EM-5.22
Lessons Learned
Bulletin

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Integrated Risk Management and Joint Confidence Levels

Contact: **Johnnie Newson, EM-5.22** johnnie.newson@em.doe.gov
202-586-8849

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Statement:

The AACE International (formerly the Association for the Advancement of Cost Engineering) professional association released a **Recommended Practice No. 57R-09 titled *Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model*.** This standard practice guide discusses and demonstrates the integration of cost and schedule risk using Monte Carlo as an analytical tool to perform sensitivity analysis to provide a more holistic view of the project risks. The intent is to discuss the importance of performing sensitivity analysis in order to develop better Management Reserve (MR) and Contingency values. In EM, projects typically maintain risk registers which are used to determine the appropriate Management Reserve to be maintained by the Contractor, and the Contingency to be maintained by DOE for DOE owned risks. However, sensitivity analyses are not always performed for all risks. This bulletin provides some examples of projects that would have benefited from application of this practice.

Discussion:

The AACE International released a Recommended Practice (RP) No. 57R-09 titled *Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model* addressing this topic and has identified the benefits, which provide "(1) more accurate cost estimates than if the schedule risk were ignored or incorporated only partially, and (2) illustrates the importance of schedule risk to cost risk when the durations of activities using labor-type (time dependent) resources are risky". An EM project exceeded its projected cost and schedule due to a major risk realization. The project was a soil remediation project which was part of a larger remediation program. The project performed characterization of the site, but relied heavily on historical records to quantify the project scope. The actual site conditions ended up having 90% more waste than originally identified and a material at risk 10 times higher than originally planned. The project achieved CD-4; however, the original TPC was overrun by 24% and the schedule was extended by 6 months due to a failure in fully understanding the risks. The additional funding needed to complete the project was supported through base funding from the site, taking advantage of project opportunities, and included moving funding from lesser priority work. In the projects Lessons Learned, it was stated that the project would have benefited from spending more time calculating the costs of both risk and mitigation. Had the landfill been more thoroughly characterized, the team would have realized the increase in scope and developed a higher original TPC. Sensitivity analysis is a tool that supports risk analysis based on how sensitive a risk is to scope change.

By integrating estimated costs with a Critical Path Method (CPM) schedule, sensitivity analysis can support management in better understanding the full impact of a risk event. If the scope of the project changes slightly, is the risk sensitive enough that it will go away or compound or will there be no impact? If the same risk occurs, via correlation does the likelihood of other risks occurring change and what is the full cost impact (delayed contracts, hotel load, extended rental agreements, etc.) when a risk actualizes?

The RP suggests that any analytical software tool used needs to be able to handle schedule risk, burn-rate risk, and time-independent resource risk. To run this calculation, the RP identifies three inputs which are required:

- *A high quality project schedule, whether a detailed schedule or a summary schedule that represents all of the work, is completely logically linked, does not rely on constraints or lags/leads, has resources loaded, durations are unbiased estimates, and is updated – basically a schedule following recommended practice of CPM scheduling.*
- *A contingency-free cost estimate, meaning that line items do not have padding built in to accommodate risk and there is no below-the-line contingency included.*

- *Good quality risk data – usually risks that have been identified during a qualitative risk analysis of the project leading to a list of prioritized risks, with probability and impact parameter data collected so that they fully represent the risks and are not biased. Other risk data might include probabilistic risk events that alter the project schedule by adding recovery activities not necessary if the risk does not occur.* [1]

When schedule risk is calculated, the typical output is a duration (time) contingency needed to meet the expected confidence level. There is no impact to cost when schedule risk is calculated. When cost risk is calculated, the output is based on cost alone with no impact from schedule risks. A typical approach to costing the financial impact of schedule risk is to determine the hotel load/burn rate (operating or management cost) and apply that rate to the duration calculated for schedule contingency. This gives consideration to the cost impact of schedule risks yet it is also inaccurate. What is not captured is the appropriate labor rates for extended work activities such as commissioning, the extended costs of maintaining rented equipment on site, or the cost of additional characterization of a site if unexpected contamination is found. These elements are not part of a traditional hotel load but need to be taken into account as well. The RP suggests that by using Monte Carlo analysis, the cost and schedule impacts associated with a unique risk can be attached to activities within a CPM resource loaded schedule. Iterations can then be run to give a more accurate prediction of the combined cost and schedule impacts of the risk. When loading the schedules, the RP identifies the following precautions:

- *Ensure all resources are appropriately marked for dependency:*
    - *"Labor-Type" (time dependent) resources are those that will cost more if they work longer. These include contract labor, engineering labor, the project management team (a level–of-effort resource), and equipment that is billed by the day such as cranes, earth movers, drill rigs, installation barges and the like.*
    - *"Material-type" (time-independent) resources include those that have uncertain costs but do not necessarily cost more if their activity takes longer. The main examples of these resources are manufactured equipment and bulk raw materials. Their costs may be uncertain but not because of time.*
- *Ensure all resources are loaded into the CPM schedule:*
    - *The entire budget is represented, so any change in the duration of activities supported by time-dependent resources will capture the cost effect of schedule uncertainty.*
    - *Placing resources on individual activities will place the costs correctly in time, permitting the computation of probabilistic cash flow. The more the resources and costs can be placed on individual activities correctly, the more accurate the probabilistic cash flow will be.*[1]

The use of hammock activities (summary activities having no duration but derives one from the time difference between the two points it connects [2]) can also be useful in this approach by including multiple activities into a single risk event from the project integrated schedule. Highly detailed schedules may not neatly align with the project risks. By using hammock activities the forecasted resources can be applied at a higher level, rather than broken out against several highly detailed activities. This technique can be used when correlation is found between risks creating a domino effect of a single risk or to address significantly detailed schedules where risks cannot easily be assigned. This allows for real resources to be applied to specific risks that can then be run through Monte Carlo simulation.

A benefit of having the risks uniquely assigned to resource loaded schedule activities is that each risk can be viewed independently analyzed for impact on the project. Analysis can be performed identifying which carry the highest impact on the project and if those risks carry more cost or schedule impact. The RP suggests that by using this simulation method, it allows a user to:

- Determine the likelihood of finishing on time and on budget
- Calculate the contingency reserve of time and cost to provide an acceptable level of certainty for stakeholders
- Identify the main risks to cost and schedule for the next phase, risk mitigation

In the time that the AACE International RP was published other programs have been developed to support sensitivity analysis. Monte Carlo is the not only method nor is it singled out as the recommended method. This Lessons Learned is intended to educate the reader in a best practice, and encourage additional rigor in the development of cost and schedule contingency.

Recommended Actions:

1. Prior to performing risk simulations, work with project controllers to ensure that cost estimates and project schedules have been developed with no embedded contingency.
2. FPDs should work with stakeholders and the project team to independently review each risk, risk sensitivity, and the mitigation techniques to develop changes in the means and methods of scope execution which will reduce the overall risk to the project.
3. FPDs should ensure that contractors include sensitivity analysis as part of their risk management plans.

Critical Decision(s):	CD-0 to CD-4
Facility Type(s):	All
Work Functions(s):	Project/Program Management
Technical Discipline(s):	All

References:

1. Hulett, Dr. David, "Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model", *AACE International Recommended Practice,* No. 57R-09 (2011).
2. AACE International, "Cost Engineering Terminology", *AACE International Recommended Practice,* No. 10S-90 (2015).