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Risk Review of Recovery Schedules

Mr. John Ciccarelli, PE CCE PSP, and
Mr. Matthew Murch

When construction projects experience delay and disruption and deviate from the original baseline plan, owners and contractors typically develop a recovery schedule to rebaseline the project. How realistic is the recovery schedule? Is the recovery schedule a reasonable plan or was it forced to achieve a pre-determined completion date? The ultimate issue is determining the probability that the recovery schedule will be met, especially considering past performance on the project. This paper will explore methods for using current Monte Carlo based risk analysis techniques to review recovery schedules and will discuss methods for incorporating past performance on the project (including scope growth and productivity) as risk to demonstrate the reasonableness of achieving the rebaselined planned completion date. The paper will also discuss the importance of rebaselining direct and indirect costs to reflect changes and the adjusted risks.

Introduction

Quantitative risk analysis is a growing field that the construction industry is increasingly applying to project management to determine confidence levels for project cost and schedule success, determine contingency, and establish risk mitigation plans. Typically, this type of risk analysis is performed during the early stages of a project's life-cycle, however, an existing risk analysis can be further refined as risks evolve or a risk analysis can be developed from the ground-up at any point during project execution, i.e., when a recovery schedule is developed. The balance of this paper will discuss industry issues relative to the use of recovery schedules followed by an overview of quantitative risk analysis and the application of quantitative analysis to the review of recovery schedules.

Recovery Schedules

When the critical path method (CPM) technique is used to plan and schedule a project, it is standard to develop a "baseline schedule" against which the contractor should measure progress and update progress. Assuming that the contractor and owner have reviewed and agreed to the baseline CPM schedule, a schedule update is typically submitted at a pre-determined cutoff date, i.e., monthly, to report progress achieved. Properly updated schedules indicate whether activities on the critical path are proceeding as planned, which activities are falling behind schedule, how far they are lagging at any given point, and whether actual progress (or lack thereof) has caused the critical path to change.

Under standard CPM scheduling practice, the baseline schedule remains in effect until there are substantial changes to the plan that affect the critical path (i.e., delays). When the project experiences delay, the contractor is typically required to prepare a recovery schedule that demonstrates how the lost time will be recovered. As such, recovery schedules are often used when the assessment of liquidated damages is a risk issue. Typically, a revised baseline schedule is necessary when:

- The critical path changes as a result of major delays and/or scope changes.
- Delays have consumed the total float on non-critical activities and pushed them into the critical path.
- The project schedule does not accurately reflect the actual planned execution, project scope or progress of the work. And/or,
- The project is performing major out of sequence work.

The Association for the Advancement of Cost Engineering International defines the recovery schedule as *"A special schedule showing special efforts to recover time lost compared to the master schedule. Often a contract requirement when the projected finish date is no longer showing timely completion. (6/07)"* [1].

While the construction industry is more often including recovery schedule requirements in contracts, these contracts contain a variety of conditions under which a recovery schedule is required. The following examples illustrate the varying contract conditions that define the need for a recovery schedule:

- If the project falls behind schedule more than 14 days or 10 percent of the remaining duration, whichever is less, for non-excusable delays.
- In the event that the Progress Schedule Update indicates that the project, or progress toward any interim milestone, falls 20 or more work days behind schedule.
- When requested by the owner or Engineer.
- When the owner determines that the contractor is behind any mandatory specific milestone or completion dates or any interim milestone completion date.
- When the contractor determines that the progress schedule requires revision for any reason. And,
- When departure from the existing schedule makes it apparent that the project will be late.

In addition to the "triggers" for determining the need for a recovery schedule, there are other considerations with respect to developing a recovery schedule. First, the need for a recovery schedule should consider any excusable delays or changes and all time extensions to which the contractor is entitled. Second, the timing for submittal of the recovery schedule can also be specified. For example, some contracts require that a recovery schedule shall be submitted 14 calendar days after the monthly progress schedule update was submitted. Further, some contracts allow for the owner to withhold progress payments until the contractor submits a revised recovery schedule, acceptable to the owner. When specific contract language exists, but the contractor fails to produce an acceptable recovery schedule, there may be breach of contract issue. The refusal, failure, or neglect to take appropriate recovery action or to submit a recovery schedule could constitute evidence that the contractor was not diligently prosecuting the work and could be considered grounds for termination. Finally, the owner is typically entitled to direct the contractor to prepare the recovery schedule at no extra cost to the owner.

The recovery schedule should show a workable plan and represent the contractor's best judgment as to how it will regain the lost time. The recovery schedule is typically prepared to a similar level of detail as the baseline schedule. Contractors have several options for mitigating delay in a recovery schedule, include the following:

- provide additional resources (labor, materials, or equipment) and allocate the resources first to the critical path and near-critical path activities;
- work additional shifts or increased hours;
- expedite procurement;
- re-sequence work activities;
- change the duration of work activities;
- revise the logic relationships between activities; and/or,
- use alternate construction methods.

The contractor should also obtain by-in from its subcontractors before submitting and implementing the recovery plan. The owner then reviews the recovery schedule, and, upon acceptance by the engineer or owner, the contractor incorporates the recovery schedule into the current progress schedule and the revised schedule should be recognized as the baseline going forward to more accurately reflect project status and the contractor's current plan. Once the owner accepts or agrees to the revised CPM schedule, it normally becomes the new baseline schedule against which the contractor should update progress and measure performance, until another change in the critical path necessitates further revision.

The owner's acceptance (or non-acceptance) of a recovery schedule is often the source of disagreement among the project parties. How does the owner know that the recovery schedule is realistic and can be achieved? There are qualitative and quantitative techniques to consider when assessing the viability of a recovery schedule as a revised baseline schedule. The options used to mitigate delay will determine the risks to consider from a qualitative perspective. For example, if the contractor has revised logic and activity durations, one should consider assessing the percentage of critical or near-critical activities that are in the schedule. One rule of thumb is that it is reasonable for 15 percent to 20 percent of the total work to be on the critical or near-critical paths. If more than 20 percent of the work is near-critical, the schedule is potentially too aggressive and might not be workable. Also, if the contractor plans to add resources or another shift, confirm that the contractor has considered the availability of additional labor, material, and equipment resources and the availability of additional site laydown area required. Additionally, consider whether or not the contractor has met the productivity or performance levels as planned or as adjusted the plan for any deviations. The reasonability of the mitigation efforts included in the recovery schedule must be considered within the framework of the actual events on the job site. The balance of this paper will focus on a quantitative technique that can be used to review recovery schedules before accepting as a new baseline schedule.

Quantitative Risk Analysis of Recovery Schedules

Quantitative risk analysis is a growing field as corporations become more cognizant of risk issues and develop sophisticated capabilities for actively managing risks associated with their construction projects. Risk and uncertainty cannot be entirely controlled and each project will face numerous unknowns; however, developing a strategy to proactively monitor and mitigate risk will help to optimize profits and align expectations.

When a clear understanding of the risk and uncertainty has been achieved, expectations for performance may be properly established. What if a project manager wants to know how aggressive or how conservative the project schedule is? Is the probability of finishing the project by the CPM completion date, 20 percent or 80 percent? Quantitative risk analysis, if properly used, can help to quantify and answer these difficult questions. The results from the quantitative risk analysis may help establish realistic expectations for each of the project stakeholders. As Dan Patterson, Vice President of North America operations of Primavera Pertmaster, states:

> *... when agreeing to the contract, it is essential that the scope of work and the timescale of delivery are both fully understood. In a nutshell, expectations from both parties need to be mutually recognized and agreed upon – risk management essentially negates the uncertainty around such expectations. Successful subcontracting is about managing expectations of all parties involved* [4].

The alignment of expectations helps foster a teaming relationship between the stakeholders and allows all parties to focus on common, achievable goals. By defining the potential risk events and uncertainty, each stakeholder should have a better understanding of which risks it has accepted and the potential impact they may have upon their bottom line. In this way, quantitative risk analysis provides a useful tool for developing an adequate risk sharing strategy. As will be discussed later in this paper, it also provides a useful means for managing risk and mitigating potential impacts.

One of the common methods for quantitatively evaluating risk is Monte Carlo simulation, which uses probability distributions to model risks and variance in the schedule tasks. Task durations may be affected by numerous factors that may either increase or decrease a task's duration; however, traditional CPM scheduling does not account for the variance or uncertainty in task durations. Traditional CPM scheduling uses single point estimates representing the most likely durations to model the project schedule. Monte Carlo simulation uses probability distributions that account for the uncertainty in the task durations. Using these statistical tools, Monte Carlo Simulation can determine the potential outcomes of project based upon the model's risk inputs. Schedule simulations can be run thousands of times in a very short period of time to evaluate probable completion dates, identify "high impact" risks or tasks and evaluate numerous risk scenarios. This paper will focus on the use of Monte Carlo Simulation for performing risk analyses of recovery schedules.

There are several commercially available software packages for performing Monte Carlo based quantitative risk analyses including Pertmaster, Crystal Ball, and @Risk. Both Crystal Ball and @Risk are compatible with Excel and have strong capabilities for performing spreadsheet analyses. Pertmaster is compatible with Primavera, Microsoft Project, and SureTrak and it has robust capabilities for performing schedule analyses. Pertmaster may also be used to perform cost analyses and model cash flows.

Using Quantitative Risk Analyses to Develop Realistic Recovery Schedules

As discussed above, oftentimes project management develops recovery schedules because it has lost confidence in the successful completion of the original baseline schedule. Risk analyses offer a methodology for quantitatively evaluating the risks, uncertainty, and overall "confidence" of the project's completion date.

There are four primary steps in performing quantitative risk analyses for recovery schedules, including:

- Assess the quality of the current schedule and make necessary revisions to establish a logical, realistic schedule which may be used as a starting point for the risk analysis.
- Use historical data (productivity rates) and industry expertise/professional judgment to establish realistic distributions for key activities.
- Develop a risk register listing potential risk events and quantify their impact upon the schedule. And,
- Develop mitigation scenarios to analyze risk reduction strategies and to optimize both the project's performance and cost.

Assess the Schedule Quality

The first step of performing quantitative risk analyses involves evaluating the quality of the current schedule. Often times, projects requiring a recovery schedule have experienced significant strains or encountered extraordinary issues which have prevented the project from being completed as originally planned. Because of these issues, the project schedules may have underwent substantial revisions including logic changes and/or duration changes. In addition, the original baseline schedule may have been unrealistic and the assumptions upon which the original schedule was based may need to be revisited. For these reasons, the logic and accuracy of the current schedule may have been compromised at some point during the course of the project and it is critical to examine the quality of the current schedule before proceeding with the quantitative risk analysis. Some of the common scheduling errors that should be evaluated include the following:

- appropriate logic ties;
- open ends (i.e., no successor activities);
- out of sequence logic;
- accurate durations; and
- minimal constraints.

The critical and near critical paths should accurately represent core work driving the schedule as these tasks will become a primary focus of the risk analysis. In addition, any constraints impacting the behavior of the schedule should be removed. During the Monte Carlo simulation, the dates within the schedule need to have the ability to move as different duration values are selected for each task. This "movement" is what allows the simulation to develop a range of completion dates for the project. If for example, a key activity has a "Must Start On" constraint then there is only one day the activity can start on. This will impact the results of the simulation because the schedule cannot move freely around this activity because it has been "pinned" down by the constraint. Pertmaster contains a user friendly feature called the "schedule check report" that will identify and summarize many of the common scheduling errors listed above in an easy to read Microsoft Word format.

Develop Appropriate Probability Distributions

Once a quality schedule has been established, the next step involves developing risk inputs for specific activities within the schedule. The key activities (critical and near critical activities) which may have significant uncertainty in their durations should be identified. One of the key benefits of performing risk analyses for recovery schedules is that historical data from the project may be leveraged to develop realistic inputs for modeling the specific circumstances of the project.

The historical production rates for a particular trade or even a specific contractor / work crew may be analyzed to develop a range of realistic production rates which can be used to develop accurate duration risk inputs for the various schedule tasks. A measured mile approach may be used to identify consistent, sustainable production rates which may then be used to develop accurate duration risk inputs. In addition, the physical percent complete should compared against the planned progress and planned expenditures for each of the key work tasks. Evaluating these types of earned value measures will help to identify potential delays which should be accounted for in the risk model. Any scope changes should also be accounted for in developing appropriate inputs for the risk analysis. Change orders should be analyzed in detail to determine their anticipated impact upon the project.

In performing Monte Carlo simulations, probability distributions are used to model expected durations for particular activity. For example, a triangle distribution may be used to represent the duration of a particular task. A triangle distribution consists of three defining points: a minimum duration, a most likely duration, and a maximum duration. Figure 1 illustrates what a triangle distribution may look like for a hydro-testing activity.

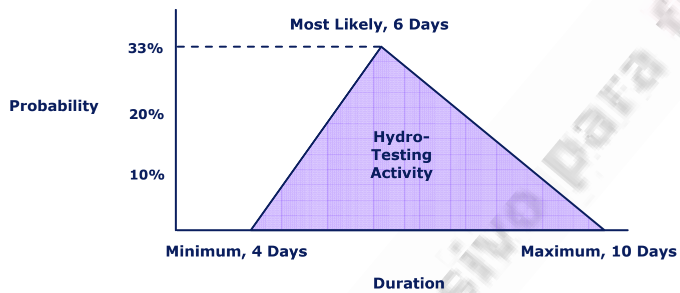

Figure 1 ─ Triangle Distribution

As can be seen from the chart, the most likely duration, six days, has the highest probability of occurring and the probability gradually drops off as one moves towards the minimum or maximum durations of four days and ten days respectively. By adjusting the duration parameters, one may develop probability distributions for numerous tasks within a project schedule. There are many types of probability distributions that may be used; however, some of the specific types of duration probability distributions commonly used in the construction industry include: the Beta Distribution, the betapert distribution, the modified betapert distribution, the trigen distribution and the Triangle Distribution.

In developing risk inputs for the simulation model, one should account for any relationships which may exist between tasks in the schedule. A large number of independent tasks modeled with probability distributions may have a tendency to underestimate the overall variance or range of completion dates of the schedule. This is because correlation or the relationships between the activities are not properly accounted for in the Monte Carlo simulation. If two activities are correlated, then as one activity's duration increases, the other activity's duration is also likely to increase and similarly, if one activity's duration decreases, the other activity's duration is also likely to decrease. Incorporating correlation can facilitate modeling the underlying relationships between tasks. For example, two similar piping activities being performed under similar circumstances would likely be strongly correlated.

If correlation is not properly accounted for, there is a tendency to underestimate the true variance in the overall schedule completion dates. If multiple task durations expand or contract at the same time (in a correlated fashion) then the chances of reaching longer or shorter durations for the overall project is increased. The key concept is to model reality as best possible, including any relationships that may exist between activities. Typically, as schedules are developed in detail, the likelihood of tasks being correlated is higher because the content of the detailed work is often similar for certain groups of tasks. For example, a level four schedule may contain similar piping activities being performed in a certain area of a power plant which are likely to be correlated. However, in a summary level schedule, a task encompassing all of the piping activities is less likely to be correlated to other summary level tasks with dissimilar work content such as engineering or electrical work. Therefore, performing risk analyses on summary levels schedules may help simplify the correlation modeling.

Modeling Risk Events (Risk Register)

A common strategy for conducting quantitative risk analyses is to separate duration risk uncertainty and specific risk events. For example, a task may have a certain amount inherent uncertainty which may cause it to finish early or later than its most likely duration. This is defined as duration uncertainty. There may also be certain risk events, external to the project tasks, which may impact the duration of one or more tasks within a schedule. For example, an unknown site conditions risk event may impact the duration of certain tasks within a schedule. Risk events are typically modeled using inputs including a probability of existence and an associated impact. For example, the probability of finding unknown site conditions may be 20 percent and it may have impact of 30 days to a site excavation activity within a schedule. Ideally, risk events are modeled separately from the duration uncertainty to allow better visibility as to the true drivers of the project's overall completion.

Some of the "snowball" effects commonly seen in recovery schedules may be modeled using specific risk events. These effects may include lowered productivity because of acceleration and/or stacking of trades. Another risk event for recovery schedule might be late engineering because of redesign issues. During the course of the project, the stakeholders should continually identify and gather information regarding specific risk events which may impact the project. Each of the risk events should be documented in a risk register including an explanation of the risk, the probability of the risk occurring and the anticipated impact the risk will have upon the schedule. To the extent possible, each of the project stakeholders should provide input regarding the risk register and agree upon the parameters used for the simulation model.

Modeling Mitigation Scenarios

Another risk analysis concept involves developing mitigation strategies which may have a beneficial impact upon the schedule. Mitigation strategies may include reducing, avoiding or transferring risk. By implementing risk mitigation strategies the probability of a risk occurring should be reduced or the impact upon the schedule may be reduced. Using risk analysis, mitigation scenarios can be modeled and quantified to determine mitigation strategies having the greatest beneficial impact upon the overall project completion. These scenarios may be developed manually using the entry level version of the Pertmaster Software, "Project Risk" version. The upgraded "Risk Expert" version provides a Risk Register tool which includes the ability to evaluate mitigation scenarios using a predefined template. When evaluating mitigation scenarios, one should also account for any additional costs impacts associated with the various mitigation strategies as this may be a deciding factor as to whether or not the mitigation strategy will add value to overall project goals.

Evaluating the Risk Analysis Results

Once the model inputs have been developed, simulations can be run to obtain a variety of useful results. The simulation will select the duration for each task and risk event based on the probability distributions established. The simulation will run through the entire network of project tasks selecting an appropriate duration for each task and risk event. The simulation can be run thousands of times while various statistics are collected. Eventually, the results will converge to a level of confidence such that running additional simulations will not have a significant impact on the results already collected.

One of the most useful results from the simulation consists of a range of project completion dates and their associated probabilities or confidence levels. This relationship can be represented graphically as show in the figure 2 and figure 3.

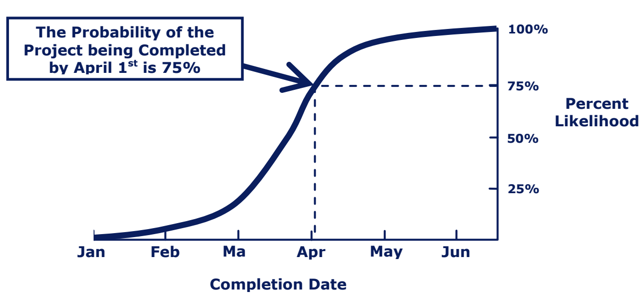

Figure 2 – S-Curve

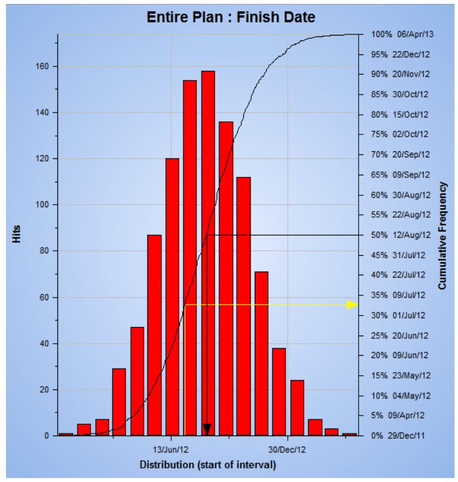

Figure 3 — Histogram

The completion dates are listed on the x-axis and their associated percent likelihood on the y-axis. This information helps to answer questions regarding the conservativeness or in contrast, aggressiveness of the project schedule. If the deterministic or traditional CPM schedule completion date corresponds to a five percent chance as shown in figure 3, the project manager may want to adjust the CPM schedule to extend the completion date or develop acceleration strategies to give the project a better chance of achieving the planned completion date. In this way, Monte Carlo Simulation can provide valuable foresight to help predict scheduling problems before it is too late to correct them.

During the simulation analysis various statistics may be collected including duration sensitivity and criticality. Duration sensitivity is a measure of the correlation between the duration of a particular task and the duration of the overall project. Therefore, if a task has high duration sensitivity, then as the duration of the task increases, the duration of the project is also likely to increase. Using this statistic, schedulers may identify the key tasks likely to affect the overall completion date. Pertmaster uses a tool called a Tornado Chart (shown in figure 4 and figure 5) to focus on and isolate the tasks or risk events that are most critical.

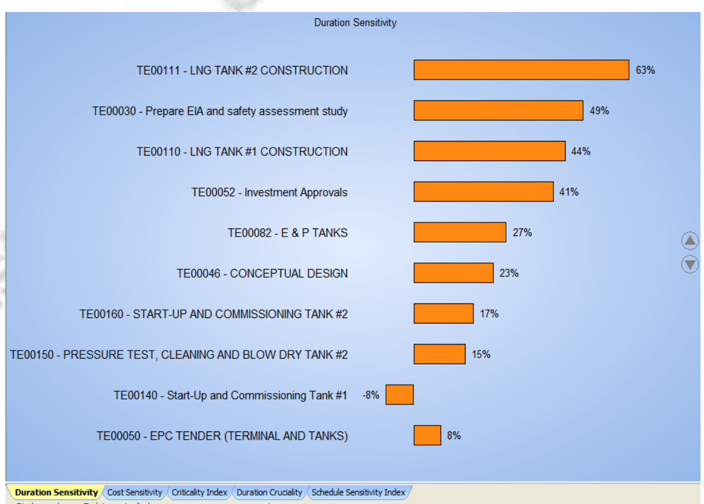

Figure 4 — Tornado Chart – Duration Sensitivity

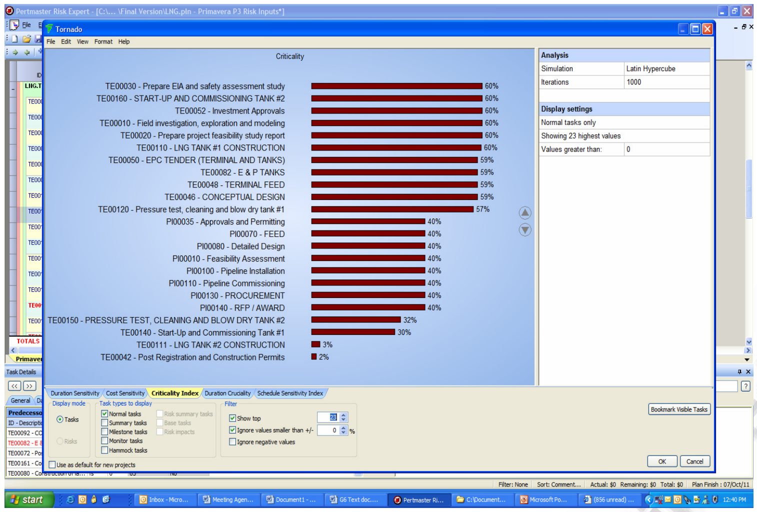

Figure 5 ─ Tornado Chart – Criticality

The criticality measure shows the percentage of time each task appeared on the critical path during the simulation analysis. Using this report one can determine the likelihood that a task will be on the critical path. This is a useful measure for evaluating whether the tasks appearing on the critical path are reasonable and it may help to identify any logic flaws within the schedule. Additionally, if a schedule has parallel critical paths, the criticality statistic may help to determine which path is likely to be controlling. Using these measures, the "high impact" tasks or risks may be identified, and targeted mitigation strategies developed to provide the largest beneficial impact to the schedule. In this way, simulation helps to identify those activities that will provide the most value in terms of schedule risk mitigation.

Incorporating Project Costs

While this paper has focused on evaluating project schedules, project costs can also be incorporated into Monte Carlo based schedule simulation models using resource loading. Evaluating cost in this manner can provide useful information regarding expected total project cost and potential contingency; however, one must be careful to use the proper methodology and develop realistic assumptions for the model. The key challenge for incorporating cost resources is separating fixed versus variable costs for each task or risk event. The fixed costs typically include materials, non-time related equipment, and non-time related labor. Variable costs typically include time-related overhead, construction management costs, and time-related labor. The definition of costs my also depend upon the structure of the project's contract. For example, from an owner's perspective, the rental equipment for a lump sum contract may not be related to durations since the contractor has accepted the risk. However, for a cost reimbursable contract, the rental equipment would be dependant on durations. For these reasons it is important to evaluate and develop a standardized methodology for incorporating costs into the simulation model. The variable costs will change with the durations of the simulation model; however, the fixed costs will remain constant. Once the model has been resource loaded with cost, the simulation may be run to evaluate the anticipated project costs and confidence levels, identify "high impact" cost items, and evaluate probabilistic cash flows.

Recovery schedules are often required for troubled projects facing a great deal of uncertainty. Quantitative risk analysis helps assess the reasonableness of a recovery schedule by defining this uncertainty, aligning stakeholder expectations and developing effective strategies to mitigate risk. Overall, performing quantitative risk analyses for recovery schedules provides a tool for project management to more accurately gauge the potential outcomes using confidence levels produced by the simulation model and provides additional information to consider before accepting a recovery schedule as the revised baseline schedule. The historical data from the project may be incorporated into the model to improve the accuracy of the results and provide a more realistic assessment of the reasonableness of a proposed recovery schedule. In addition, the risk analysis may be used as a management tool to anticipate risks and proactively mitigate their impacts going forward. The model should be refined and updated on a periodic basis as more information becomes available.

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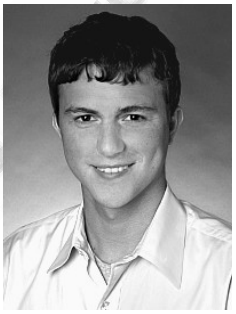
Mr. John J. Ciccarelli, PE CCE PSP
Deloitte Financial Advisory Services LLP
jciccarelli@deloitte.com



Mr. Matthew Murch
Deloitte Financial Advisory Services LLP
mmurch@deloitte.com