Sensitivity and Risk Path Analysis

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Introduction

So, you have assigned duration uncertainty information, performed a schedule risk analysis, and hopefully have some pretty histograms to show for your efforts.

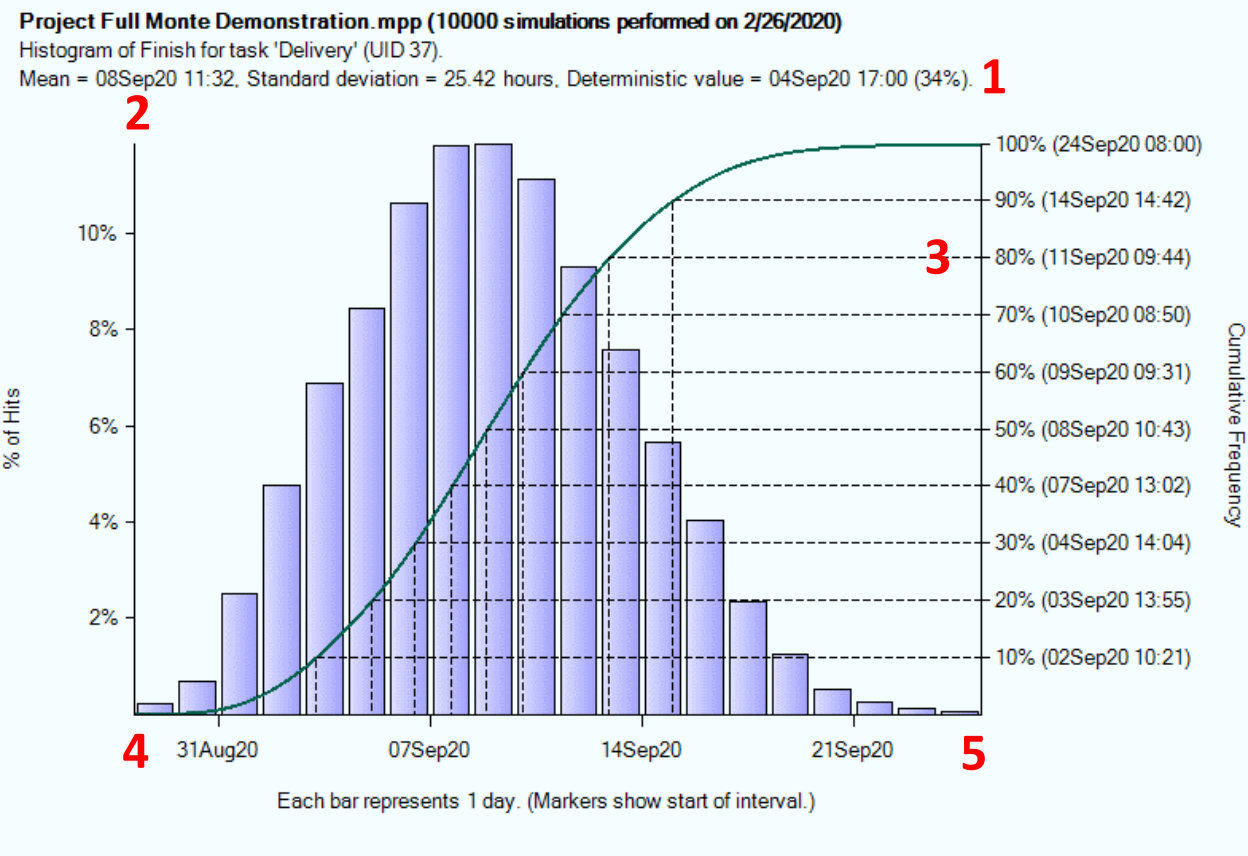

Figure 1

The example in Figure 1 provides several important pieces of information. We can see that:

1. The analysis is suggesting we only have a 34% chance of delivery occurring on the finish date calculated by the scheduling tool (4Sep20). Only 34% of the simulations finished by this date.
2. The Mean finish for the project during the simulations was 8Sep20.
3. The 80% Confidence (P80) Finish is 11Sep20. This means 80% of the simulations showed a finish on or before 11Sep20.
4. The earliest the project finished during the simulations was 27Aug20.
5. The latest the project finished during the simulations was 24Sep20.

*Note: We call the dates calculated by the scheduling tool **Deterministic** dates as they are not subject to uncertainty. The dates calculated by Full Monte are **Stochastic** as they include uncertainty.*

It is usual that the chance of achieving the finish date calculated by the scheduling tool is less than 50%. In fact, a probability of 50% or greater is an indication of invalid assumptions when defining duration uncertainty. It is not unusual for the probability, of achieving the finish date calculated by the scheduling tool, to be 0% once uncertainty is considered.

But what is causing the dates shown in the Histogram? How can we improve them? This is where sensitivity analysis comes in.

An Unfortunate Truth

The finish date calculated by the scheduling tool is unlikely to be achievable.

Even if estimates and execution are extremely good, factors like Merge Bias are going to make it next to impossible to deliver by the date calculated by a scheduling tool. This is why we perform a schedule risk analysis (SRA).

Of course, some projects are delivered on time, but this is more a testament to herculean effort and overtime hours than it is to the realism of the original schedule.

The SRA will simulate the execution of the project thousands of times, taking uncertainty into account, and will calculate a range of completion dates (the histogram in Figure 1). Using the cumulative S-Curve overlaid on the Histogram, we can see the finish dates at various degrees of probability. In Figure 1 we can see that 80% of the simulations finished on or before 11Sep20 and 90% of the simulations finished on or before 14Sep20 etc.

What we do with this information depends on who controls the required delivery date. If we control the date then we can commit to, for example, 11Sep20 to have an 80% chance of delivery by that date. However, if we are already committed to delivery on 4Sep20 (based on the dates from the schedule) we have a problem. The SRA says we only have a 34% chance of being able to achieve that.

In this later case, we need to modify the schedule to finish earlier so that when we take uncertainty into account, we have a better chance of delivery by 4Sep20. Most organizations aim for between an 80% and 90% chance of delivery by the committed date.

Sensitivity and Risk Path Analysis are the tools to help us achieve this.

Why 80% or 90% and not 100%?

So why, in the example above, did we suggest committing to an 80% date of 11Sep20? Why not the 100% confidence date of 24Sep20?

This choice depends on your 'appetite for risk'. The problem is that if we commit at 100% then we cannot commit resources to other projects before 24Sep20. There's an opportunity cost associated with having resources potentially standing idle until 24Sep20. Now if delivery after the committed date will result in catastrophic penalty clauses or reputational loss then we might want to commit at the 100% date, but most organizations choose to commit at something lower (generally 80%-90%). This becomes a trade-off between potential penalties for late delivery vs lost opportunity cost.

Sensitivity Analysis

Sensitivity Analysis shows us which tasks are creating uncertainty in a selected outcome. The outcome might be the entire project or an interim deliverable. Understanding the potential impact of each task on the outcome helps us focus management effort and perhaps identify opportunities for schedule compression.

Technically, the sensitivity index is a measure of the correlation between the duration of a task and variability in the dates of the desired outcome.

Consider the schedule shown in Figure 2.

Task Name	Duration	Start	Finish
Full Monte Demonstration	**70 days**	**6/1/20 8:00 AM**	**9/4/20 5:00 PM**
Sample Project	**70 days**	**6/1/20 8:00 AM**	**9/4/20 5:00 PM**
Initiate	5 days	6/1/20 8:00 AM	6/5/20 5:00 PM
Development	**60 days**	**6/8/20 8:00 AM**	**8/28/20 5:00 PM**
Hardware	**60 days**	**6/8/20 8:00 AM**	**8/28/20 5:00 PM**
HW Task 1	20 days	6/8/20 8:00 AM	7/3/20 5:00 PM
HW Task 2	20 days	7/6/20 8:00 AM	7/31/20 5:00 PM
HW Task 3	20 days	7/6/20 8:00 AM	7/31/20 5:00 PM
HW Task 4	20 days	8/3/20 8:00 AM	8/28/20 5:00 PM
HW Complete	0 days	8/28/20 5:00 PM	8/28/20 5:00 PM
Software	**54 days**	**6/8/20 8:00 AM**	**8/20/20 5:00 PM**
SW Task 1	18 days	6/8/20 8:00 AM	7/1/20 5:00 PM
SW Task 2	18 days	7/2/20 8:00 AM	7/27/20 5:00 PM
SW Task 3	18 days	7/2/20 8:00 AM	7/27/20 5:00 PM
SW Task 4	18 days	7/28/20 8:00 AM	8/20/20 5:00 PM
SW Complete	0 days	8/20/20 5:00 PM	8/20/20 5:00 PM
Integration	**5 days**	**8/31/20 8:00 AM**	**9/4/20 5:00 PM**
Integration	5 days	8/31/20 8:00 AM	9/4/20 5:00 PM
Marketing	**15 days**	**8/10/20 8:00 AM**	**8/28/20 5:00 PM**
Brochure Development	10 days	8/10/20 8:00 AM	8/21/20 5:00 PM
Brochure Printing	5 days	8/24/20 8:00 AM	8/28/20 5:00 PM
Delivery	0 days	9/4/20 5:00 PM	9/4/20 5:00 PM

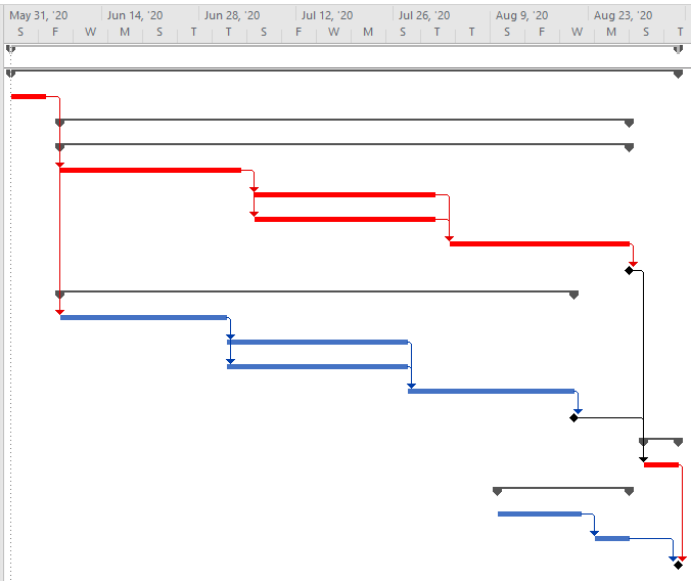

Figure 2

The scheduling tool has calculated that the critical/longest path runs through Initiate, the Hardware tasks, and finally Integration and this critical path is highlighted with red bars. The final delivery is calculated as 4Sep20.

The big question is: How likely are we to achieve that date?

Every estimate is subject to some uncertainty. For this example, we are going to apply some simple uncertainty of ± 25% to every duration estimate. This means that each task is just as likely to finish early as late, meaning that on average each task should be completed in the duration originally estimated.

Now let's perform the risk analysis.

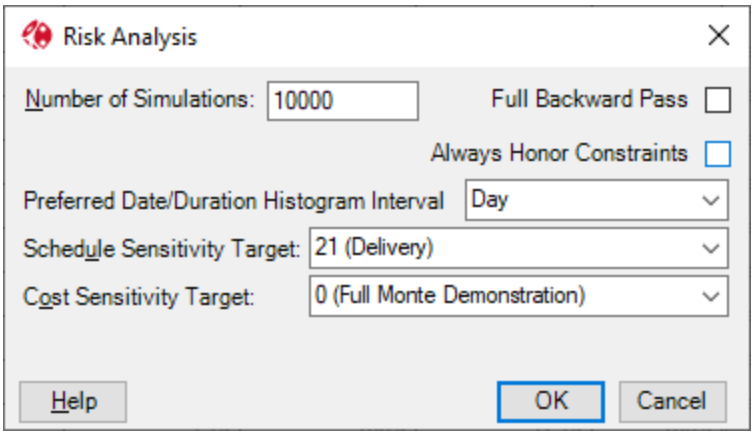

Figure 3

In Figure 3, we have typical settings for a risk analysis. We are going to perform 10,000 simulations of the project execution and focus the sensitivity analysis on the final Delivery milestone.

After the analysis is complete, we can review the histogram for the Delivery milestone as shown in Figure 1.

The analysis is indicating we only have a 34% chance of Delivery by 4Sep20. Some might find this surprising given every task is expected, on average, to finish on its estimated duration. However, because of the parallel paths through the project logic, the analysis is suggesting delays will occur due to Merge Bias.

If we need to increase our chance of delivery by 4Sep20 what can we do?

The place to start is the Tornado Chart; View, Open named View…, Tornado (Schedule with Index).

ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Sensitivity Index 20.0 40.0	Optimistic Finish of Milestone ID 21	Pessimistic Finish of Milestone ID 21	Mean Date Range 2020 Sep 30 06 13
5	HW Task 1	20 days	89%	89%	57%		9/3/20 3:14PM	9/15/20 11:32...	
8	HW Task 4	20 days	89%	89%	57%		9/3/20 3:14PM	9/15/20 11:32...	
7	HW Task 3	20 days	46%	46%	29%		9/7/20 3:25PM	9/14/20 1:41PM	
6	HW Task 2	20 days	43%	43%	28%		9/7/20 3:49PM	9/14/20 1:04PM	
2	Initiate	5 days	97%	97%	16%		9/7/20 11:52AM	9/9/20 2:32PM	
17	Integration	5 days	97%	97%	16%		9/7/20 11:52AM	9/9/20 2:32PM	
14	SW Task 4	18 days	8%	8%	5%		9/8/20 11:11AM	9/10/20 9:46AM	
11	SW Task 1	18 days	8%	8%	5%		9/8/20 11:11AM	9/10/20 9:46AM	
13	SW Task 3	18 days	4%	4%	2%		9/8/20 11:25AM	9/9/20 2:57PM	
12	SW Task 2	18 days	4%	4%	2%		9/8/20 11:25AM	9/9/20 2:30PM	
19	Brochure Develop...	10 days	3%	3%	1%		9/8/20 11:30AM	9/9/20 8:11AM	

Figure 4

The Tornado Chart highlights the tasks creating uncertainty in the selected sensitivity target (Delivery).

> *Note: The Tornado Chart will only show tasks that are on the critical path to the target (at least some of the time) and that have duration uncertainty assigned.*
>
> *Note: The Optimistic and Pessimistic Finish Dates columns show the **mean** finish of the sensitivity target (in this case our Delivery milestone) for each task when the task finishes closer to its Optimistic Duration vs Pessimistic Duration. They are **not** best/worst case date for Delivery. The*

*best/worst case dates **always** come from the histogram for the sensitivity target (Delivery – see figure 1).*

The Sensitivity Index ranks the tasks in order of their impact on the outcome and clearly shows that HW Task 1 and 4 are having the greatest effect. The split between green and red areas in the time scaled bar chart shows the potential impact versus the mean finish for the outcome (8Sep20 from the Histogram in Figure 1). This highlights that, during the simulations, when tasks HW Task 1 and 4 finished closer to their Optimistic (best case) duration estimate then the finish date for Delivery tended to be earlier than its expected mean. Conversely, if the tasks finished closer to their Pessimistic (worst case) duration estimate then the finish for Delivery tended to be later than the mean.

Observe that SW Tasks 1 and 4 only have red bars. This might be surprising given they have the same ± 25% uncertainty as all the other tasks but because of the project logic, if these tasks finished early, they were no longer on the critical path so them finishing early had no beneficial impact.

So, if the 36% chance of delivery by 4Sep20 was not acceptable, HW Tasks 1 and 4 are good candidates for schedule compression given that when they finished early (closer to their optimistic duration estimate) the mean delivery date was also earlier (the green bar).

There are three main techniques to reduce the overall project duration:

- Reduce Task Durations (can we use more/better resources?)
- Change the logic so they are no longer on the critical path
- Review the estimate and see if uncertainty can be reduced

For this example, we will reduce the durations of HW Tasks 1 and 4 by two days each. After repeating the schedule risk analysis with the revised data, the Delivery histogram is now shown in Figure 5.

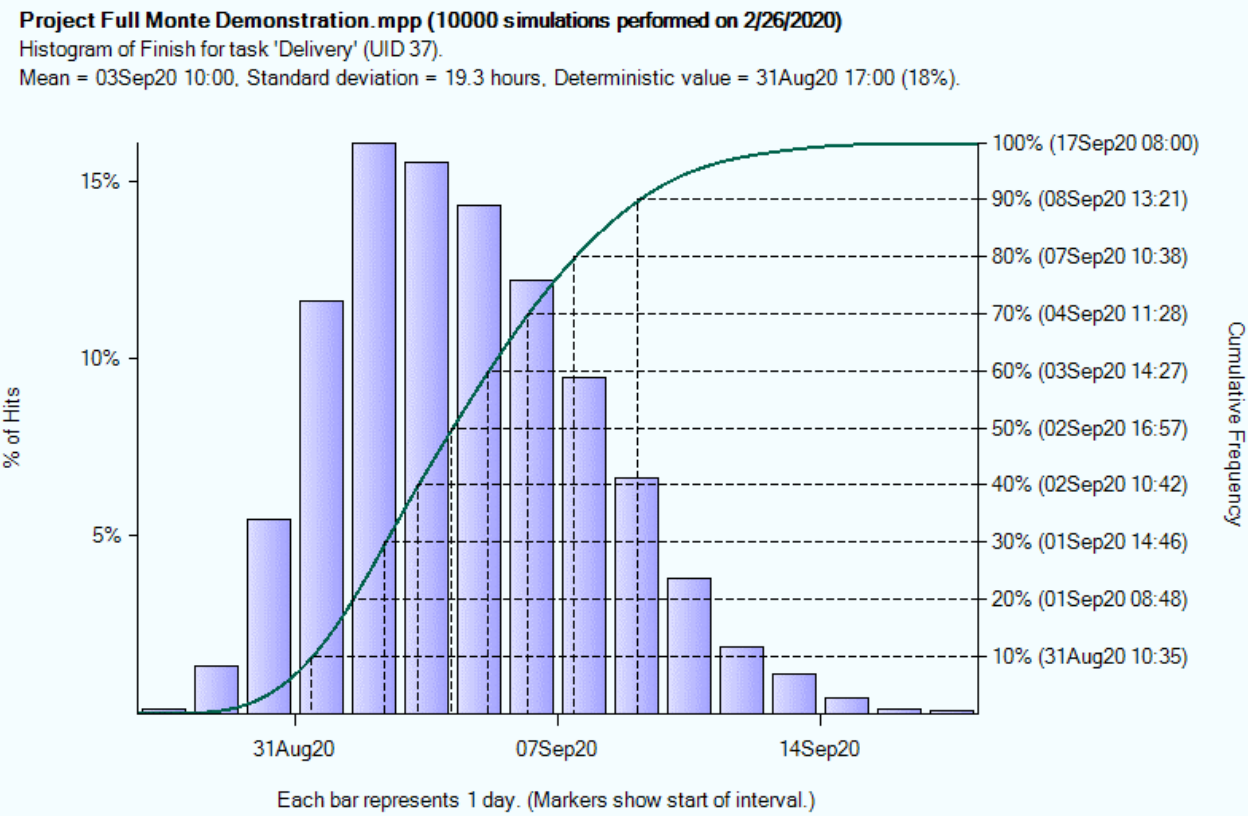

Figure 5

The 80% confidence date for Delivery is now 7Sep20 (compared to 11Sep20 before our change). Clearly there is more work to be done. Let's revisit the Tornado Chart.

ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Sensitivity Index 20.0 40.0	Optimistic Finish of Milestone ID 21	Pessimistic Finish of Milestone ID 21	Mean Date Range 2020 Aug Sep 30 06
5	HW Task 1	18 days	59%	59%	45%		9/2/20 10:59AM	9/9/20 10:33AM	
8	HW Task 4	18 days	59%	59%	45%		9/2/20 10:59AM	9/9/20 10:33AM	
6	HW Task 2	20 days	31%	31%	26%		9/2/20 4:12PM	9/8/20 3:29PM	
7	HW Task 3	20 days	29%	29%	24%		9/2/20 4:26PM	9/8/20 2:50PM	
11	SW Task 1	18 days	25%	25%	19%		9/3/20 8:09AM	9/8/20 9:31AM	
14	SW Task 4	18 days	25%	25%	19%		9/3/20 8:09AM	9/8/20 9:31AM	
12	SW Task 2	18 days	12%	12%	9%		9/3/20 9:21AM	9/7/20 11:20AM	
13	SW Task 3	18 days	12%	12%	9%		9/3/20 9:21AM	9/7/20 11:14AM	
17	Integration	5 days	84%	84%	18%		9/2/20 2:37PM	9/4/20 12:00PM	
2	Initiate	5 days	84%	84%	18%		9/2/20 2:37PM	9/4/20 12:00PM	
19	Brochure Develop...	10 days	16%	16%	7%		9/3/20 9:29AM	9/4/20 1:45PM	
20	Brochure Printing	5 days	16%	16%	3%		9/3/20 9:45AM	9/3/20 4:23PM	

Figure 6

In Figure 6 we can see the change we made (reducing the duration of tasks HW Task 1 and 4) has resulted in less 'green' bar for those tasks. This is telling us that now, when they finish closer to their optimistic estimates, other tasks must be preventing the Delivery from moving earlier. This is reflected in their Percent Criticality dropping from 89% to 59%.

One interesting development is that 'Brochure Development' and 'Brochure Printing' now have a Percent Critical of 16%. Clearly, we don't want project delivery delayed by a brochure so that needs to be investigated. Brochure development has a Start No Earlier than constraint that prevents it from moving earlier. This is the reason the histogram in Figure 5 is less symmetrical compared to Figure 1.

Back to the schedule and let's move the Brochure Development constraint 1 week earlier and reduce the 'Initiate' task duration by 1 day. Re-run the analysis.

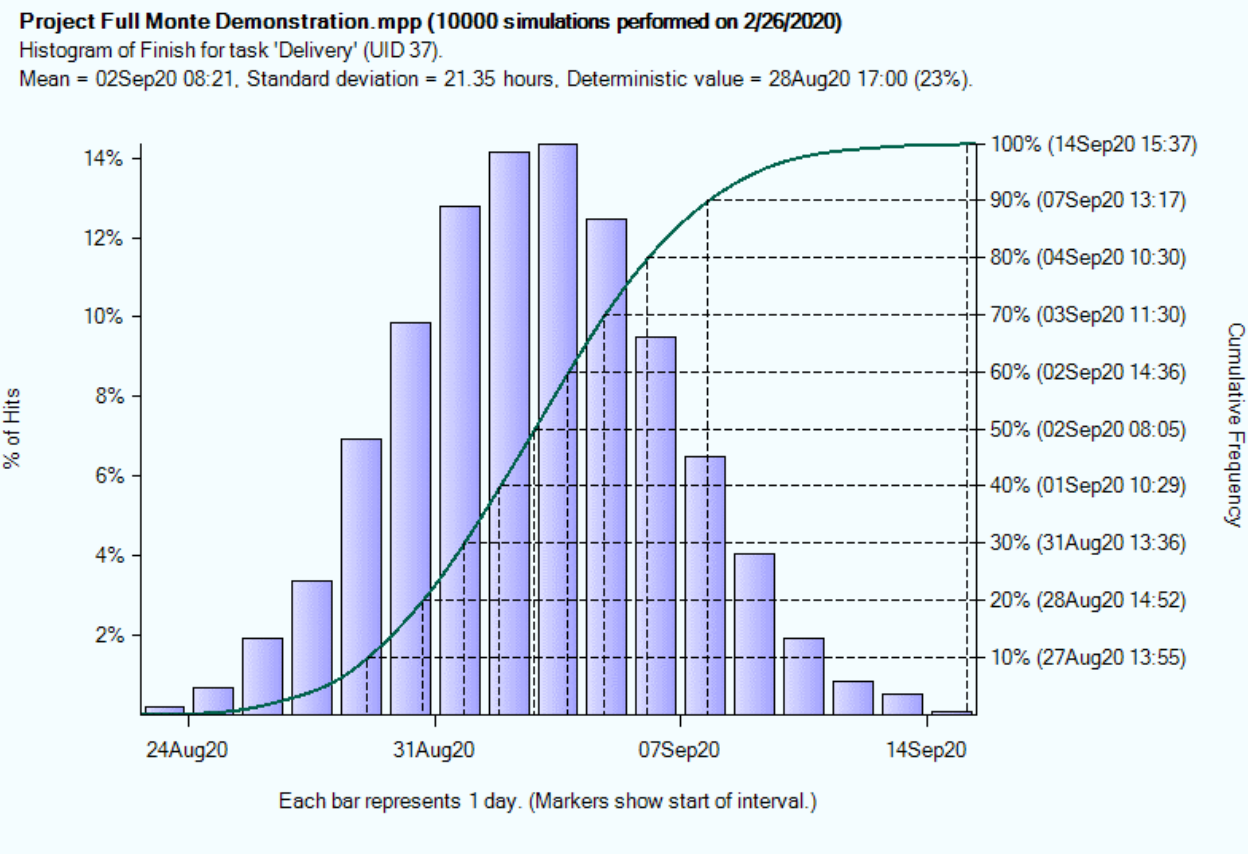

Figure 6

In Figure 6 we can now see we have achieved an 80% confidence for a delivery on 4Sep20.

The deterministic date for Delivery from the schedule is now 28Aug20 after the schedule compression changes we made. There is a 28% chance we might achieve that date but that isn't the date we are committing to our client.

Schedule Margin

The difference between 28Aug20, as shown by the schedule, and the 4Sep20 date we are committing to our client, at 80% confidence, is called Schedule Margin. This can be described as a 'risk contingency buffer' and belongs to the project manager.

Execution

The project is executed based on the plan in the schedule. The aim is to deliver by 28Aug20 (as shown in the schedule). However, we now understand the risk/uncertainty in the plan, and now have the schedule margin to protect our committed delivery date of 4Sep20.

Risk Path Analysis

Another technique to view tasks responsible for the dates of the outcome is a Risk Path report as shown in Figure 7. This groups tasks based on their probability of affecting the outcome. Unlike the Sensitivity Tornado chart, the Risk Path report includes any task driving the outcome even if they have no uncertainty and do not appear on the sensitivity report.

Task Name	Duration	Start	Finish	Start Percentile (80%)	Finish Percentile (80%)
Risk Path: 1	**65d**	**6/1/20 8:00 AM**	**8/28/20 5:00 PM**		
Initiate	4 days	6/1/20 8:00 AM	6/4/20 5:00 PM	6/1/20 8:00 AM	6/5/20 11:02 AM
HW Task 1	18 days	6/5/20 8:00 AM	6/30/20 5:00 PM	6/5/20 11:03 AM	7/2/20 2:17 PM
HW Task 2	20 days	7/1/20 8:00 AM	7/28/20 5:00 PM	7/2/20 2:19 PM	7/31/20 11:17 AM
HW Task 4	18 days	7/29/20 8:00 AM	8/21/20 5:00 PM	8/3/20 10:45 AM	8/27/20 4:04 PM
HW Complete	0 days	8/21/20 5:00 PM	8/21/20 5:00 PM	8/27/20 4:04 PM	8/27/20 4:04 PM
Integration	5 days	8/24/20 8:00 AM	8/28/20 5:00 PM	8/28/20 10:15 AM	9/4/20 10:30 AM
Delivery	0 days	8/28/20 5:00 PM	8/28/20 5:00 PM	9/4/20 10:30 AM	9/4/20 10:30 AM
Risk Path: 2	**20d**	**7/1/20 8:00 AM**	**7/28/20 5:00 PM**		
HW Task 3	20 days	7/1/20 8:00 AM	7/28/20 5:00 PM	7/2/20 2:19 PM	7/31/20 11:11 AM
Risk Path: 3	**54d**	**6/5/20 8:00 AM**	**8/19/20 5:00 PM**		
SW Task 1	18 days	6/5/20 8:00 AM	6/30/20 5:00 PM	6/5/20 11:03 AM	7/2/20 2:25 PM
SW Task 2	18 days	7/1/20 8:00 AM	7/24/20 5:00 PM	7/2/20 2:26 PM	7/29/20 10:13 AM
SW Task 4	18 days	7/27/20 8:00 AM	8/19/20 5:00 PM	7/30/20 9:09 AM	8/25/20 2:10 PM
SW Complete	0 days	8/19/20 5:00 PM	8/19/20 5:00 PM	8/25/20 2:10 PM	8/25/20 2:10 PM
Risk Path: 4	**18d**	**7/1/20 8:00 AM**	**7/24/20 5:00 PM**		
SW Task 3	18 days	7/1/20 8:00 AM	7/24/20 5:00 PM	7/2/20 2:26 PM	7/29/20 10:22 AM
Risk Path: 5	**15d**	**8/3/20 8:00 AM**	**8/21/20 5:00 PM**		
Brochure Development	10 days	8/3/20 8:00 AM	8/14/20 5:00 PM	8/3/20 8:00 AM	8/17/20 4:18 PM
Brochure Printing	5 days	8/17/20 8:00 AM	8/21/20 5:00 PM	8/17/20 4:19 PM	8/24/20 4:57 PM

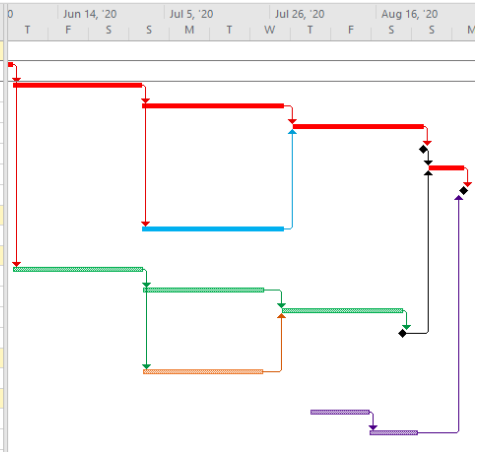

Figure 7

The Risk Path report can make it easier to understand the most likely critical path to any outcome and hence identify opportunities for schedule compression or risk reduction by changing logic between the tasks.

Sensitivity and Risk Path analysis can be focused either on the entire project or a selected interim deliverable.

Conclusion

Sensitivity and Risk Path Analysis can highlight schedule issues like unexpected tasks driving deliverables and opportunities for schedule compression in order to achieve required levels of confidence in committed delivery dates.

Projects can realize significant cost savings and a greater chance of meeting commitments by understanding and managing the potential critical paths based on schedule risk analysis.