entirety

[1] The P80 cost is the amount for which there is 80% chance that the final cost will be lower (and hence, still 20% chance that it will be higher).

6: Avoid double dipping (in particular with allowances)

In the Monte-Carlo model exercise it is extremely important to avoid any double-dipping between what is being considered as contributors to the contingency and the hypothesis underlying the rest of the Project cost model, in particular any allowance that would have been created or kept in some budgets – explicitly or implicitly.

This requires the Risk Engineer to establish the model in very close cooperation with the Cost Controller so as to make sure that the uncertainty elements in the Monte-Carlo model do not double-dip, and adequately complete the underlying assumptions of the base budget. This needs to be also identified so that budget owners clearly understand what is included in the base cost when asked to give sensitivities.

Monte Carlo as a method is not always sufficient to protect the project against all Known Unknowns.

7: Treat explicitly common causes and correlations

Monte-Carlo method supposes each line to be independent – unless some kind of correlation is imposed between the lines. We do not recommend to introduce correlations in project cost models as it is very cumbersome and difficult to trace and justify properly.

When it comes to common causes of variances, such as for example commodity prices (oil, steel…), it is recommended to extract these variances from the fundamental variances of each cost line item and to add a single line dealing with this particular possible variance. The best and worst cases of the original lines are then estimated without taking into account that particular cause; and the new line item will carry the entire impact of the variation of that common cause. This will much better represent the common cause risk than trying to introduce correlations.

8: Check that you did not include inadequate revenue opportunities

Revenue opportunities which are unsigned Change Orders need to be treated with care, because it is not adequate to recognize any component of this revenue in the prudent accounting cost forecast (refer to White Paper 2014-08 'Why the 'Achievable' project forecast is as important as the Prudent 'Estimate At Completion'). The official contingency should not take into account any of these revenue opportunities. Monte Carlo calculations can be done separately to give an appreciation of the project outcome, but that should not be mixed with the contingency calculation.

On the other hand cost savings opportunities or other revenue opportunities that correspond to signed contractual terms can be safely included in the Monte Carlo calculation.

Conclusion - Caution on Monte Carlo

The best practices described in this White Paper are rarely all implementation which leads to issues with the result of calculations of contingency with this method. Monte Carlo as a way to calculate contingency might not always be sufficient, but when it is used it is important that the basics are covered to give some reliability and repeatability to the result.

While this White Paper elaborated on best practices for the conventional way of calculating a cost reserve based on a Monte Carlo analysis of the Project budget, this approach is not always sufficient to protect the Project against all Known-Unknowns.

There is actually no other way to determine the 'right' level of contingency than to rely on actual experience in a specific domain or industry. In some particular instances, it can be adequate to add very significant amounts of contingency. The Apollo Project mentioned in our handbook provides a good example[2]. Other considerations include the dominance of time delays as a source of cost risk, refer to guidance given in our White Papers 2012-11 and 2012-12 'Estimate Your Actual Risk Level in a Project: the PVD Risk Level Formula'.

[2] The initial budget churned by the cost estimators was $7 billion. However, based on his experience of such programs, the NASA administrator James Webb included some (!) contingency and presented to the President and Congress of the United States a budget of $20 billion. The program finally cost around $24-25 billion. This is an example of setting a very significant contingency, based on experience, due to the challenging nature of the Project (technologically and logistically).