Sensitivity and Risk

John Owen – Barbecana Inc.

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10th, UVA Darden Center, Arlington VA

Learning Objectives

So who is John Owen?

Barbecana Inc.

- COO, CEO
- 2014 –
- Full Monte SRA

Deltek

- Senior Product Director Schedule and Risk Products
- 2006 – 2014
- Open Plan, Acumen

Welcom

- VP Development
- 1986 – 2006
- Cobra, Open Plan, WelcomRisk, WelcomHome

Various…

- UK MOD (Defence), Worley Engineering (O&G), Metier (Artemis)

Sensitivity Analysis

- A practical approach to determining how sensitive the project manager is to criticism.
- Just how sensitive to delays are the project stake holders, and what makes them cry.
- How long will you read this before starting to throw things?

Sensitivity Analysis

Sensitivity Analysis is a technique to find what uncertainty is having the largest effect on the outcome, often project delivery.

Project uncertainty has two sources: Estimate Uncertainty and Discrete Risks.

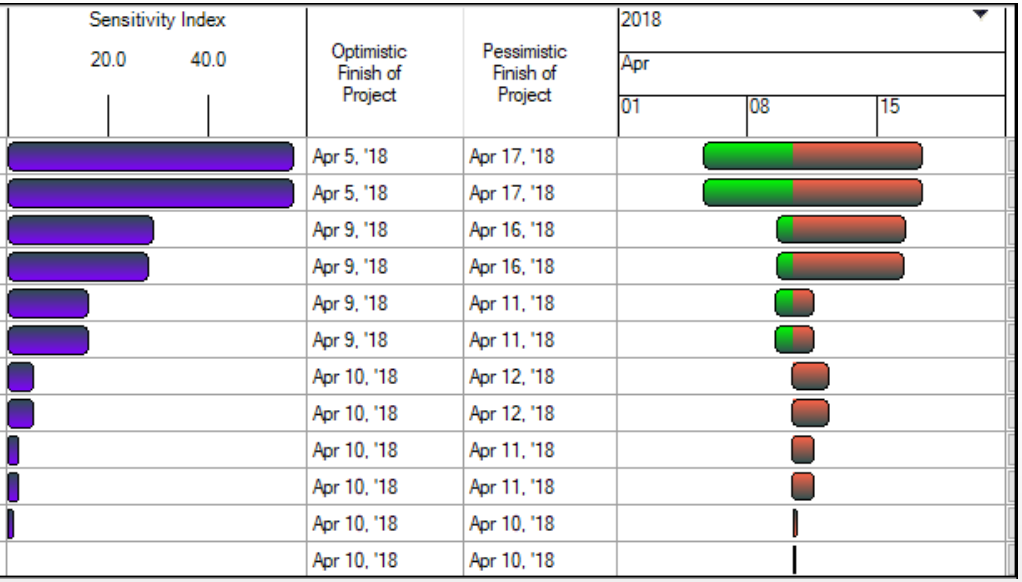
Only tasks with uncertainty will appear in a sensitivity analysis.

Why is Sensitivity Analysis useful?

- Because it helps us understand:
  - Opportunities for Schedule Compression.
  - Opportunities to improve estimates to reduce uncertainty.
  - Opportunities to modify schedule logic to improve the chance of success.
  - Verify the major WBS elements are on the critical path to the delivery.
  - Verify unimportant things are not on the critical path to delivery.
  - It’s an opportunity to be Pro-Active

What Does Sensitivity Look Like?

ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Optimistic Finish of Project	Pessimistic Finish of Project
8	HW Task 4	20 days	89%	89%	57%	Apr 5, '18	Apr 17, '18
5	HW Task 1	20 days	89%	89%	57%	Apr 5, '18	Apr 17, '18
7	HW Task 3	20 days	45%	45%	29%	Apr 9, '18	Apr 16, '18
6	HW Task 2	20 days	44%	44%	28%	Apr 9, '18	Apr 16, '18
17	Integration	5 days	97%	97%	16%	Apr 9, '18	Apr 11, '18
2	Initiate	5 days	97%	97%	16%	Apr 9, '18	Apr 11, '18
11	SW Task 1	18 days	8%	8%	5%	Apr 10, '18	Apr 12, '18
14	SW Task 4	18 days	8%	8%	5%	Apr 10, '18	Apr 12, '18
12	SW Task 2	18 days	4%	4%	2%	Apr 10, '18	Apr 11, '18
13	SW Task 3	18 days	4%	4%	2%	Apr 10, '18	Apr 11, '18
19	Brochure Develop...	10 days	3%	3%	1%	Apr 10, '18	Apr 10, '18
20	Brochure Printing	5 days	3%	3%	0%	Apr 10, '18	Apr 10, '18



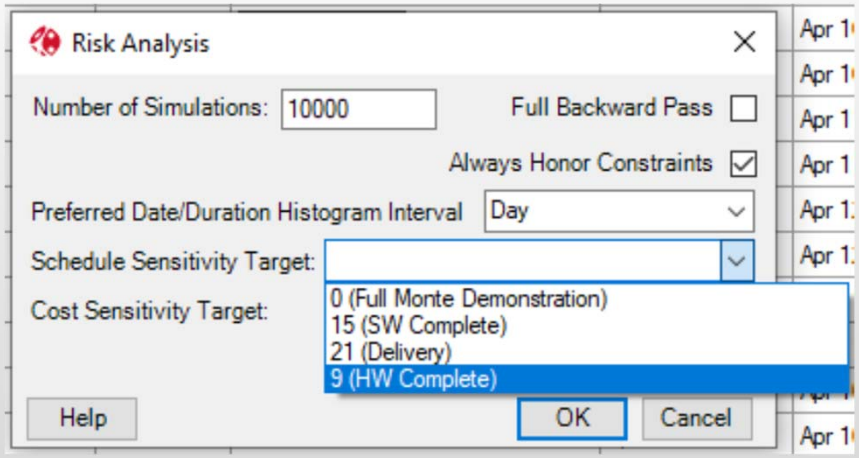
A typical presentation of sensitivity data uses a ‘Tornado’ chart.

A sensitivity index is calculated by most Schedule Risk Analysis (SRA) tools and just shows the relative contribution of each task to uncertainty. Barbecana’s Full Monte also calculates the mean start/finish of the sensitivity target based on the best/worst case duration estimates for each task.

Sensitivity Target

Most projects have multiple deliverables or important interim milestones. Projects may also have multiple suppliers or assemblies and it is useful to understand the tasks affecting each assembly.

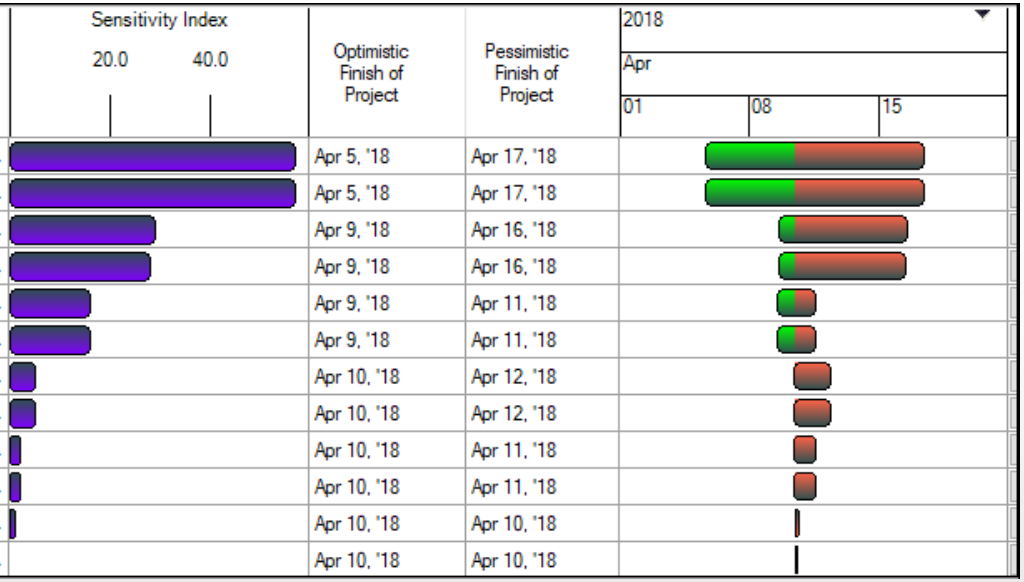
Most SRA tools allow you to choose any milestone as the sensitivity target.



Sensitivity Target Example

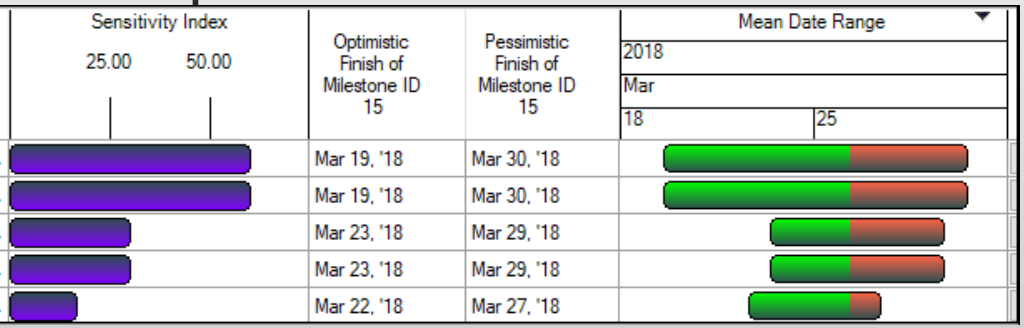
The overall project

ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Optimistic Finish of Project	Pessimistic Finish of Project
8	HW Task 4	20 days	89%	89%	57%	Apr 5, '18	Apr 17, '18
5	HW Task 1	20 days	89%	89%	57%	Apr 5, '18	Apr 17, '18
7	HW Task 3	20 days	45%	45%	29%	Apr 9, '18	Apr 16, '18
6	HW Task 2	20 days	44%	44%	28%	Apr 9, '18	Apr 16, '18
17	Integration	5 days	97%	97%	16%	Apr 9, '18	Apr 11, '18
2	Initiate	5 days	97%	97%	16%	Apr 9, '18	Apr 11, '18
11	SW Task 1	18 days	8%	8%	5%	Apr 10, '18	Apr 12, '18
14	SW Task 4	18 days	8%	8%	5%	Apr 10, '18	Apr 12, '18
12	SW Task 2	18 days	4%	4%	2%	Apr 10, '18	Apr 11, '18
13	SW Task 3	18 days	4%	4%	2%	Apr 10, '18	Apr 11, '18
19	Brochure Develop...	10 days	3%	3%	1%	Apr 10, '18	Apr 10, '18
20	Brochure Printing	5 days	3%	3%	0%	Apr 10, '18	Apr 10, '18



Focused on interim SW Complete milestone

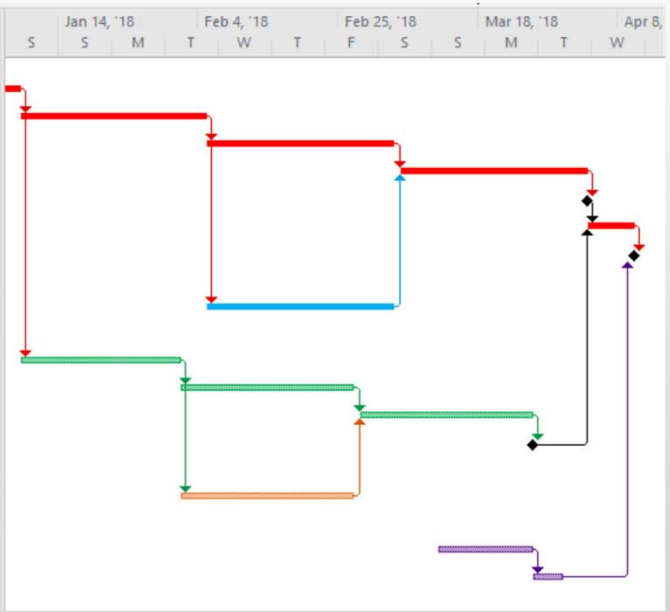
ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Optimistic Finish of Milestone ID 15	Pessimistic Finish of Milestone ID 15
11	SW Task 1	18 days	8%	100%	60%	Mar 19, '18	Mar 30, '18
14	SW Task 4	18 days	8%	100%	60%	Mar 19, '18	Mar 30, '18
12	SW Task 2	18 days	4%	51%	30%	Mar 23, '18	Mar 29, '18
13	SW Task 3	18 days	4%	49%	30%	Mar 23, '18	Mar 29, '18
2	Initiate	5 days	97%	100%	17%	Mar 22, '18	Mar 27, '18



Driving ‘Risk’ Path Analysis.

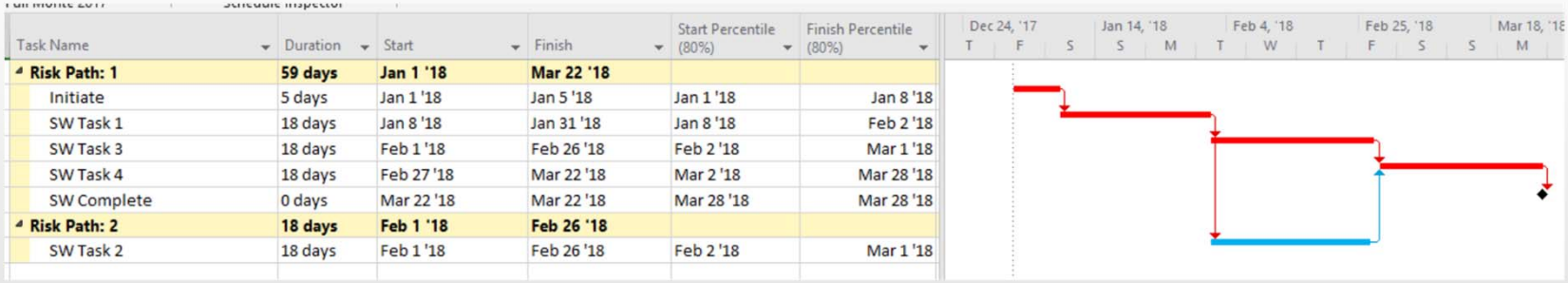
As mentioned earlier, only tasks contributing uncertainty to a sensitivity target will appear on a sensitivity report. A Risk Path analysis shows the most probable driving path to any selected milestone.

Task Name	Duration	Start	Finish	Start Percentile (80%)	Finish Percentile (80%)
Risk Path: 1	**70d**	**Jan 1 '18**	**Apr 6 '18**		
Initiate	5 days	Jan 1 '18	Jan 5 '18	Jan 1 '18	Jan 8 '18
HW Task 1	20 days	Jan 8 '18	Feb 2 '18	Jan 8 '18	Feb 6 '18
HW Task 2	20 days	Feb 5 '18	Mar 2 '18	Feb 6 '18	Mar 7 '18
HW Task 4	20 days	Mar 5 '18	Mar 30 '18	Mar 8 '18	Apr 6 '18
HW Complete	0 days	Mar 30 '18	Mar 30 '18	Apr 6 '18	Apr 6 '18
Integration	5 days	Apr 2 '18	Apr 6 '18	Apr 6 '18	Apr 13 '18
Delivery	0 days	Apr 6 '18	Apr 6 '18	Apr 13 '18	Apr 13 '18
Risk Path: 2	**20d**	**Feb 5 '18**	**Mar 2 '18**		
HW Task 3	20 days	Feb 5 '18	Mar 2 '18	Feb 6 '18	Mar 7 '18
Risk Path: 3	**54d**	**Jan 8 '18**	**Mar 22 '18**		
SW Task 1	18 days	Jan 8 '18	Jan 31 '18	Jan 8 '18	Feb 2 '18
SW Task 2	18 days	Feb 1 '18	Feb 26 '18	Feb 2 '18	Mar 1 '18
SW Task 4	18 days	Feb 27 '18	Mar 22 '18	Mar 2 '18	Mar 28 '18
SW Complete	0 days	Mar 22 '18	Mar 22 '18	Mar 28 '18	Mar 28 '18
Risk Path: 4	**18d**	**Feb 1 '18**	**Feb 26 '18**		
SW Task 3	18 days	Feb 1 '18	Feb 26 '18	Feb 2 '18	Mar 1 '18
Risk Path: 5	**15d**	**Mar 12 '18**	**Mar 30 '18**		
Brochure Development	10 days	Mar 12 '18	Mar 23 '18	Mar 12 '18	Mar 26 '18
Brochure Printing	5 days	Mar 26 '18	Mar 30 '18	Mar 26 '18	Apr 3 '18



Risk Path to an Interim Milestone

Similar in concept to Float Path analysis in a regular CPM schedule but based on the probability that tasks will be on the critical path to the selected sensitivity target.



Task Name	Duration	Start	Finish	Start Percentile (80%)	Finish Percentile (80%)
Risk Path: 1	**59 days**	**Jan 1 '18**	**Mar 22 '18**		
Initiate	5 days	Jan 1 '18	Jan 5 '18	Jan 1 '18	Jan 8 '18
SW Task 1	18 days	Jan 8 '18	Jan 31 '18	Jan 8 '18	Feb 2 '18
SW Task 3	18 days	Feb 1 '18	Feb 26 '18	Feb 2 '18	Mar 1 '18
SW Task 4	18 days	Feb 27 '18	Mar 22 '18	Mar 2 '18	Mar 28 '18
SW Complete	0 days	Mar 22 '18	Mar 22 '18	Mar 28 '18	Mar 28 '18
Risk Path: 2	**18 days**	**Feb 1 '18**	**Feb 26 '18**		
SW Task 2	18 days	Feb 1 '18	Feb 26 '18	Feb 2 '18	Mar 1 '18

Sensitivity Summary

Sensitivity analysis is a powerful tool to help understand what is creating uncertainty in project deliverables.

It can also help identify opportunities to improve an unacceptable probability of success.

Remember that only tasks with uncertainty appear on a Tornado Chart so either give all tasks some uncertainty or use Risk Path analysis to see the complete picture.

Risk Management

Most projects manage risk. This usually takes the form of a risk register where the probability of a threat occurring and its impact should it occur, are cataloged.

The main purpose of the Risk Register is to be pro-active and provide a response to the risk.

The objective is to reduce either the chance of the threat occurring or reduce the impact should it occur.

Risk Responses

- **Avoidance**: Can we modify the project, so the risk is no longer relevant?
- **Mitigation**: Can we reduce the chance of the risk occurring and/or reduce the impact of the risk.
- **Transference**: Can we make it someone else's problem?
- **Acceptance**: It’s possible the cost of avoiding or mitigating the risk is greater than the cost to the project should the risk occur. Accept the risk and have a plan ready should it occur and become an Issue.

Modeling Risks in a Schedule

Reminder: Risks are random events that may, or may not, occur. Duration uncertainty will always occur.

All the SRA tools will model both risks and duration uncertainty.

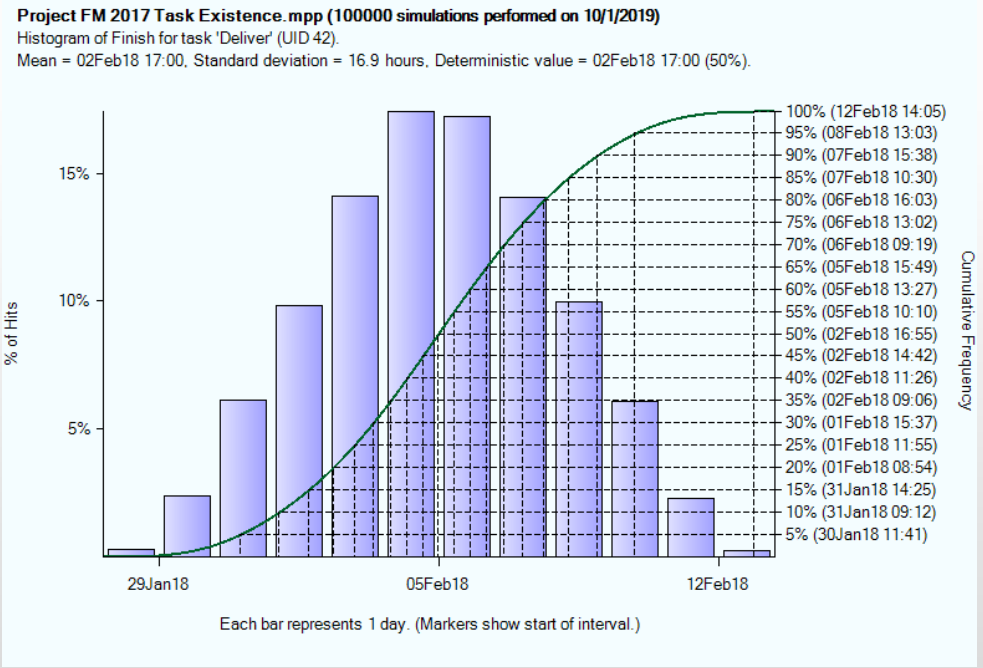
The problem with choosing to model risks in a schedule is the results becomes complex to interpret and difficult to present to stakeholders.

A simple example

Project	25 days	Jan 1 '18	Feb 2 '18
Make	4 wks	Jan 1 '18	Jan 26 '18
Test	1 wk	Jan 29 '18	Feb 2 '18
Deliver	0 days	Feb 2 '18	Feb 2 '18

We are going to make something, test the completed work and deliver.

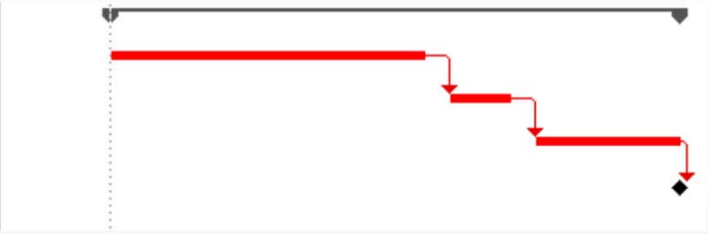
This gives us a pretty histogram and an 80% chance of delivering on Feb 6.



Let’s add a ‘Risk’

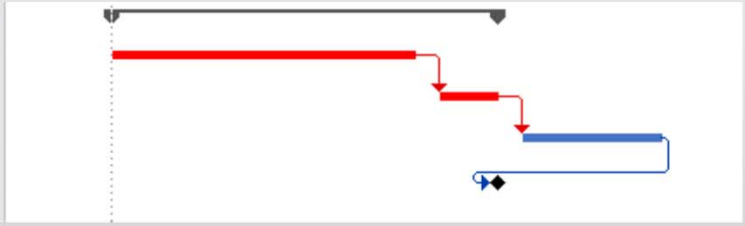
We identified a risk that re-work may be required after testing with a probability of occurrence of 20% and an impact of 2 weeks should it occur.

Project	35 days	Jan 1 '18	Feb 16 '18
Make	4 wks	Jan 1 '18	Jan 26 '18
Test	1 wk	Jan 29 '18	Feb 2 '18
Re-Work (20%)	2 wks	Feb 5 '18	Feb 16 '18
Deliver	0 days	Feb 16 '18	Feb 16 '18



Adding the risk of ‘Re-Work’ has pushed out the schedule completion to Feb 16. We can hide the extra time in Project by marking the task as inactive.

Project	25 days	Jan 1 '18	Feb 2 '18
Make	4 wks	Jan 1 '18	Jan 26 '18
Test	1 wk	Jan 29 '18	Feb 2 '18
~~Re-Work (20%)~~	~~2 wks~~	~~Feb 5 '18~~	~~Feb 16 '18~~
Deliver	0 days	Feb 2 '18	Feb 2 '18

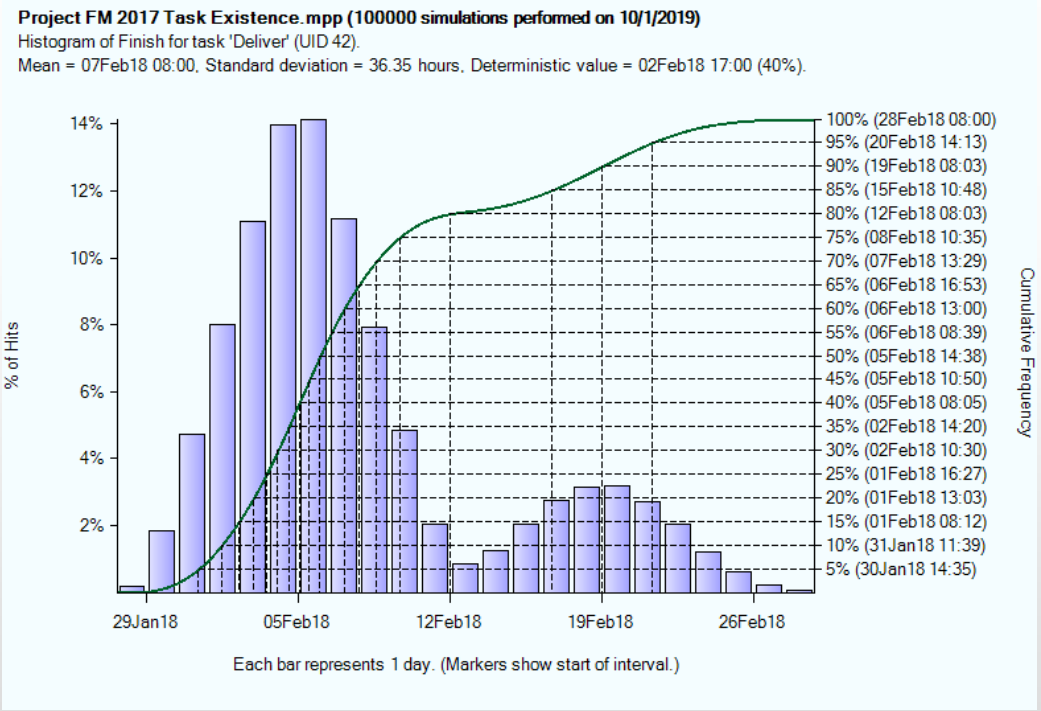


And the result is…

Not such a pretty histogram…

With this simple example of a single risk the resulting histogram is becoming more complex to interpret.

Technically it's becoming multi-modal.



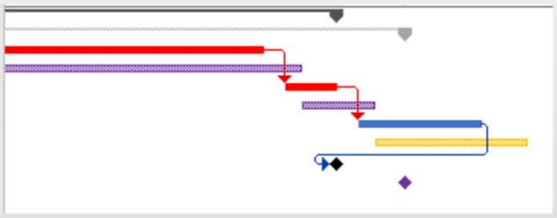
A Risk Adjusted Gantt Chart

A Risk Adjusted Gantt allows us to compare what we are planning to do with what we are committing to do.

The difference between the plan and the commitment is **Schedule Margin**

Even this simple Gantt can be harder to explain when risks are included in the schedule.

Project	25 days	Jan 1 '18	Feb 2 '18	100	Jan 1 '18	Feb 9 '18
Make	4 wks	Jan 1 '18	Jan 26 '18	100	Jan 1 '18	Jan 30 '18
Test	1 wk	Jan 29 '18	Feb 2 '18	100	Jan 30 '18	Feb 6 '18
~~Re-Work (20%)~~	~~2 wks~~	~~Feb 5 '18~~	~~Feb 16 '18~~	~~20~~	~~Feb 6 '18~~	~~Feb 21 '18~~
Deliver	0 days	Feb 2 '18	Feb 2 '18	100	Feb 9 '18	Feb 9 '18



Modelling Risk Mitigation

If you identify a risk mitigation plan as part of your risk assessment, you can model this in your schedule.

One technique is to use Conditional Branching.

This allows the schedule to follow different paths depending on dates calculated during the simulation.

Risk Mitigation Example

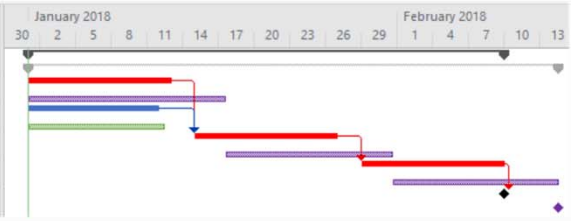
As a prime contractor we are responsible for integrating two assemblies from suppliers.

We have identified a risk that one of the assemblies may be delivered late and this will delay integration testing.

Our response to mitigate the late delivery will be to perform additional unit testing on the late item and then include the late item in final system testing.

Pre-Risk Mitigation Schedule

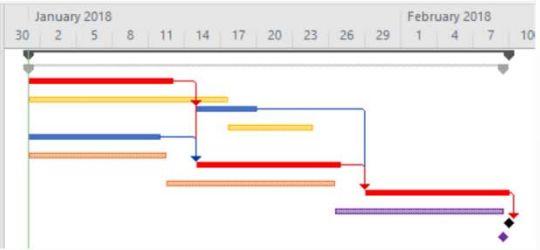
	Task Name	Duration	Predecessors	Risk Assessment	Percent Critical	Percent Active (branching)	Chance of Achieving MSP Early Finish	Finish	Early Finish Percentile (80%)
1	**Pre-Risk Model**	**30 days**			**100**	**100**	**9.09**	**Feb 9 '18**	**Feb 14 '18**
2	Assembly A	10 days		High Risk	100	100	9.09	Jan 12 '18	Jan 17 '18
3	Assembly B	9 days		Low Risk	0	100	50.39	Jan 11 '18	Jan 12 '18
4	Integration Testing	10 days	2,3		100	100	9.09	Jan 26 '18	Jan 31 '18
5	System Test	10 days	4		100	100	9.09	Feb 9 '18	Feb 14 '18
6	Launch	0 days	5		100	100	9.09	Feb 9 '18	Feb 14 '18



- Before risk mitigation, the risk of late delivery of Assembly A is always delaying the schedule.
- The probability of achieving the required launch date of February 9 is just over 9%.
- The 80th percentile date is February 14.

Post-Risk Mitigation Schedule

	Task Name	Duration	Predecessors	Risk Assessment	Percent Critical	Percent Active (branching)	Chance of Achieving MSP Early Finish	Finish	Early Finish Percentile (80%)
7	**Risk Mitigation Model**	**30 days**			**100**	**100**	**100**	**Feb 9 '18**	**Feb 9 '18**
8	Assembly A	10 days		High Risk	13	100	9.1	Jan 12 '18	Jan 17 '18
9	Additional Unit Test	5 days	8		4	91	0	Jan 19 '18	Jan 24 '18
10	Assembly B	9 days		Low Risk	87	100	49.96	Jan 11 '18	Jan 12 '18
11	Integration Testing	10 days	8,10		96	100	100	Jan 26 '18	Jan 26 '18
12	System Test	10 days	11,9		100	100	100	Feb 9 '18	Feb 9 '18
13	Launch	0 days	12		100	100	100	Feb 9 '18	Feb 9 '18



- We adapted the model to include Additional Unit testing that is only performed when Assembly A delivery is delayed.
- The chance of Launch on Feb 9 is now 100%
- Additional Unit testing was performed 91% of the time and was critical 4% of the time in the simulations.

Modelling Risks Summary

My Personal Recommendation…

If you are new to using Monte Carlo Simulation, focus on modelling Duration Uncertainty.

Duration Uncertainty is the primary reason for unexpected late delivery. Standard CPM models are unfortunately overly optimistic because Duration Uncertainty can create delays even if work is, on average, completed on time.

Use the Risk Register to understand and respond to risks. Start adding risk impacts to the schedule once your stakeholders have a good understanding of risk modelling.

Are CPM Schedules Optimistic?

Let's assume that our estimates and execution are excellent and that, ON AVERAGE, work items are completed in the estimated time.

Consider a single task: An Estimated Duration of 20 days with +/- 10% uncertainty which means we expect the actual duration may vary between 18 and 22 days.

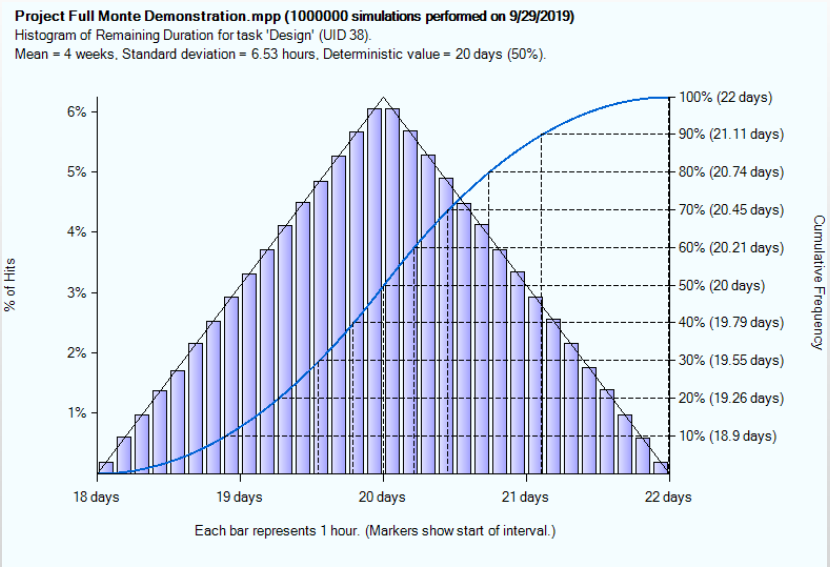
Here is a sample simulation, using a Triangular distribution, where the execution of the task was simulated 1 million times.

The task duration varies between 18 and 22 days as expected. The MEAN/AVERAGE duration was 4 weeks (20 days) in line with the estimated duration.

The simulation suggests we have a 50% chance of completing the work in the estimated duration.

The software is also suggesting that we have an 80% chance (right Y-Axis) of completing the work in 20.74 days.

So given we accept uncertainty will occur, we might prefer to commit to 20.74 days rather than 20.



Two Tasks Finish to Start (Series)

Let us add a second, identical task, as a successor to the first. The total project duration is now 40 days.

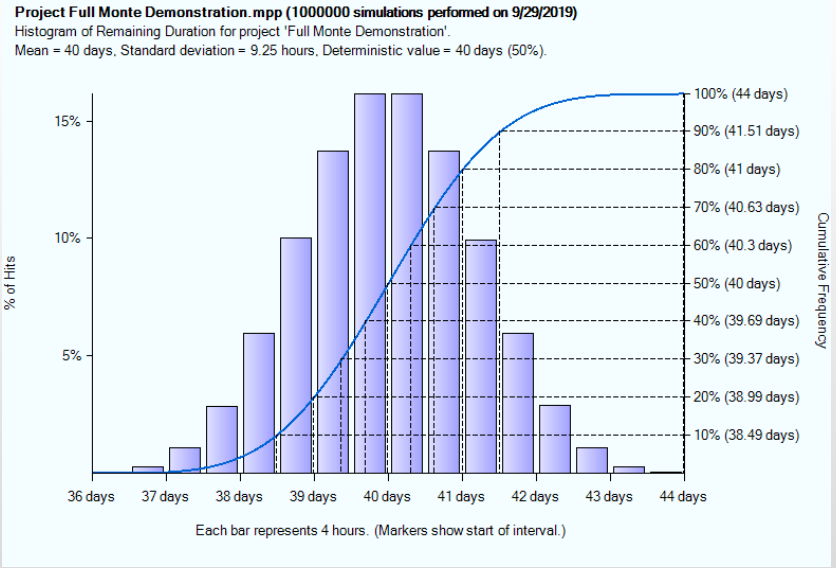
The individual tasks will still, on average, complete in their estimated durations.

In the simulation, the total project duration was as expected, ON AVERAGE, 40 days. The shortest duration was 36 days (both tasks finishing in 18 days) and the longest was 44 days (both tasks finishing in 22 days).

We still have a 50% chance of delivering in the estimated project duration from the schedule.

The 80% confidence duration is 41 days. Uncertainty, is to some extent 'cancelling out'.

Note: The histogram no longer looks Triangular. This effect is called the 'Central Limit Theorem' which basically says that, when independent random distributions are summed, the results tends toward a 'normal' (bell shaped) distribution.



Two Tasks

When we added a second Finish to Start task, uncertainty actually tended to cancel out. So the overall result meant that more simulations finished closer to the deterministic result from the schedule.

Of course, the range of the data increased because there was always the possibility that both tasks might finish early or late together but in general the results were closer to the mean duration and this matched the deterministic duration from the schedule.

So more tasks = less uncertainty?

Unfortunately no…

Two Tasks in Parallel

Let's change the project so the two 20-day tasks are in parallel as we see in many schedules. Both must be completed for the project to finish. The project is expected to take 20 days.

Each task individually will, on average, still finish in its estimated duration. They each have +/- 10% uncertainty.

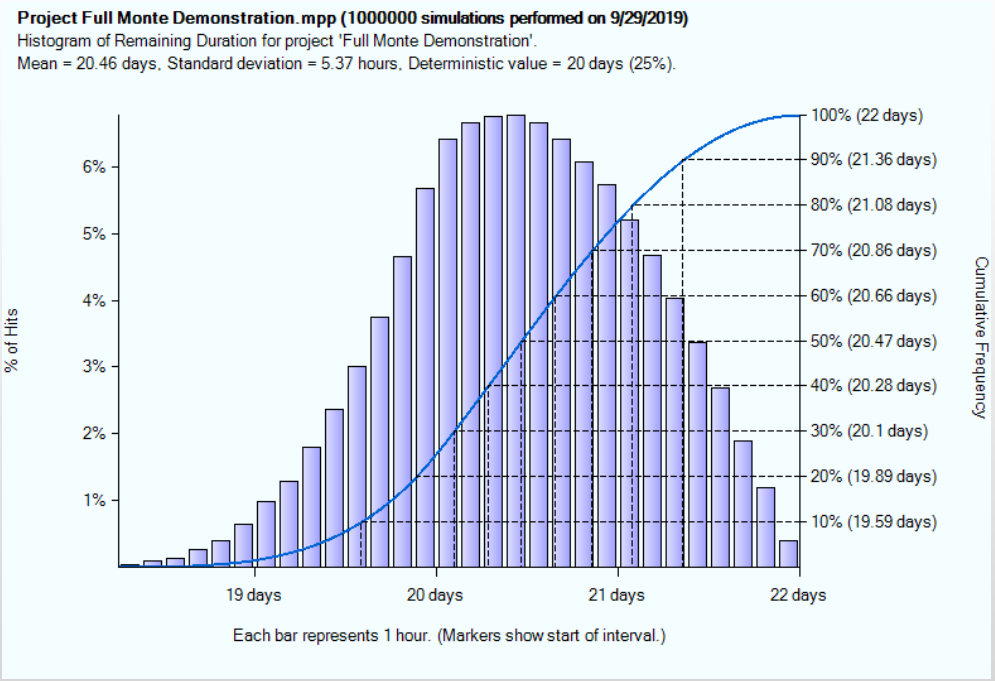
So with two identical tasks, in parallel, each with a 50% chance of completing on time we **only have a 25% chance** of the project completing on time.

A tabulation of the possible results (Early = On Time or Early)

Task A	**Task B**	**Project**
Early	Early	Early
Early	Late	Late
Late	Early	Late
Late	Late	Late

We only have a 1 in 4 chance of the project finishing early or on-time (this validates the 25% from the simulation).

This phenomenon is call **Merge Bias** and is often the single biggest reason projects are delivered late.

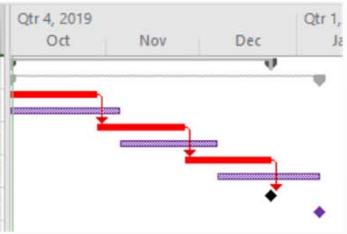


Risk and Estimates to Complete

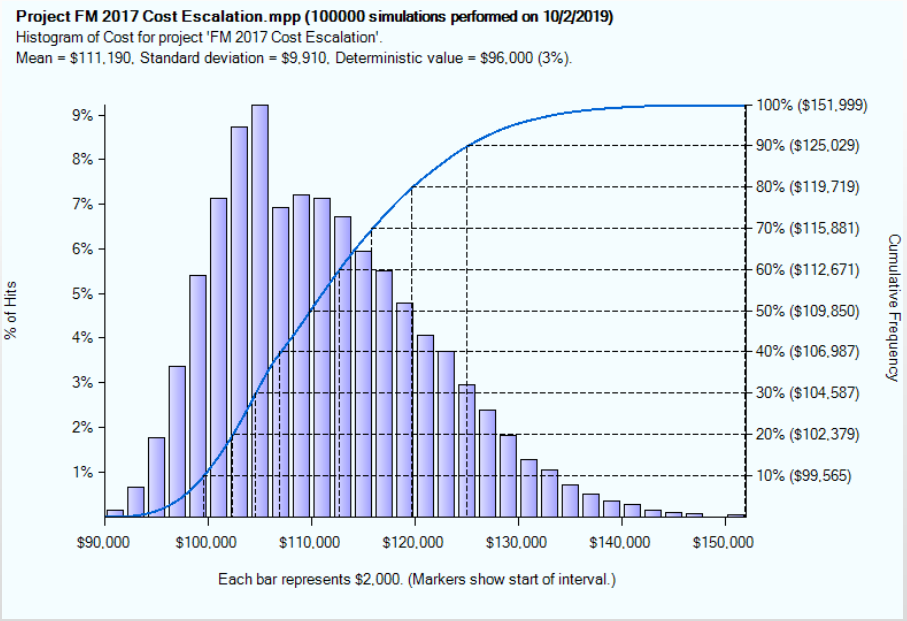
- **Estimate to Complete** is the amount of money required to **complete** the remaining work from a given date.
- Uncertainty can affect ETC in two ways:
  - The time to complete work is uncertain.
  - The cost of resources may increase if work occurs later due to cost escalation.
- Both effects can be simulated.

Cost Simulation

Task Name	Duration	Start	Finish	Cost	Cost Expected Value	Cost Percentile (80%)	Start Percentile	Finish Percentile
FM 2017 Cost Escalation	**60 days**	**Oct 1 '19**	**Dec 23 '19**	**$96,000.00**	**$111,160.00**	**$119,714.00**	**Oct 1 '19**	**Jan 8 '20**
Task A	4 wks	Oct 1 '19	Oct 28 '19	$32,000.00	$36,240.00	$40,199.00	Oct 1 '19	Nov 5 '19
Task B	4 wks	Oct 29 '19	Nov 25 '19	$32,000.00	$36,280.00	$40,211.00	Nov 5 '19	Dec 6 '19
Task C	4 wks	Nov 26 '19	Dec 23 '19	$32,000.00	$38,640.00	$44,104.00	Dec 6 '19	Jan 8 '20
Delivery	0 days	Dec 23 '19	Dec 23 '19	$0.00	$0.00	$0.00	Jan 8 '20	Jan 8 '20



- Average (Expected) cost for tasks increases due to duration uncertainty (32k to 36k)
- Task C is occasionally pushed into 2020 where there is a rate increase.
- 80th Percentile cost projection is significantly higher than that forecast by the CPM schedule.



Cost Simulation Summary

- Resource loading (with rates) can significantly improve the realism of Estimates To Complete.
- Make sure the SRA tool considers rate escalation.
- Look for a tool that automatically pro-rates uncertainty as tasks are progressed.

Key Takeaways

- A schedule risk analysis is a best practice
- It doesn't have to be a lot of extra work
- Start simple with Duration Uncertainty. Results are easier to present and can build confidence in the technique.
- Sensitivity Analysis helps identify opportunities to improve and validate schedule integrity.
- Model Risk Mitigation as well as Risks
- An SRA can produce a more realistic ETC.