Understanding and Managing Uncertainty in Schedules

Realistic Plans for Project Success

Presented by: John Owen
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1981-1985  Worley Engineering (Planning Systems Manager)
1986-2006  Welcom (VP Development)
2006-2014  Deltek (Director Products and Strategy – Schedule & Risk)
2014-      Barbecana Inc. (Chief Crazy Person)

Producing tools for organizations where outstanding project execution is a critical business requirement
Objectives

• Explain how uncertainty can make our project models unrealistically optimistic.

• Show how we can improve our models to consider the impact of uncertainty.

• Identify the tasks in the schedule that are most likely to impact project success.

• Consider a technique for managing uncertainty during project execution.

• Reduce project management costs.
Uncertainty / Sources of Risk

There are two basic types of uncertainty that we can consider

**Estimate Uncertainty / Duration Risk**

Estimate uncertainty is caused by a lack of knowledge

- We don’t know exactly how long something will take
  - We can capture a range of estimates

**Event Uncertainty / Unplanned Events**

aka Threats (Risks) and Opportunities

- The impact of random events
  - Something may or may not happen
    - We can plan for different eventualities
The effect of uncertainty

- Variation of the project completion date
- Variation of the project cost
- Changes to the Critical Path
- Increased management effort
- Reduction in the perceived value of the project

So the purpose of modelling uncertainty is not just to understand the impact but also to help focus efforts to increase confidence and reduce management effort (reduce cost)
We already create great CPM models...

Critical Path Method calculates a single projection for a project completion date (Deterministic).

Every project, no matter how similar to projects before it, is always subject to some uncertainty.

This means that the only sure fact, for the project end date calculated by CPM, is that it will almost certainly be wrong.

Worse, the end date calculated by CPM is usually overly optimistic.

Here’s why...
Consider two activities...

In this ‘serial’ example, if Task A is delayed, we can potentially make up the time while executing Task B.

In this ‘parallel’ example, if Task A is delayed, then the delivery is delayed regardless how well we perform on Task B.
Let’s tabulate the possible outcomes for Task A and B (and to simplify the table we’ll count an on-time finish as early).

<table>
<thead>
<tr>
<th>Task A</th>
<th>Task B</th>
<th>Project</th>
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<tbody>
<tr>
<td>Early/On-Time</td>
<td>Early/On-Time</td>
<td>Early/On-Time</td>
</tr>
<tr>
<td>Late</td>
<td>Early/On-Time</td>
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<td>Late</td>
<td>Late</td>
<td>Late</td>
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</table>

We know that the project will only complete on time if **both** Task A and B finish early or on-time. Of our four possible outcomes we can see this only happens one time. Any of the other three possible outcomes results in a late project completion (75% chance of failure!)
One reason projects fail...

As the number of predecessors for any given activity increases, it becomes less likely that it will start on time.

This effect is called Merge Bias.

Merge Bias is the single biggest reason that project models, built using Critical Path Method (CPM), inherently produce an unrealistic forecast for project completion.

As the complexity of the project model increases, and the number of activities with multiple predecessors grows, the probability of attaining the deliverable dates, suggested by CPM, decreases.

So project failure may not be caused by poor estimating or execution, but simply by the fact that the plan was never realistic or achievable in the first place.
Modelling Uncertainty

There have been two primary attempts to help model uncertainty in schedules.

**Program/Project Evaluation and Review (PERT).**

Captured a range of duration estimates for each task but then used an algebraic expression to convert that to a single duration for CPM analysis. This cannot quantify merge bias.

**Monte Carlo Simulation / Schedule Risk Analysis (SRA)**

Captures a range of duration estimates for each task and then simulates the execution of the project many times using different durations sampled from within the specified range for each task on each iteration of the simulation. This allows for the measurement of the impact of merge bias.
Can SRA really reduce project costs?

There is a perception that schedule risk analysis is an overhead forced on organizations by bid/contract requirements:

• It is perceived as time consuming (a lot of work)
• It is perceived as something only required to win the work
• It is perceived as little value for in-progress projects
• It is perceived as being a luxury overhead that costs money

Other objections:

• It’s too advanced / we’re not there yet
• I do my risk assessment based on cost
• It doesn’t help me meet targets already set
Opportunities for cost savings

Produce a more realistic forecast that reduces the likelihood of penalties for delays.

Reduce management effort by understanding in advance what might happen.
  • Focus on the thing that matter
  • Reduce reactive change meetings

Identify opportunities for schedule compression to meet contract requirements.

Use ‘schedule margin’ as an ongoing tool to manage expectations.

Surprises cost Money!
Before we go any further...

We need a sound schedule!

- Project logic is present and correct.
- Project status/progress information is up-to-date.
- ‘Hard’ constraints (anything that prevents dates from pushing into the future) have been removed.
- Make sure support/management (Level of Effort) work is not driving the schedule.
Assessing the impact of Merge Bias

Merge Bias comes into play when there are multiple paths through a schedule – and they don’t have to be critical paths.

We can very easily understand the possible impact of Merge Bias by making a few simple assumptions:

• Our estimates are reasonable
• We execute well against the estimates
• All tasks are subject to some uncertainty, and for the purposes of analysis, that uncertainty is symmetrical (just as likely to deliver each task early as late)

While these may seem very generous/unrealistic assumptions we can use them to quickly find out the potential impact of Merge Bias.
A simple project
Add some symmetrical uncertainty

<table>
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<tr>
<th>ID</th>
<th>Task Name</th>
<th>Remaining Duration</th>
<th>Duration Distribution Type</th>
<th>Duration Optimistic</th>
<th>Duration Most Likely</th>
<th>Duration Pessimistic</th>
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Symmetrical uncertainty on one activity
Do I need 1000000 simulations?

Histogram of Remaining Duration for task 'HW Task 1' (UID 21).
Mean = 4 weeks, Standard deviation = 17 hours, Deterministic value = 4 wks (50%).

Each bar represents 4 hours. (Markers show start of interval.)
The effect of Merge Bias

Even with symmetrical uncertainty we only have a 35% chance of completing on time!
Hmmm...

OK, so we learned that Merge Bias may affect our ability to deliver, but the uncertainty we introduced was quite unrealistic and won’t it be a great deal of effort to get better data?
Identify tasks for estimate refinement

Based on our simplistic assumptions, the sensitivity tornado chart can highlight the tasks that are affecting the deliverable outcome and gives us an indication of tasks worth the effort of estimate verification and refinement.
Refining Estimates

Monte Carlo simulation uses a range of estimates for tasks - often called 3-Point estimates

- Optimistic
- Most Likely
- Pessimistic

These estimates can be captured as specific durations or as percentages of the remaining duration.

A distribution type can also be specified to control where samples are likely to be taken between the three estimates.

This is starting to sound complicated and time consuming...
Estimate Uncertainty - Probability Distributions

The durations sampled in the range specified by the optimistic, most likely, and pessimistic durations, can be weighted using a probability distribution.

This allows us to define how likely sampled durations are to be closer to the Most Likely vs Optimistic and Pessimistic values.

- Normal Distribution
- Triangular Distribution
Distribution Types

[Image of various charts and graphs showing distribution types for different scenarios.]
Which Distribution?

General Guidance

• Use historical data to determine an appropriate distribution
• Unless there is a compelling reason, do not use Uniform
• In the absence of specific guidance, use Triangular or Lognormal
• Use Beta or Triangular if you need to specify the degree of skew (e.g. transportation)
• Use Confidence Limits if the estimator wants to hedge

It’s more important to get good duration estimates than worry about distribution types...
This historical analysis of all projects in our E&C division clearly shows that using a beta distribution with an Optimistic value of 90%, Most Likely of 100% and Pessimistic of %130 would be defensible.

The outliers may be data entry errors, short duration tasks, or threats that were not correctly identified as discrete tasks.
Categorize duration estimates using simple ‘estimate confidence’ scoring systems:

- Hardware - High Confidence/Low Risk
- Hardware - Low Confidence/High Risk
- Software - High Confidence/Low Risk
- Hardware - Low Confidence/High Risk
- Earthworks - High Confidence/Low Risk
- Earthworks - Low Confidence/High Risk
Define what ‘confidence’ means

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<thead>
<tr>
<th>Distribution Type</th>
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<th>Most Likely</th>
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And apply that to the SRA

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<th>Duration Distribution Type</th>
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And the result is...

Despair and Disbelief!
Only a 2% chance of success!

The Histogram shows the chance of finishing on a date while the S-Curve shows the chance of finishing by a date.

According to the simulation we have just a 2% chance of delivering on 9/4.

A more realistic date might be 9/21 for which we have an 80% chance.
Why is SRA so depressing?

Forecasts from a project management process that includes schedule risk analysis are often unpalatable for two reasons:

1. Practitioners are more likely to validate the quality of the schedule which tends to push dates to the right

2. Schedule Risk Analysis tends to push dates even further to the right (Merge Bias). This is true even if estimates reflect the fact that historically an organization has been very good at estimating/executing individual tasks (Actual/Estimate=1)

The Critical Path Method (CPM) technique is inherently and unrealistically optimistic...

Like it or not, the results from SRA are generally more realistic.
Is there good news?

Yes!
Sensitivity Analysis (often portrayed as a Tornado chart) identifies:

- Which activities are creating variability in deliverables
- Identifying critical / near critical work
- Opportunities for schedule compression
- Where to focus management effort

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</tbody>
</table>
A Risk Adjusted Schedule shows when work will be performed at a specific level of confidence (e.g. P80)

Make commitments using the Risk Adjusted Schedule but manage using the original schedule
I need to deliver sooner...

- The client provides the delivery date
- We *have* to launch in June 2018
- Funding expires at the end of December 2017

If we need to deliver by a specific date then SRA is the best tool for identifying where we need to improve the schedule to reach a level of *confidence* that we can achieve the required date.

It’s *planning to fail* if you ignore data from SRA and just *hope* you can achieve the dates forecast by CPM.

To have an acceptable probability of success, the CPM model typically needs to show a finish earlier than required.
Event uncertainty allows us to model Threats or Opportunities that may modify the execution of our project.

Threats might include a new prototype not meeting design criteria while opportunities could include a new manufacturing process becoming available.

Several different techniques can be used to model event uncertainty.

- **Probabilistic branching** allows us to specify a probability that a particular path through the project may be taken (useful for opportunities).
- **Existence probability** allows us to model threats as activities that may occur.
- **Conditional branching** allows us to specify that specific activities will be included if desired dates are not achieved.
Probabilistic Branching

Allows us to model alternate plans

Testing -> Remediation (20%) -> Delivery

Testing -> Delivery (80%)
Conditional Branching

Allows us to revise the plan as dates change

- Fabrication
- Ship Route 1: 1 week
- Deploy: 1 week
- Ship Route 2: 5 weeks

Before 30Nov15
Schedule Margin

Cost engineers have Contingency

Schedulers have **Schedule Margin**!

*The amount of additional time needed to achieve a significant event with an acceptable probability of success.*

The best way to derive an appropriate schedule margin is Schedule Risk Analysis.
Calculating the Margin

Deterministic CPM = 1/23/2017
SRA P80 = 3/18/2017
Margin = 54 Calendar Days
Including Schedule Margin

The project manager/scheduler owns the margin and will track incursion/consumption of the margin in exactly the same way as a cost engineer allocates and tracks fiscal contingency.
Milestone Schedule Margin

As well as obvious places like key interim deliverables, consider using Merge Delay to identify good places to allocate margin.

If you don’t need the margin, great. Bring future work forward.
Combined Cost and Schedule

The Joint Confidence Limit scatter plot shows the chance of achieving both target cost and schedule delivery dates.
Summary

- Schedule Risk Analysis is a valuable tool for making schedules more realistic and improving confidence.
- It’s an iterative process. Initial results may be depressing but the technique helps identify areas for improvement.
- Schedule Risk Analysis has almost no value if you just produce a histogram to satisfy a contract requirement.
- Many organizations chose to commit to P80-95 delivery dates and have a high success rate which boosts confidence and profitability.
- It doesn’t have to be hard and saves money!
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Thank You