Measuring, Monitoring and Managing the Potential Cost of Construction Project Risk

by Frank B. Mitchell, Jr., CCC, PMP

Risk is another name for uncertainty, which includes the complete range of positive and negative impacts on the future outcome of a project.

A project’s exposure to risk can range from acts of nature to simple mistakes. The usual end result of a deviation from the original project plan, budget or schedule is additional cost to the project. Risk Management is the methodology involved in limiting exposure that can be caused by these events.

Enterprise Wide Risk Management is a corporate-wide program to share the risk of all project activities. Using modern Bayesian statistical techniques a company can predict the amount of contingency required to cover the probability of risk exposure to a single project and the capital reserves necessary to ensure a level of confidence that all ongoing projects will have enough funds to be completed without using profits. These techniques usually require fewer resources held in contingency than more traditional rules-of-thumb or heuristics. However to ensure that resources are available when required, there must be ongoing management controls over the expenditure of contingency funds.

Risk Management activities can be subdivided into four distinct areas: Risk Assessment, Risk Analysis, Risk Mitigation, and Risk Controls.

- Risk Assessment is the first phase of risk management. It includes the identification of risk or uncertainties that may affect a project.
- Risk Analysis is the second phase of risk management and it includes the quantification of the effect of all uncertainty on a project. It is usually performed using the risk assessment list of risk by estimating the impact of each risk event, establishing the probability of occurrence and the potential severity of the impact. The impact may be expressed as a range of values, with a confidence level, or as a probability distribution. The risk analysis can be performed on a schedule, cost estimate, or project plan. All risk events can be reduced to a range of potential cost impacts for purposes of calculating a contingency value that will ensure confidence that the project can be completed within the total budget.
- Risk Mitigation is the third phase of risk management. It involves the development of a Risk Management Plan.
- Risk Control is the last phase of risk management and it involves the implementation of the risk management plan.
Risk Assessment

Risk can be subdivided into external and internal sources.

External Sources of Risk
- Uncertain events such as:
  - An act of nature,
  - Political unrest,
  - War,
  - Labor unrest,
  - Limits on availability of material or
  - Skilled craft workers.
- Uncertain conditions would include:
  - Rates of exchange
  - Or inflation,
  - Productivity of the local labor force,
  - Local holiday productivity losses
  - Learning curves for new technology

Internal Sources of Risk
- Contractual risk
- Scope definition risk
- Project plan risk
- Unknown conditions risk
- Schedule risk
- Budget risk
- Project safety and quality risk
- Results definition risk

A risk assessment will usually follow several different tracks at different times during the proposal phase, design phase, planning phase and start-up phase. The Project Management team will work on:
- A survey of site conditions,
- Review the proposed contract,
- The scope of work,
- The client’s desired results and
- Any economic forecast
- Review historical local conditions and
- Begin work on a project plan that will include safety and quality plans.

The estimating team will work with the scheduling team to prepare a joint work breakdown structure that will allow each activity to estimated and scheduled. Client contract requirements may dictate that a separate WBS be developed for purposes of their bid evaluations or funding requirements.
Risk Analysis

Predicting the probability of external events is almost impossible. When there will be an earthquake, a fire, a change in the exchange rate or other activities cannot be calculated. However, there are actions that can cover the potential cost of these events such as insurance, futures contracts, advanced purchasing, early fixed price subcontracts, or arbitrage.

Modern statistical methods that calculate probability such as Monte Carlo simulations, Latin Hypercube techniques, Neural networks and other artificial intelligence programs, Multiple Regression, and Stochastic Risk analyses require multiple quantitative samples for each activity. This is usually expressed as a range of potential cost or schedule durations showing the Most Likely Value, the Least Likely Value and the Highest Likely Value. Historical data can be analyzed to discover if there is a bias in the probability of results.

The Central Limit Theorem states that there will be a binomial distribution (equal chance of a higher result or a lower result) in most cases. Actual results in construction projects show that there are many activities that have a skewed probability distribution (a greater probability of a higher result than of a lower result). The actual distribution of probability can be Normal (binomial or Bell Curve), Logistic (S Curve), Probit (a Bell Curve skewed to the high side), Exponential (a continuous rising curve), Breakpoint (rising at one rate and then changing to a different rate), Lognormal (a rising curve that has a reduced rate of increase), and Triangular (a Bell curve that has a fixed Minimum and Maximum).

When the scheduling or estimating analysis teams meet, they use the ranging technique to describe the lowest, most likely and highest probable outcome for each individual activity, work item, account, or sub-account. These numbers do not have any contingency added to them but they may have allowances included (known but undefined requirements). The most likely value is usually the “Best Estimate”. These values (either cost or schedule days) are subjected to one or more statistical analyses.

The Monte Carlo simulation is one of the most used programs and is available from several different sources. Crystal Ball and @Risk are Excel spreadsheet add-in programs, Statistica and NCSS are full statistics programs that have a Monte Carlo module, and Project Risk Analysis (PRA) or the Range Estimating Program are Monte Carlo based programs specifically designed to calculate the probability distribution of construction projects. A probability distribution listing will show the percentage of confidence and the value at that confidence. For example, the value of a project at a confidence level of 80% may be $51.7 million dollars, while the Best Cost Estimate may be $50.0 million. The amount of contingency required is $1.7 million dollars. This is enough to ensure that there is an 80% probability that the cost of the project will be less than $51.7 million. The value to achieve a 95% level of confidence may be $53.9 million and the value to achieve a 99% level may be $57.1 million.
If these same analyses are run on an enterprise level on all of the existing projects, some of each project's contingency can be held back as a corporate reserve, which will reduce the amount of contingency required for each project.

**Risk Mitigation**

Using the information developed in the Risk Assessment and Risk Analysis a Risk Management Plan is developed and published. This plan should include a list of the action steps to do the following things:

- Reduce the probability of a threat occurring.
- Reduce the impact of the threat if it does occur.
- Increase the probability of an opportunity occurring.
- Increase the impact of an opportunity if it does occur.

The plan should include specific actions to be taken for each potential problem or opportunity and the indicators that will trigger when they are to be executed. Actions can include:

- Contingency funds,
- Float time in schedules,
- Trading between cost, quality and schedule,
- Insurance,
- Subcontracting fixed price components,
- Immediate notification and refusal to proceed without approval for increases in scope.

**Risk Control**

In order to execute the Risk Management Plan there must be regular reports of the progress of the project (both budget and schedule). Any variance from the plan should be analyzed for significance from the viewpoint of the project running out of control.

Funds that are held in contingency or reserve should not be expended for any use other than an uncertain event. If one phase of a project is finished or bought out within the budget, the savings should be rolled over into the contingency for the rest of the project.

The Monte Carlo technique relies on spreading the probability over all portions of the project by assuming that not all adverse events will occur or that their impact will be at the highest cost level.

The typical practice of many project budgets is to spend any extra amount available.

Some clients and contracts call for owner control of project contingency or shared savings of project contingency. If the owner is willing to accept all risk, then this is acceptable. If the owner tries to shift the risk to the Contractor, then they must carry two different contingency programs, one for the owner and one to cover his risk.
In a GMP (Guaranteed Maximum Price) contract, the contractor is at risk for all cost above the maximum, but the contingency shown in the budget is available to the owner or for joint sharing. In this type of contract, the contractor must carry two different contingency budgets.

Samples from Project Risk Analysis (PRA)

![Data Entry Screen](image1.png)

The Data Entry Screen

![Overall Cost Distribution](image2.png)

A Typical Histogram of Overall Cost Distribution
A Typical “S”-Curve of Overall Cost Distribution

The Main Statistics Screen
Driving the building process for optimal results

CUMULATIVE PROBABILITIES

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<th>Probability</th>
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NOTE:
The indicated probabilities give the likelihood of the total cost being less than or equal to the shown project costs.

Sensitivity Analysis

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<th>Rank</th>
<th>Description</th>
<th>Expected Over-run</th>
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<td>8</td>
<td>Instruments Supply</td>
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