Modern Methods of Schedule Risk Analysis using Monte Carlo Simulations

Presented to the
2017 Large Facilities Workshop
Baton Rouge, LA

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Agenda

- Modern Methods of risk analysis
- Collecting risk data
- Introducing uncertainty to the model
- Introducing risks as Risk Drivers
- Risk drivers model correlation between activity durations
- Risks may be entered in series or in parallel
- Offshore gas production platform project
- Use Categories to apply risks to multiple activities
- Prioritizing risks for management action
- Risk mitigation actions and Results (simple example)
- Probabilistic branching for test failure possibility

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MODERN METHODS OF RISK ANALYSIS

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Modern Methods of Schedule Risk Analysis(1)

- Earlier methods of quantifying risk analysis using Monte Carlo Simulation (MCS) placed probability distributions directly on activity durations
  - Did not distinguish risks from uncertainty
  - Could not disentangle the relative impacts of several risks on one activity
  - Could not assess the whole impact of a risk that affects more than one activity
  - Therefore, could not prioritize risks for risk mitigation

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Modern Methods of Schedule Risk Analysis (2)

- In the last 10 years we have been able to specify risks and use those to directly drive the MCS
  - Distinguish uncertainty from risks
  - Model specific risks including systemic risks from benchmarking data
  - Represent failing a test with probabilistic branches
- This development allows us to model much more specifically and intelligently
  - Apply risks to multiple activities (categories of activities)
  - Apply risks in series and in parallel
  - Model how duration correlation occurs
  - Prioritize risks for focused risk mitigation

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COLLECTING RISK DATA

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Collecting Risk Data Using Confidential Interviews

- Data about risk may start with the Risk Register
- During one-on-one confidential interviews we always discover risks not on even well-developed and maintained Risk Registers
- This omission may be because there are some Unknown Knows that are not talked about in workshops
- Collect descriptions of the risk, probability it will occur, impact (multiplicative factors) on the scheduled durations and activities it will affect if it occurs
- Collect data on uncertainty too – 100% likely to occur with some impact

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INTRODUCING UNCERTAINTY TO THE MODEL

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Add components of Risk - Uncertainty

- Uncertainty is akin to "common cause" variation in the six sigma management
- "Common cause variability is a source of variation caused by unknown factors that result in a steady but random distribution of output around the average of the data. Common cause variation is a measure of the process's potential, or how well the process can perform when special cause variation is removed. ... Common cause variation is also called random variation, noise, non-controllable variation, within-group variation, or inherent variation."

https://www.isixsigma.com/dictionary/common-cause-variation/

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Specifying Uncertainty - Reference

Templated Uncertainty Editor

Templates Add Remove

Priority	Filter	Schedule Uncertainty
1	Approval	Triangular - Min:0.8 Likely:1 Max:1.3
2	Engineering	Triangular - Min:0.9 Likely:1.1 Max:1.4
3	Procurement	Triangular - Min:0.95 Likely:1 Max:1.2
4	Fabrication	Triangular - Min:0.85 Likely:1.1 Max:1.3
5	Drilling	Triangular - Min:0.8 Likely:1 Max:1.2
6	Installation	Triangular - Min:0.9 Likely:1.05 Max:1.3
7	HUC	Triangular - Min:0.85 Likely:1.1 Max:1.4

Uncertainty ranges can be applied to different types of activities "reference ranges" Uncertainty can be correlated, in this case 100% to make overall project uncertainty model what people said during interviews

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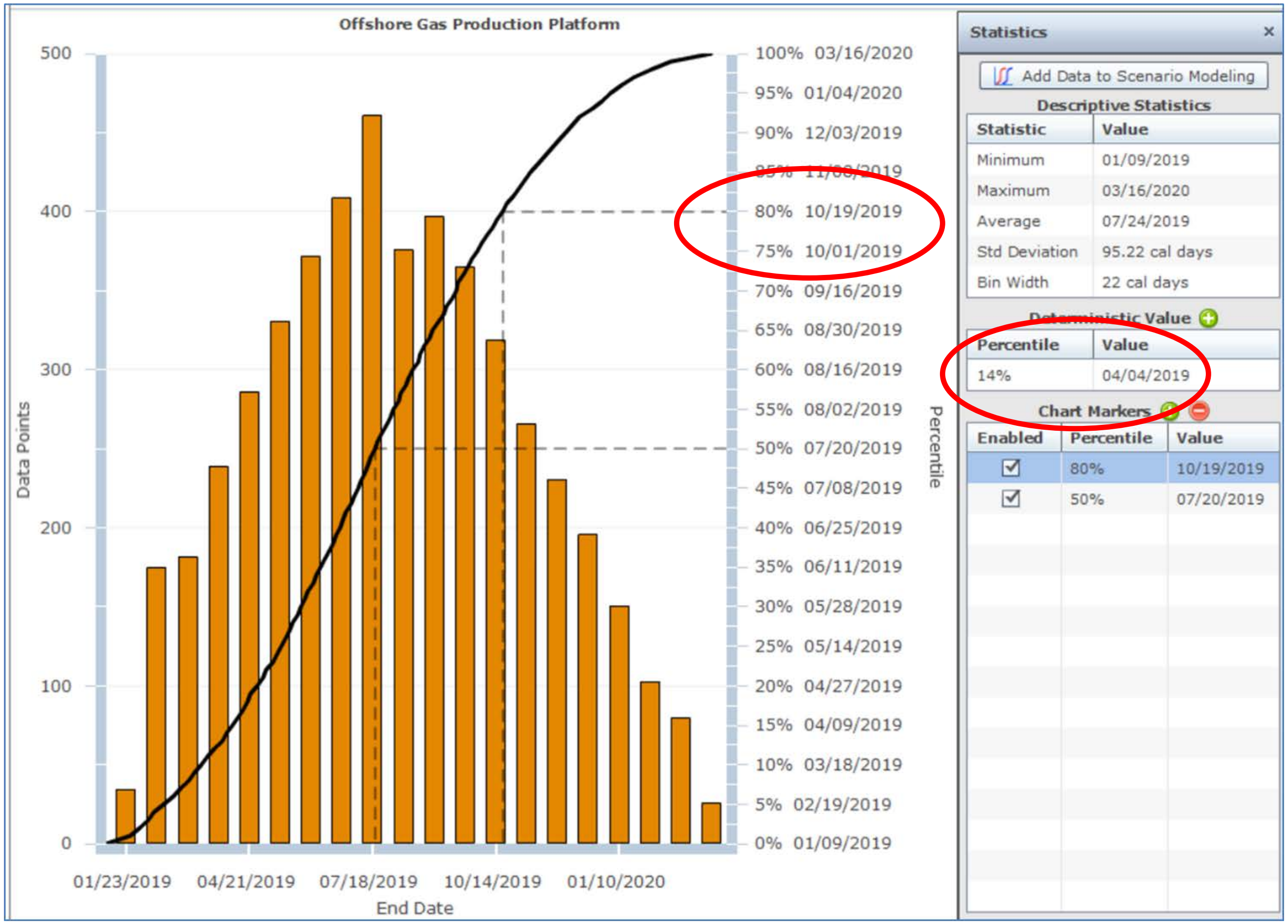
Schedule Risk with Uncertainty Only



Scheduled completion is April 4, 2019

With Uncertainty Only the P-80 completion is October 19, 2019, an addition of 6 ½ months

With Uncertainty only the likelihood of meeting the scheduled date is 14%

“P-80” means the date that the project will finish on or earlier than in 80% of the iterations

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INTRODUCING RISKS AS RISK DRIVERS

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Adding Project-Specific Risks

- Project Specific Risks are like special cause risk in the Six Sigma world
- "… Special cause variation is caused by known factors that result in a non-random distribution of output…Special cause variation is a shift in output caused by a specific factor such as environmental conditions or process input parameters. It can be accounted for directly and potentially removed…"

https://www.isixsigma.com/dictionary/special-cause-variation/

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Root Cause of Variation – Risk Drivers

- Risk Drivers came about nearly 10 years ago as the author and a colleague asked Pertmaster, on behalf of a client, to develop this method
- Risk Drivers' impacts on scheduled durations are in ranges of multiplicative factors translated into probability distributions
- Risk Drivers can be assigned to many activities so it models how a strategic risk influences the project
- Some activities can have several risk drivers

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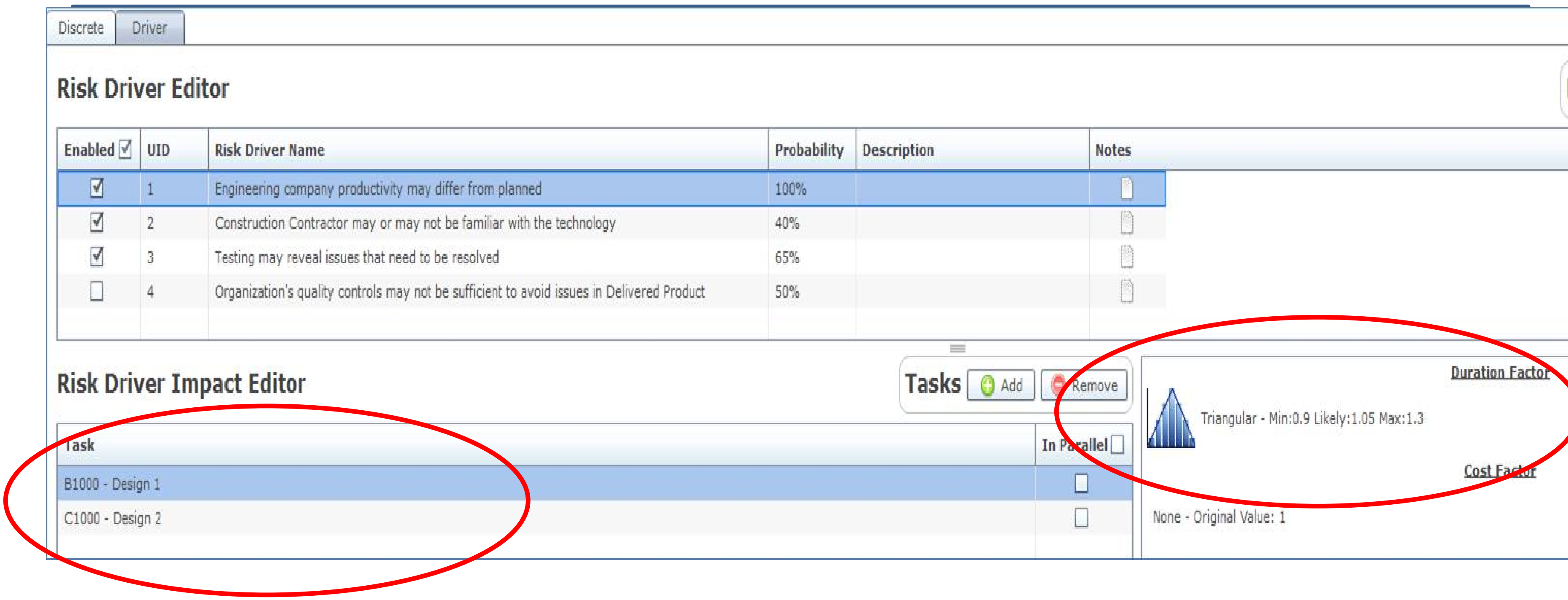
Introducing the Risk Driver Method for Causing Additional Variation in the Simulation



Four risk drivers are specified. The first is a general risk about engineering productivity, which may be under- or over-estimated, with 100% probability. It is applied to the two Design activities

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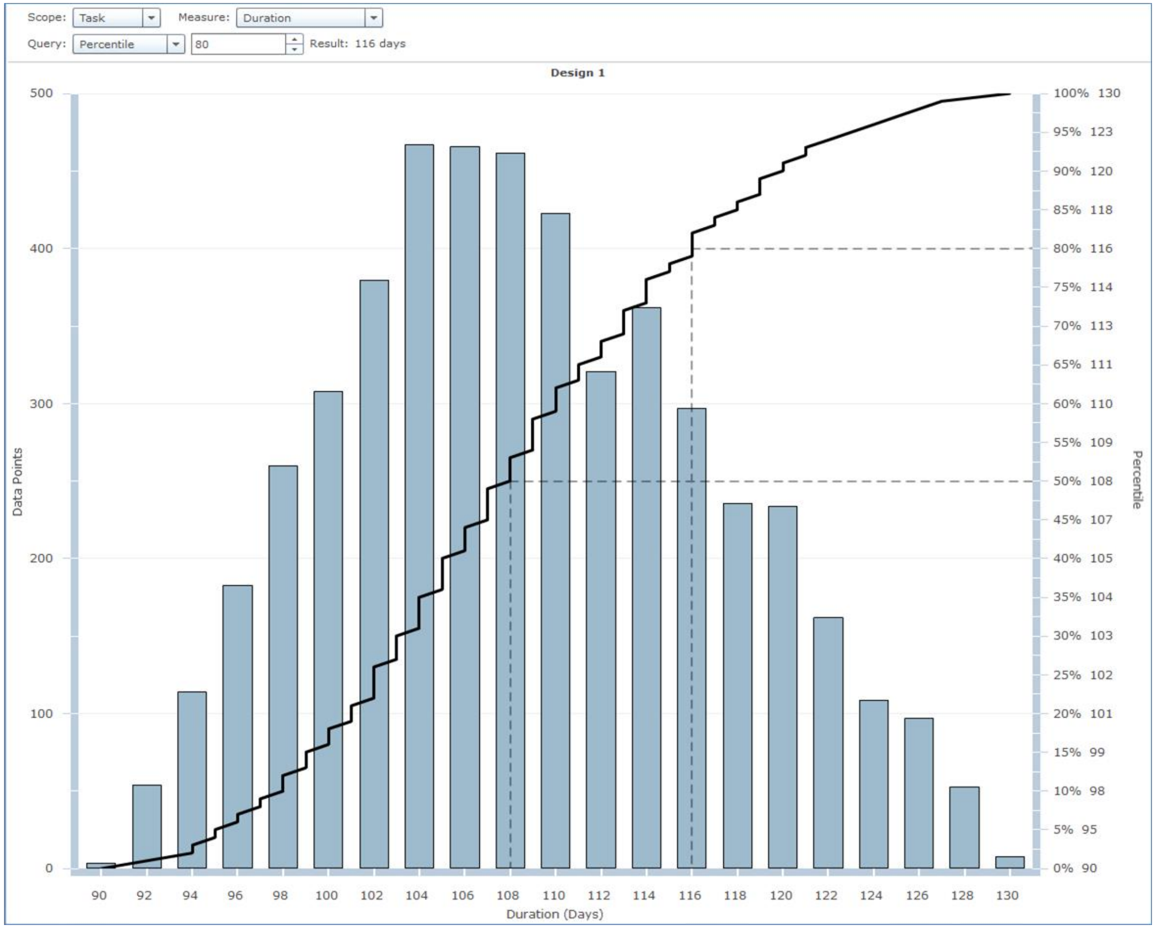
100% Likely Risk Driver's Effect on Design Duration



With a 100% likely risk the probability distribution of the activity's duration looks like a triangle. Not any different from placing a triangle directly on the activity

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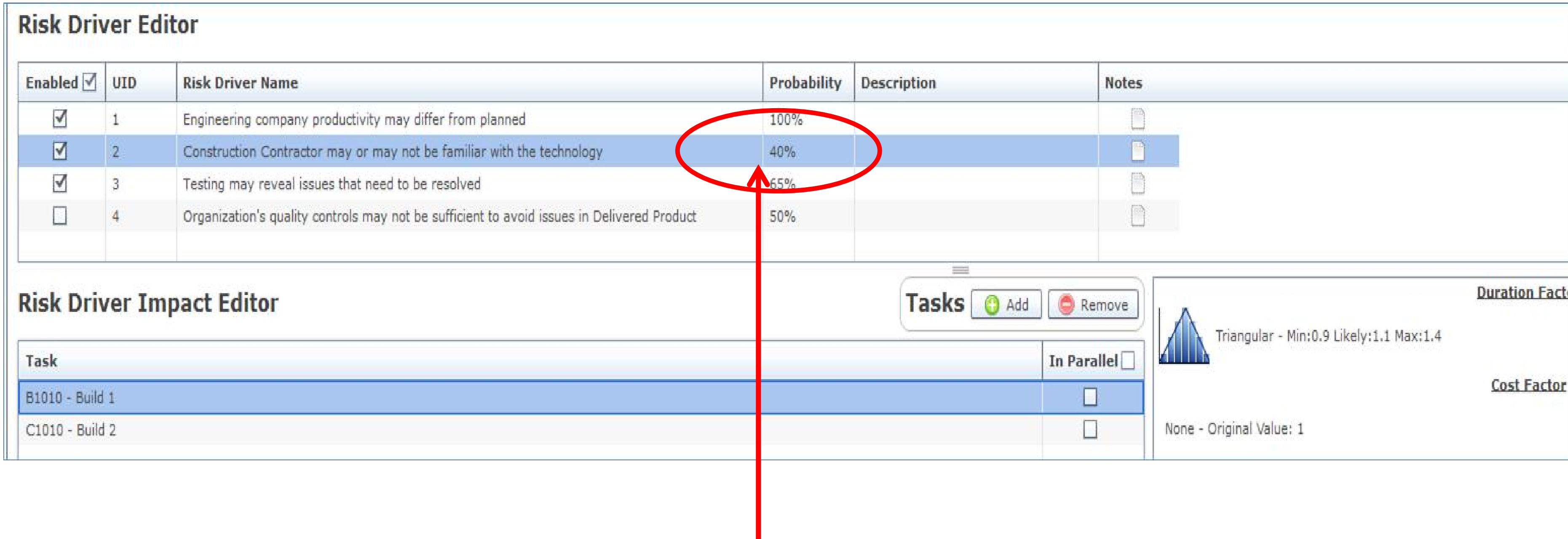
Risk Driver with Risk at < 100% likelihood



With this risk, the Construction Contractor may or may not be familiar with the technology, the probability is 40% and the risk impact if it happens is .9, 1.1 and 1.4. It is applied to the two Build activities

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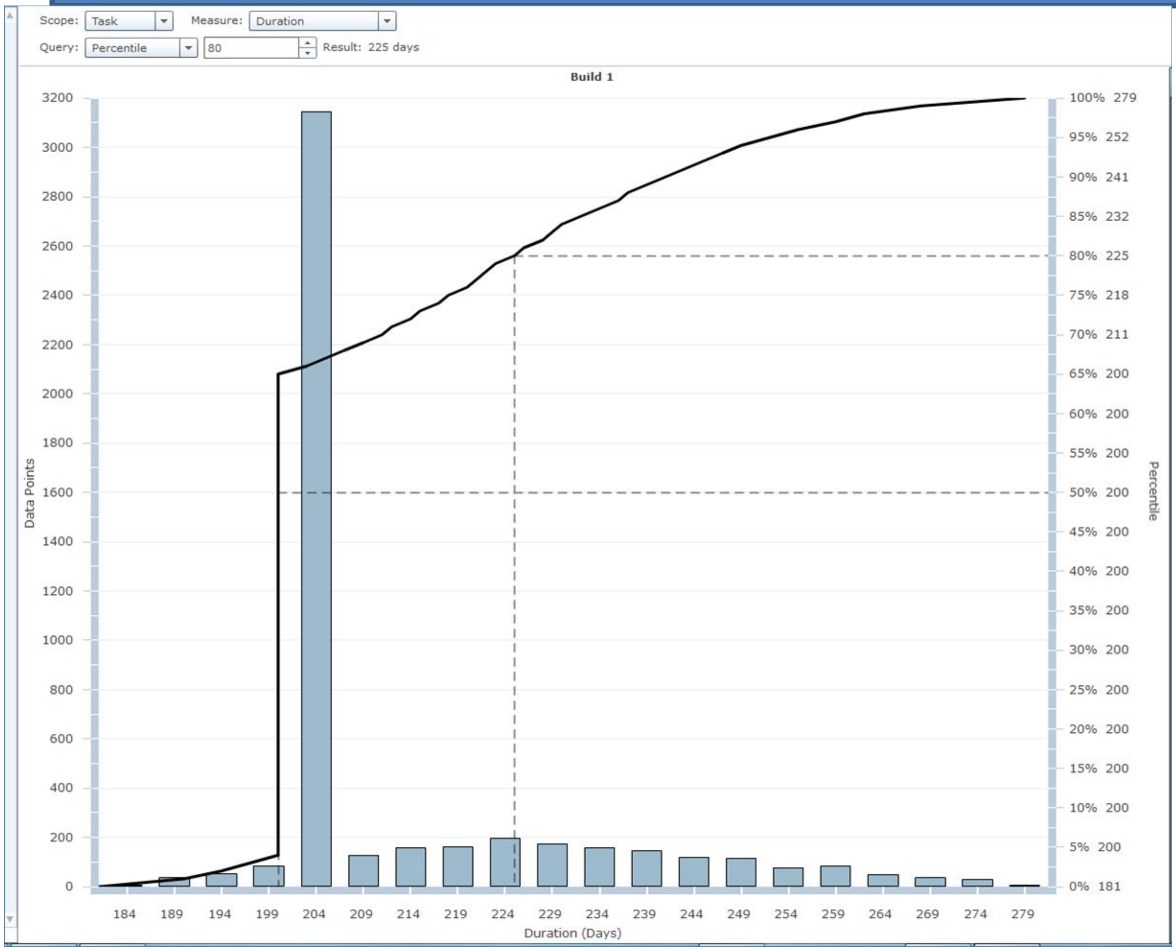
With a 40% Likelihood, the "Spike" in the Distribution Contains 60% of the Probability



Here is where the Risk Driver method gets interesting. It can create distributions that reflect:

- Probability of occurring
- Impact if it does occur

Cannot represent these two factors with simple triangular distributions applied to the durations directly

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RISK DRIVERS MODEL CORRELATION BETWEEN ACTIVITY DURATIONS

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Model Correlation of Activity Durations

- A common question with schedule (or cost) risk analysis is; "Have you considered correlation?"
- Correlation is defined between pairs of durations. A matrix of correlation coefficients is created
  - Example – Tasks may be long because subcontractor may not be able to provide high productivity
  - Example – Tasks may be long because technology may not be well understood (low TRL)
- People do not do well guessing coefficients
- Using Risk Drivers removes this problem since it models how correlation occurs in projects

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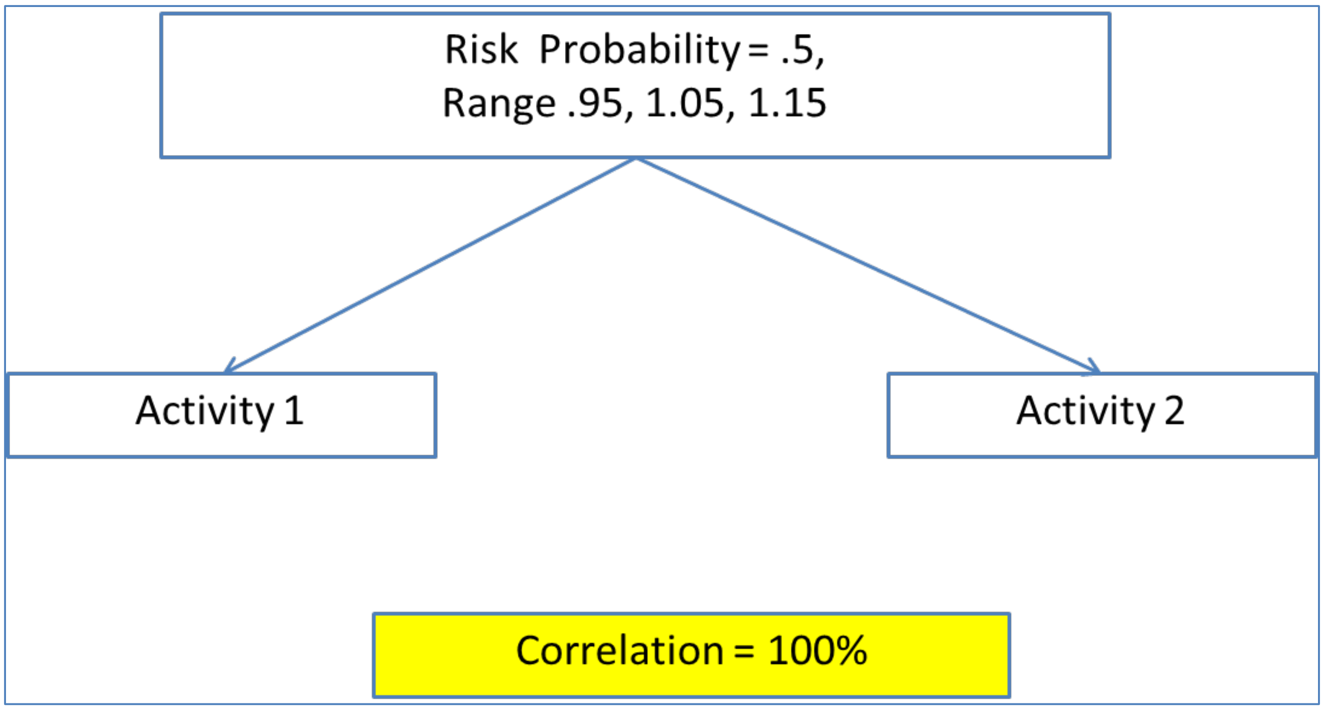
Risk Drivers Model
How Correlation Occurs



Correlation arises when two activities' durations are influenced by the same external, variable and influential force, a risk

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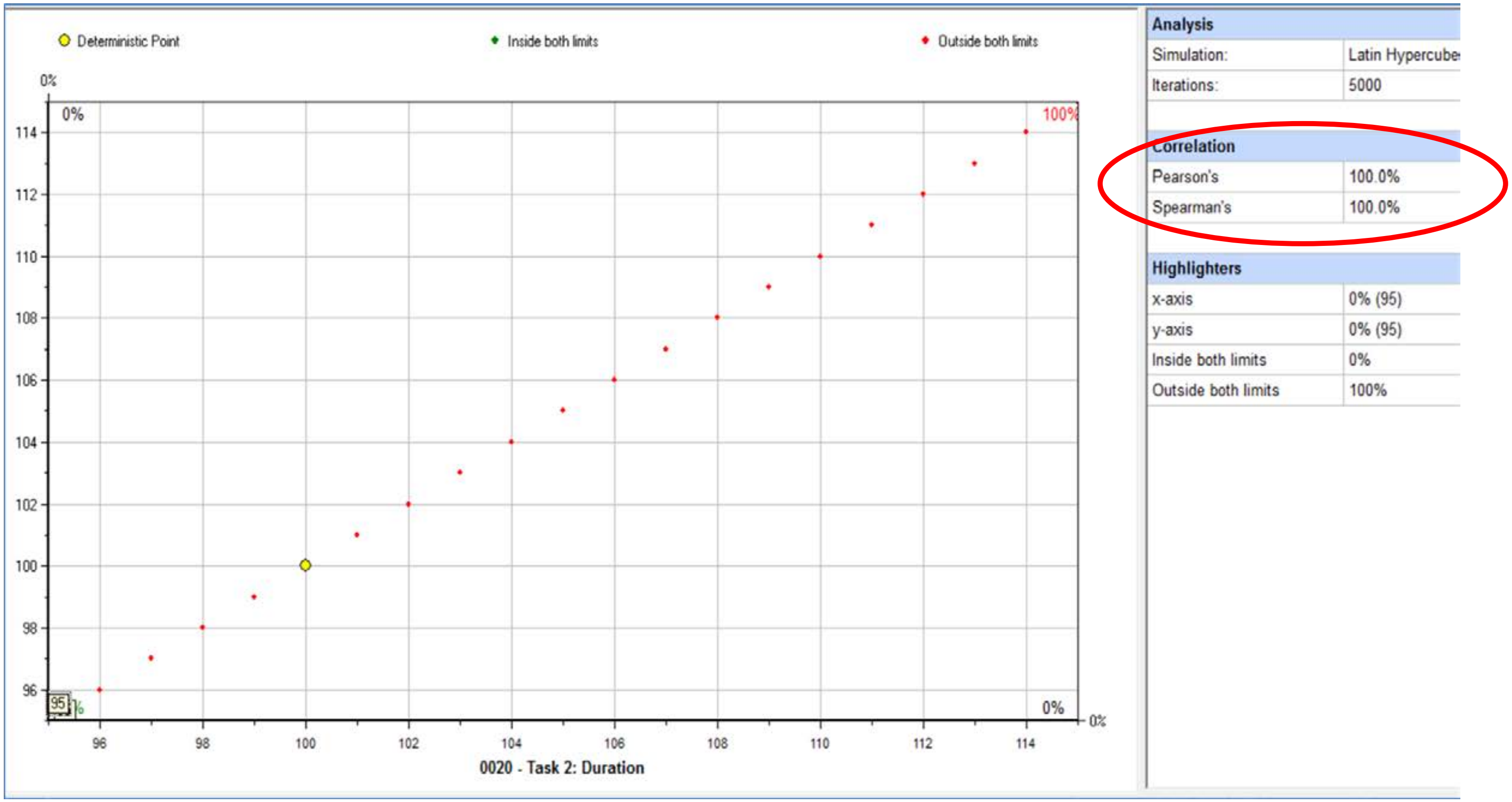
Correlation of 100% Scatterplot



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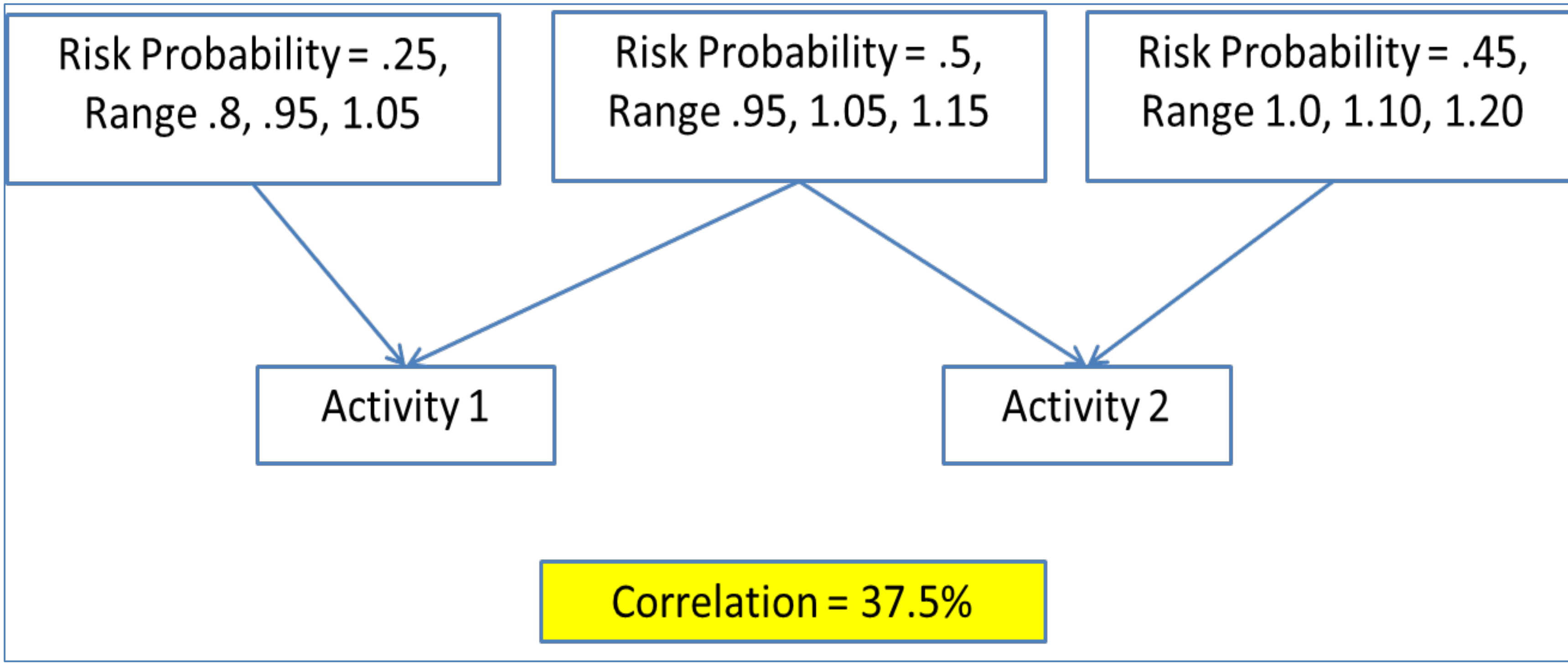
Introduce Two Confounding Risks



Two risks that affect only one but not the other activity duration drives down the correlation substantially

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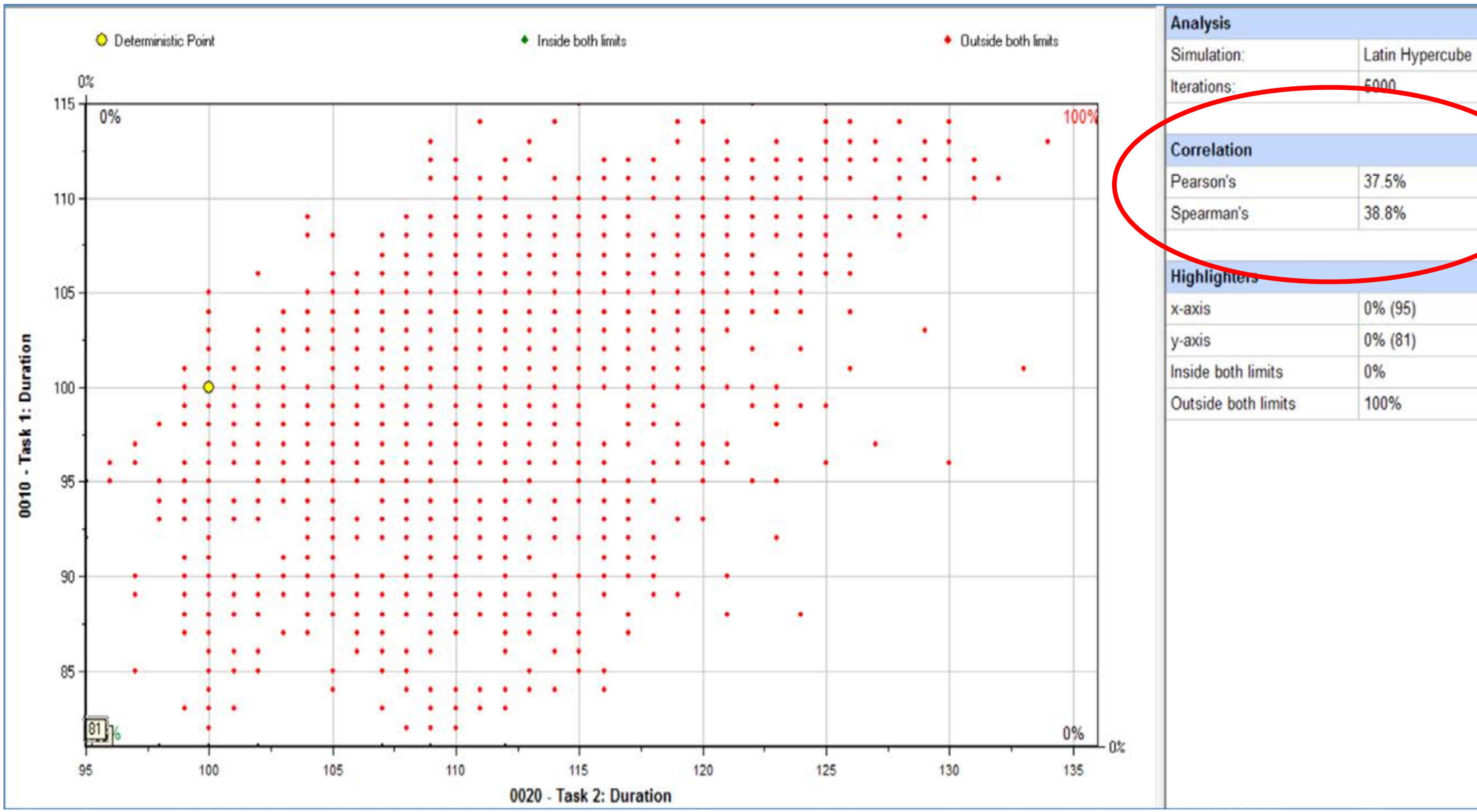
Scatterplot with 2 Confounding Risks



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RISKS MAY BE ENTERED IN SERIES OR IN PARALLEL

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Risks in Series or Parallel

- Some risks, if they happen, will stop progress until the impact is recovered
- Other risks are not that important and their recovery can occur simultaneously with other risks' recovery
- This matters only on the iterations when the two risks both occur
- An activity can be influenced by both series and parallel risks

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Entering Risks in Series or in Parallel

If these two risks cannot be recovered from simultaneously, they are entered *in series*

Risk 1 1.2 factor

Risk 2 1.05 factor

Use (1.2 x 1.05 = 1.26) Factor, multiply the two

If recovery from two risks can be accomplished simultaneously, they are entered *in parallel*

Risk 1 1.2 factor

Risk 2 1.05 factor

Use 1.2 Factor, the largest factor only

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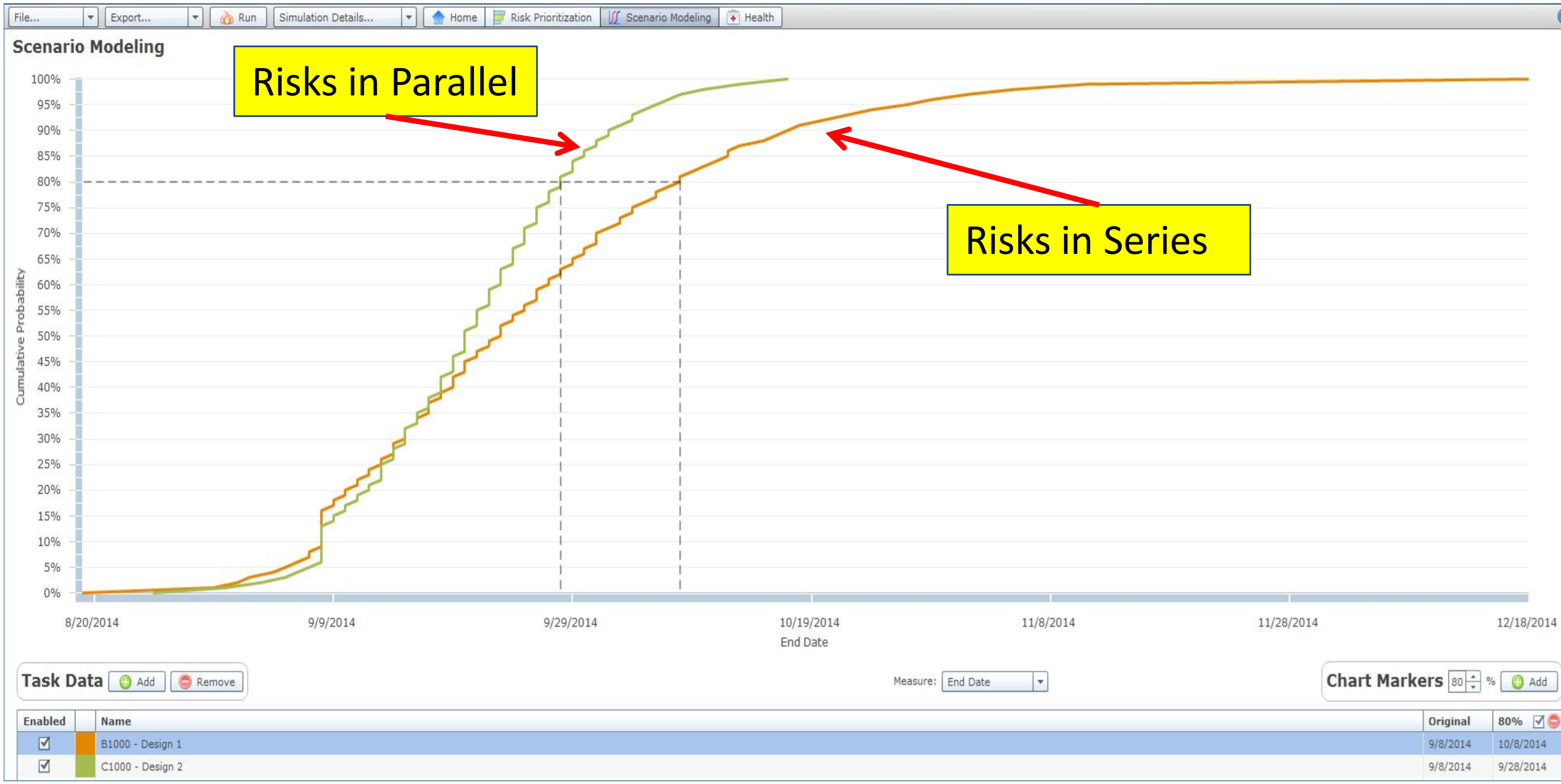
Results with Risks in Parallel or in Series



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OFFSHORE GAS PRODUCTION PLATFORM PROJECT

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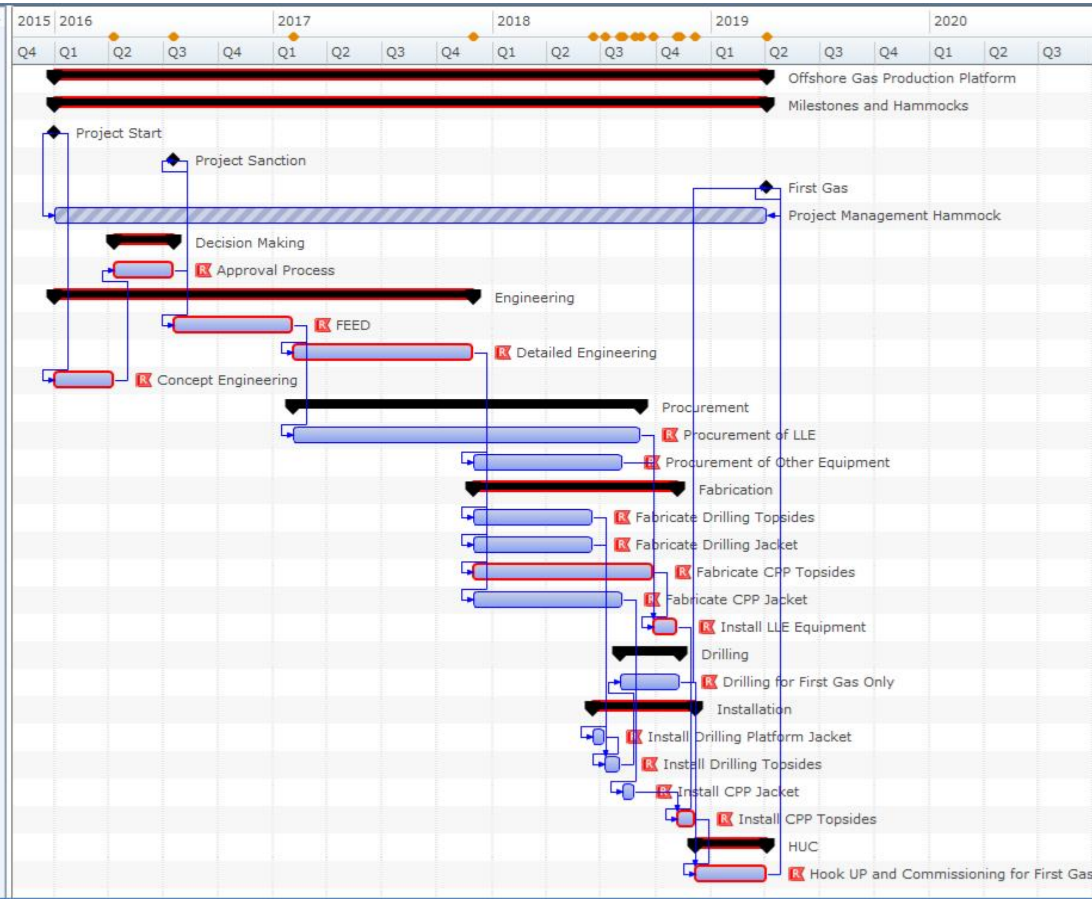
Summary Schedule of a Megaproject

UID	Task	Start Date	End Date	Duration	Cost
Gas Platform	▼ Offshore Gas Production Platfor	01/01/2016	04/04/2019	1,190	$1.717M
Gas Platform	▼ Milestones and Hammocks	01/01/2016	04/04/2019	1,190	$400,000
A1000	Project Start	01/01/2016		0	$0
A1010	Project Sanction		07/18/2016	0	$0
A1020	First Gas		04/04/2019	0	$0
A1030	Project Management Ham	01/01/2016	04/04/2019	1,190	$400,000
Gas Platform	▼ Decision Making	04/10/2016	07/18/2016	100	$8,000
B1000	Approval Process	04/10/2016	07/18/2016	100	$8,000
Gas Platform	▼ Engineering	01/01/2016	11/30/2017	700	$256,000
C950	FEED	07/19/2016	02/03/2017	200	$80,000
C1010	Detailed Engineering	02/04/2017	11/30/2017	300	$160,000
C900	Concept Engineering	01/01/2016	04/09/2016	100	$16,000
Gas Platform	▼ Procurement	02/04/2017	09/06/2018	580	$350,000
D1000	Procurement of LLE	02/04/2017	09/06/2018	580	$250,000
D1010	Procurement of Other Equ	12/01/2017	08/07/2018	250	$100,000
Gas Platform	▼ Fabrication	12/01/2017	11/05/2018	340	$536,000
E1000	Fabricate Drilling Topsides	12/01/2017	06/18/2018	200	$80,000
E1010	Fabricate Drilling Jacket	12/01/2017	06/18/2018	200	$80,000
E1020	Fabricate CPP Topsides	12/01/2017	09/26/2018	300	$240,000
E1030	Fabricate CPP Jacket	12/01/2017	08/07/2018	250	$104,000
E1025	Install LLE Equipment	09/27/2018	11/05/2018	40	$32,000
Gas Platform	▼ Drilling	08/03/2018	11/10/2018	100	$80,000
F1000	Drilling for First Gas Only	08/03/2018	11/10/2018	100	$80,000
Gas Platform	▼ Installation	06/19/2018	12/05/2018	170	$47,200
G1000	Install Drilling Platform Ja	06/19/2018	07/08/2018	20	$8,000
G1010	Install Drilling Topsides	07/09/2018	08/02/2018	25	$13,600
G1020	Install CPP Jacket	08/08/2018	08/27/2018	20	$9,600
G1030	Install CPP Topsides	11/06/2018	12/05/2018	30	$16,000
Gas Platform	▼ HUC	12/06/2018	04/04/2019	120	$40,000
H1000	Hook UP and Commission	12/06/2018	04/04/2019	120	$40,000



Offshore Gas Production Platform Project summarized from real projects
39 months duration, $1.7 billion cost
Developed in Primavera Risk Analysis® Simulated in Booz Allen Hamilton Polaris®

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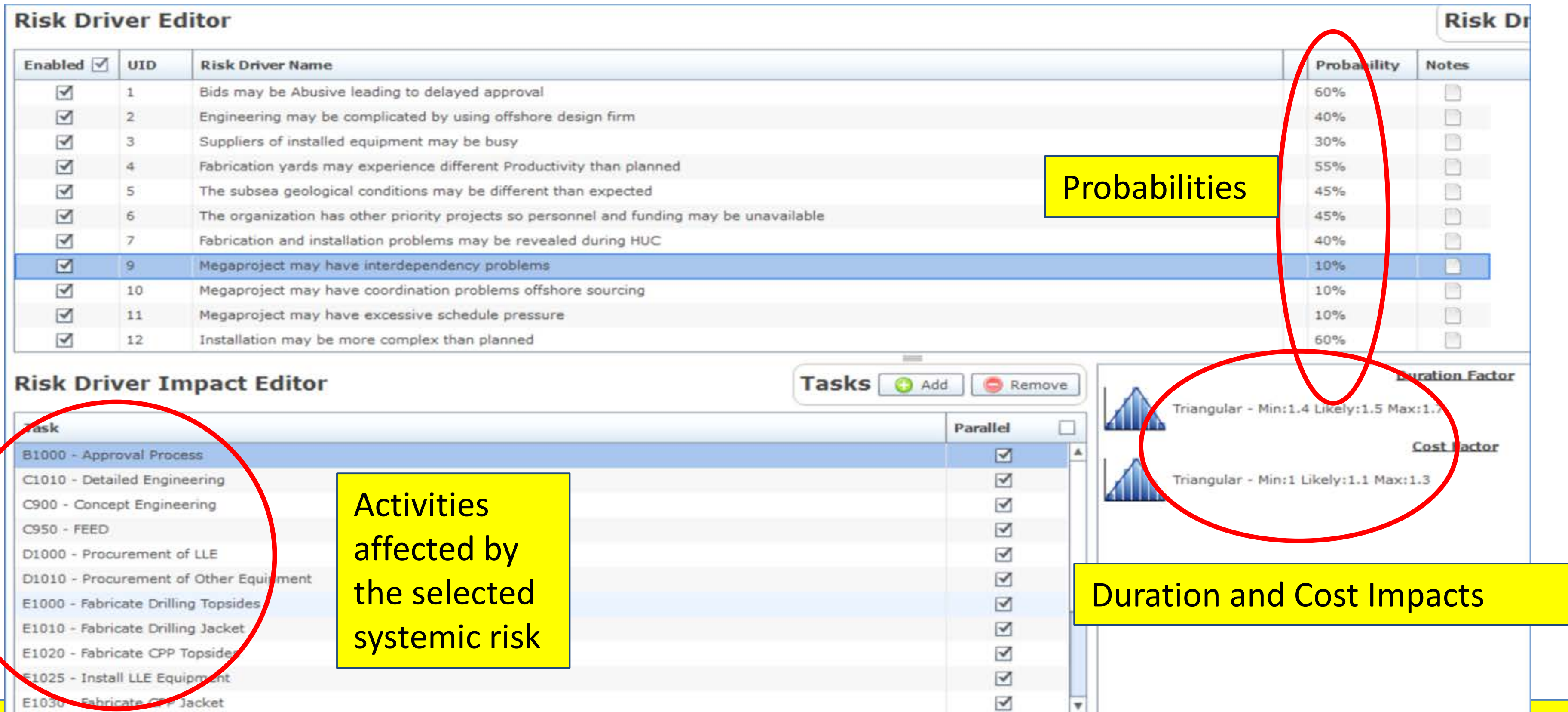
Project-Specific Risks as Risk Drivers



Here are 8 project-specific and 3 systemic risks assigned to activities

Most risks are assigned to several activities defined as a “category” for ease of application. Some activities have several risks assigned

The risks are specified by probability and impact, a distribution of multiplicative factors and are called “Risk Drivers.” If they happen on an iteration a factor is chosen at random and multiplies the duration of all activities to which the risk is assigned

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USE CATEGORIES TO APPLY RISKS TO MULTIPLE ACTIVITIES

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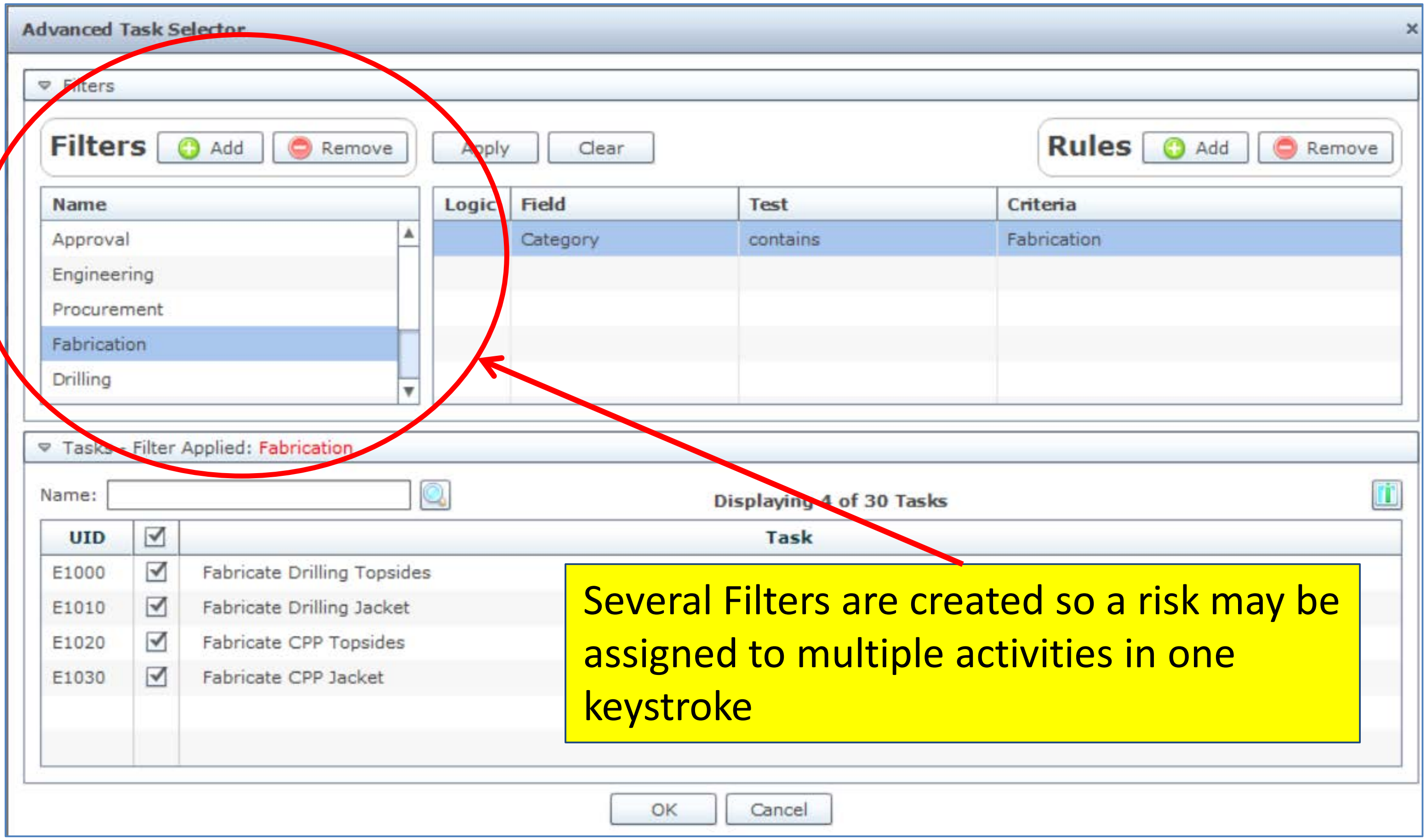
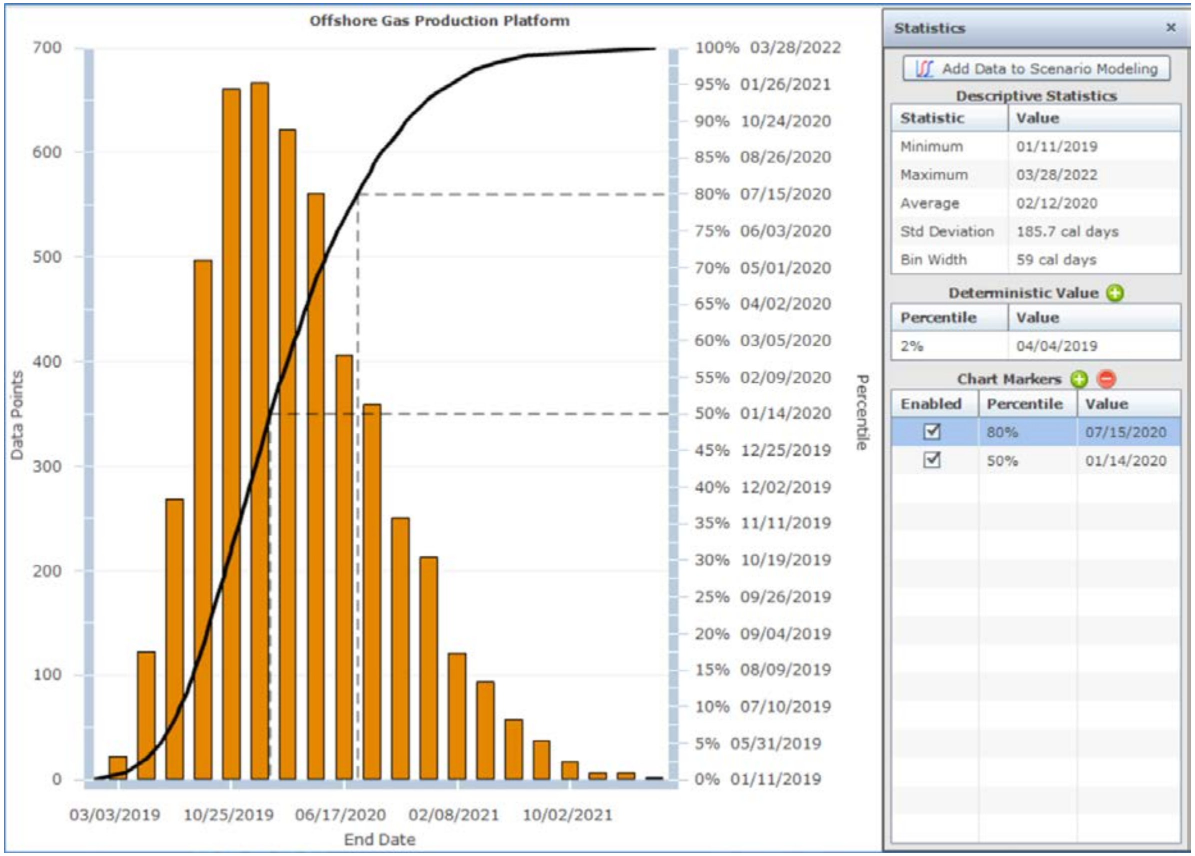
Use Categories to Enable Assigning Risks to Multiple Activities



Add Project Specific Risks



Adding Project-Specific risks brings the P-80 to 7/15/20, 15+ months after the schedule date

The scheduled date is now only 2% likely

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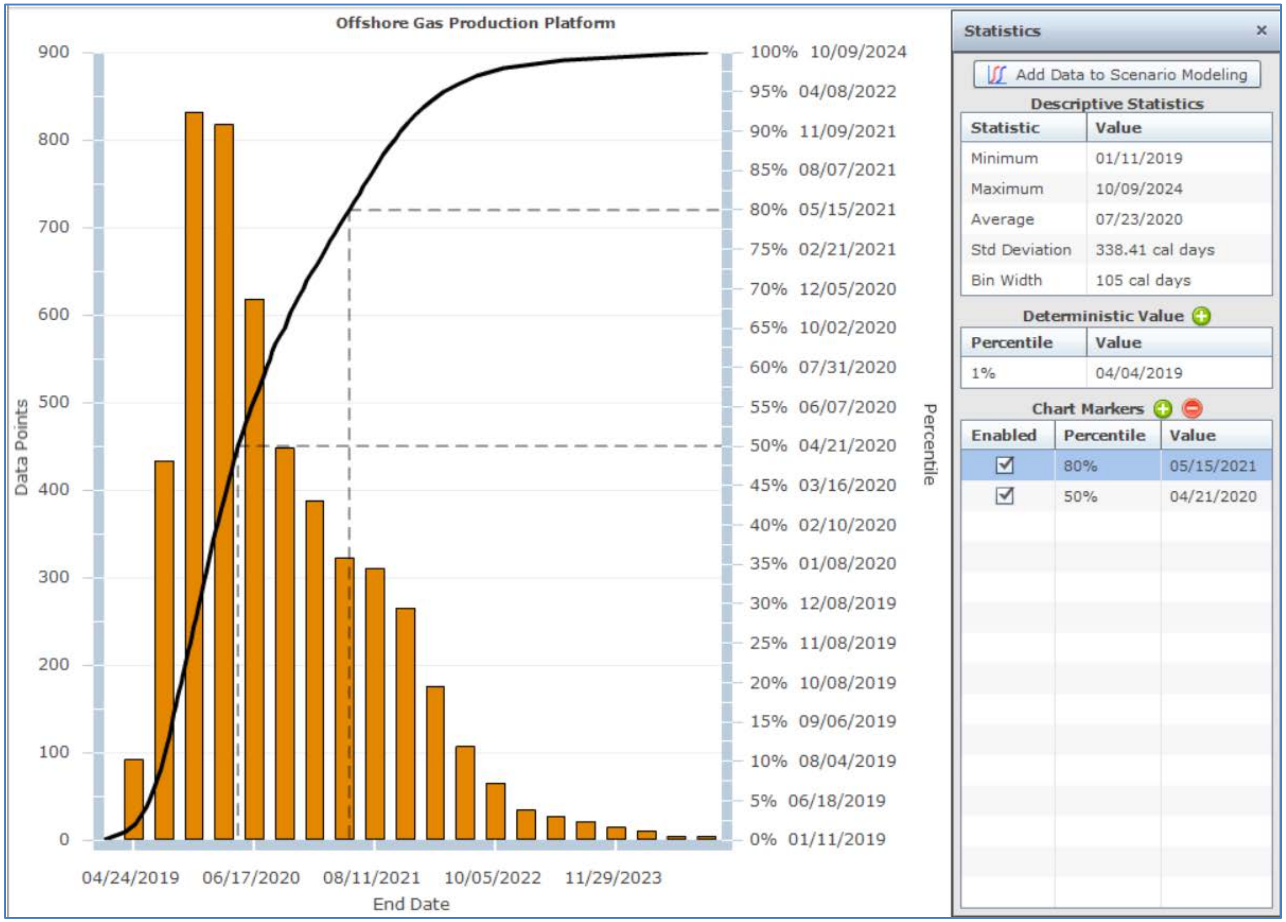
Adding 3 Systemic Risks



Three systemic risks often associated with large, complex projects:

- Interdependency
- Coordination
- Excessive schedule pressure

Adding these make the P-80 = 5/15/21 or about 25 + months late

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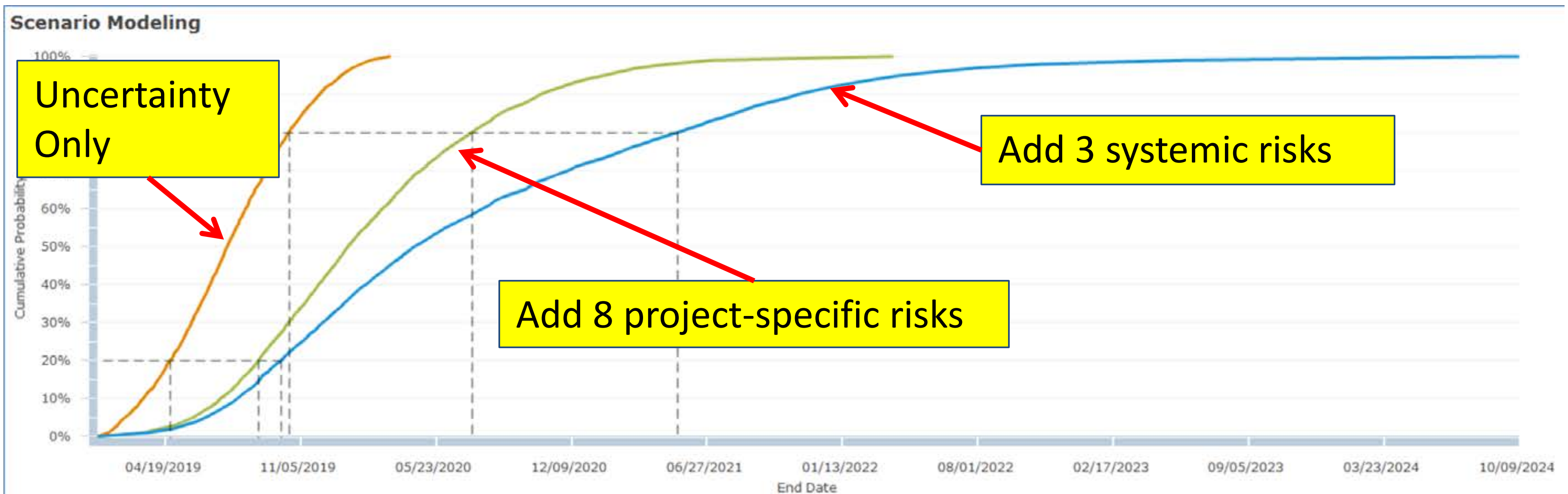
Comparing Results with Uncertainty and Risks



Task Data Add Remove

Measure: End Date

Chart Markers 70 % Add

Enabled		Name	Original	20%	80%
☑		Offshore Gas Production Platform - UNCERTAINTY ONLY	04/04/2019	04/27/2019	10/19/2019
☑		Offshore Gas Production Platform - UNCERTAINTY AND PROJECT-SPECIFIC RISKS	04/04/2019	09/04/2019	07/15/2020
☑		Offshore Gas Production Platform - UNCERTAINTY, PROJECT-SPECIFIC RISKS AND SYSTEMIC RISKS	04/04/2019	10/08/2019	05/15/2021

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PRIORITIZING RISKS FOR MANAGEMENT ACTION

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Typical Risk Prioritization Method

- Typical tornado diagrams have limitations:
  - Report correlation coefficients, but management does not know how to turn these into actionable metrics
  - Correlation centers on the means of the distributions, but management cares about other targets, e.g., P-80
  - Usually report on activities, not risks, whereas management looks to mitigate risks
  - Even when they show correlation of risks with the finish date, the algorithm can show incorrect correlation leading to incorrect conclusions

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Preferred Prioritization Method

Iterative Approach to Prioritizing Risks (Days Saved at P-80)								
Risk #	1	2	3	4	5	6	7	8
Priority Level (Iteration #)	Abusive Bids	Offshore design firm	Suppliers Busy	Fab productivity	Geology unknown	Coordination during Installation	Problems at HUC	Resources may go to other projects
1	X	X	X	X	X	X	X	**1**
2	X	X	X	**2**	X	X	X	
3	X	**3**	X		X	X	X	
4	X		X		X	X	**4**	
5	X		**5**		X	X		
6	X				X	**6**		
7	**7**				X			
8					**8**			

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Iterative prioritization method requires many simulations to order the risks correctly @ P-80 in Days Saved

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Risk Prioritization Results

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Risk Prioritization Table for Risk Mitigation Workshop

Risks Prioritized by their Contribution to P-80 Finish Date		
UID	Name	Days Saved
11	Megaproject may have excessive schedule pressure	133
6	The organization has other priority projects so personnel and funding may be unavailable	129
9	Megaproject may have interdependency problems	117
2	Engineering may be complicated by using offshore design firm	77
10	Megaproject may have coordination problems offshore sourcing	42
4	Fabrication yards may experience different Productivity than planned	31
7	Fabrication and installation problems may be revealed during HUC	17
12	Installation may be more complex than planned	10
1	Bids may be Abusive leading to delayed approval	9
3	Suppliers of installed equipment may be busy	9
5	The subsea geological conditions may be different than expected	0
	Days saved by Completely Mitigating the Risks	574
	Days Contributed to the Schedule Margin by Uncertainty	198
	Total Pre-Mitigated Schedule Contingency	772

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RISK MITIGATION ACTIONS AND RESULTS (SIMPLE EXAMPLE)

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Mitigation Workshop

- Owner and Contractor meet separately with the same prioritized list of risks
- Propose their own risk mitigations with cost of the actions, owners of the actions and improvement in the risk parameters
- Mitigation must be new, not continued practices from before
- Joint Owner / Contractor meeting to agree
- Must commit to the mitigations to get credit

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Risk Mitigation Workshop Forms

			Schedule Impact			Cost Impact			
Risk ID	Risk Description:	Probability	Optimistic Impact Factor	Most Likely Impact Factor	Pessimistic Impact Factor	Optimistic Impact Factor	Most Likely Impact Factor	Pessimistic Impact Factor	Activities Affected
26 b	**Given the quantity of piping in the project, scope may be underestimated**	**30%**	**110%**	**130%**	**170%**	**110%**	**120%**	**130%**	**Name Contains Piping**
	Mitigations Proposed								Cost Estimate, total all mitigations proposed
26b.1									$20 million
26b.2									Responsible person/persons
26b.3									Smith
26b.4									Jones
26b.5									
		Parameters After Mitigation							
26 b	Given the quantity of piping in the project, scope may be underestimated	15%	100%	115%	140%				

Fill out mitigation actions proposed, cost (ROM) for all actions as a group, risk owners, and parameters after mitigation

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Risk Mitigation Simple Example

- Probability reduced by half for each risk
- Duration impact ranges reduced – mostly schedule risk mitigation
- No change for cost impact ranges
- Cost of mitigation actions range from $10 million to $40 million in Cash (resource) paid at front end
- Mitigation costs in this example total $220 million

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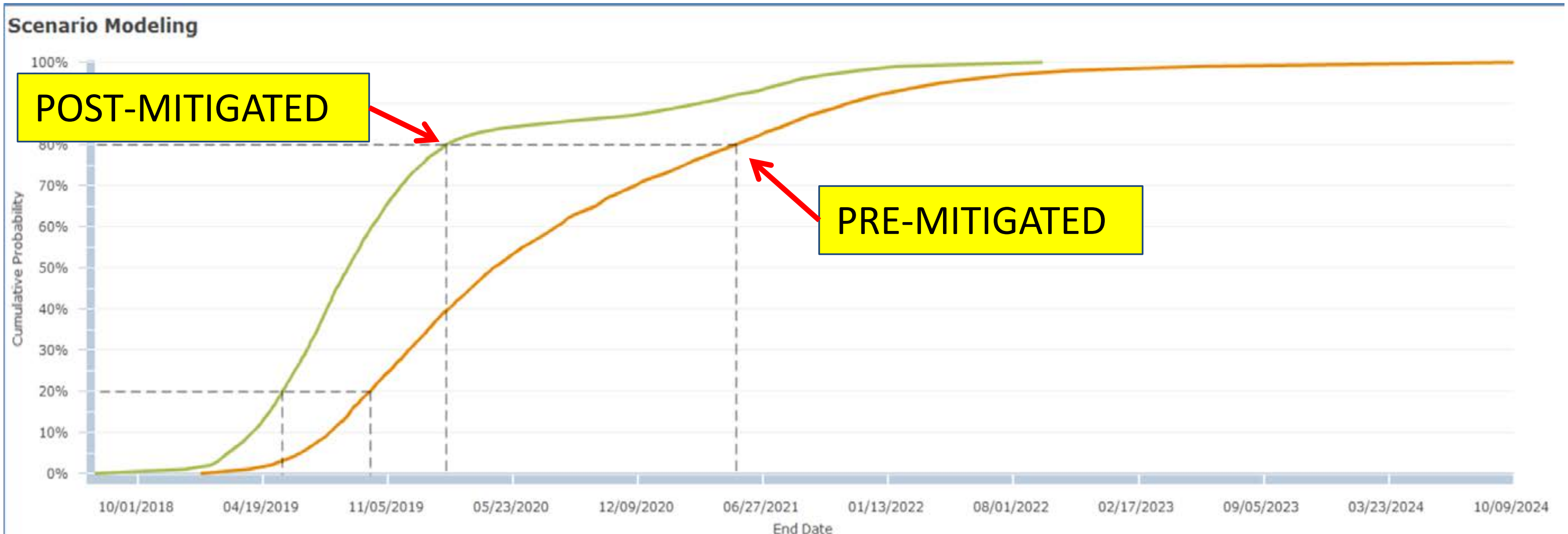
Schedule and Cost Risk Post-Mitigated



Task Data Add Remove Measure: End Date **Chart Markers** 70 % Add

Enabled		Name	Original	20%	80%
☑		Offshore Gas Production Platform -PRE-MITIGATION	04/04/2019	10/08/2019	05/15/2021
☑		Offshore Gas Production Platform - POST-MITIGATION	04/04/2019	05/20/2019	02/06/2020

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PROBABILISTIC BRANCHING FOR TEST FAILURE POSSIBILITY

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Probabilistic Branch with Test Failure

- Projects have many tests. Each of these is done because the system may fail, with consequences
- Seldom does the schedule include recovery activities, but is usually "success oriented"
- There is a probability of failure with consequences of added activities:
  - Root Cause Analysis of the Failure
  - Determining what to do
  - Doing what is planned
  - Retesting

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Failing the Test may lead to Multiple Activities that are Not In the Schedule

- If fail the test all of these activities are needed
- If pass the test none is needed
- These 4 activities constitute a probabilistic branch, since the possibility of doing them is probabilistic
- There is a probability that the instrument or system will not pass the test
  - This probability is often underestimated

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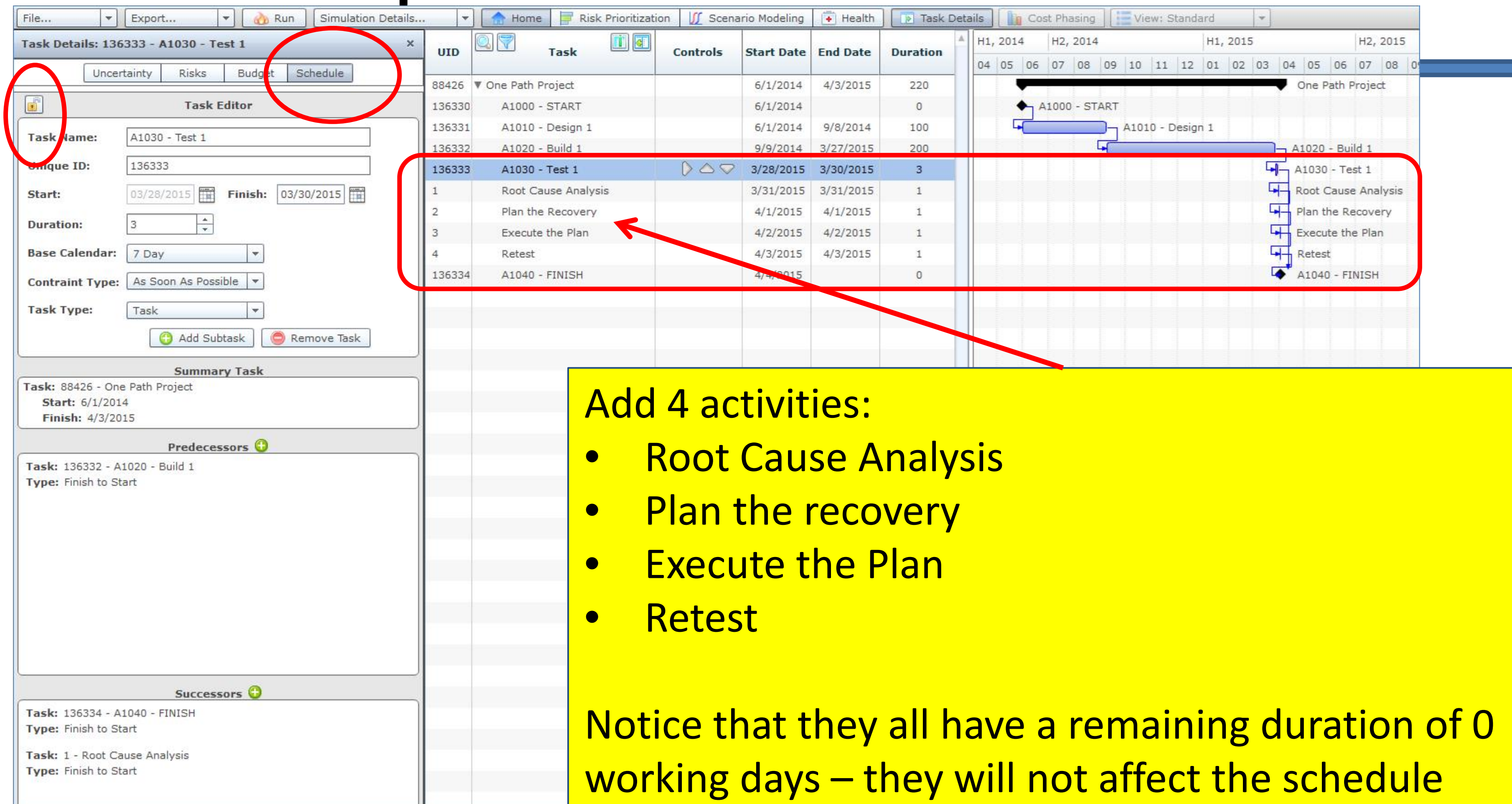
Set up the Probabilistic Branch



Add 4 activities:

- Root Cause Analysis
- Plan the recovery
- Execute the Plan
- Retest

Notice that they all have a remaining duration of 0 working days – they will not affect the schedule unless they occur

Using Booz Allen Hamilton Polaris®

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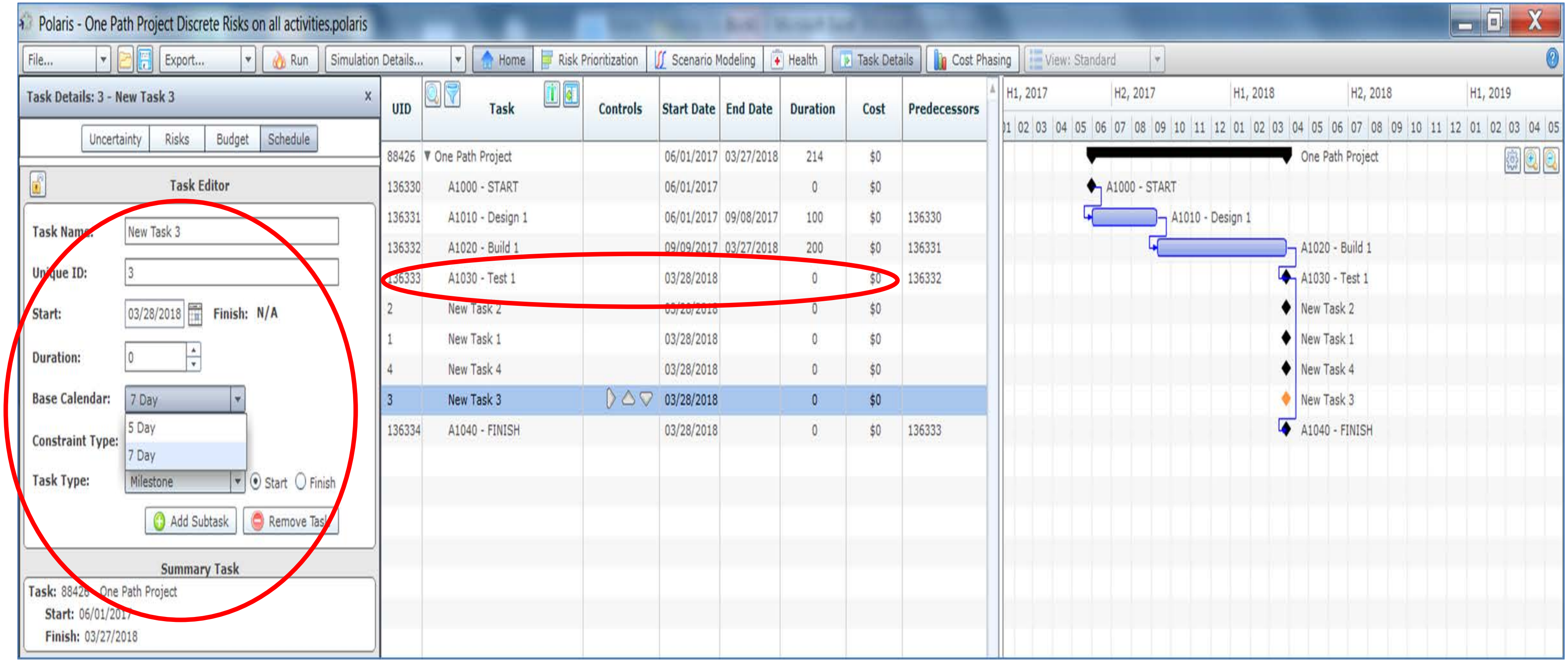
Make the Probabilistic Branch Activities, Fix Calendars and Durations



Activity A1030 Test 1 is the node from which the project either finishes or fails and goes down the branch

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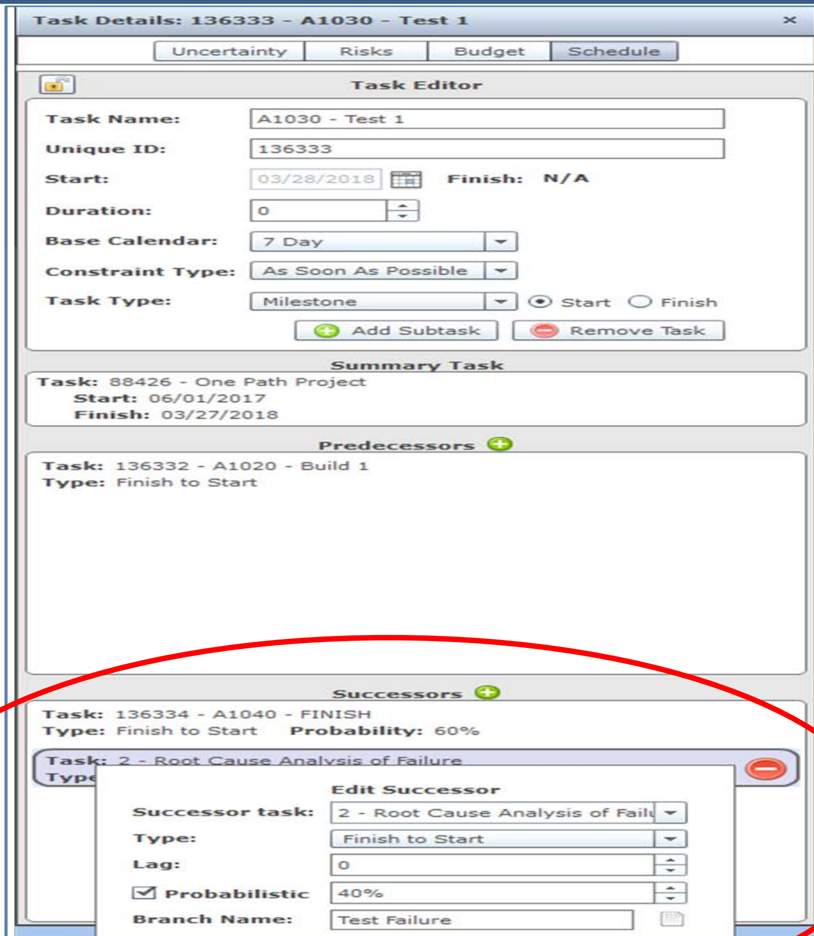
Set the Test Failure Branch as Probabilistic



Make the branch 40% if it is 40% likely to Fail the Test first time

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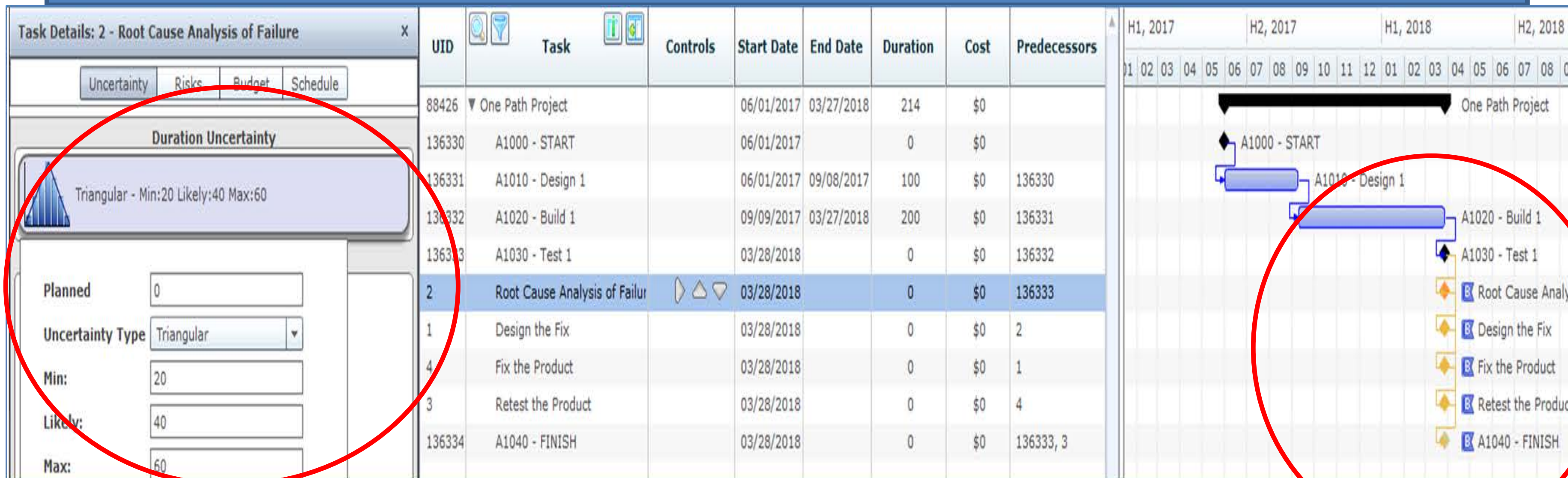
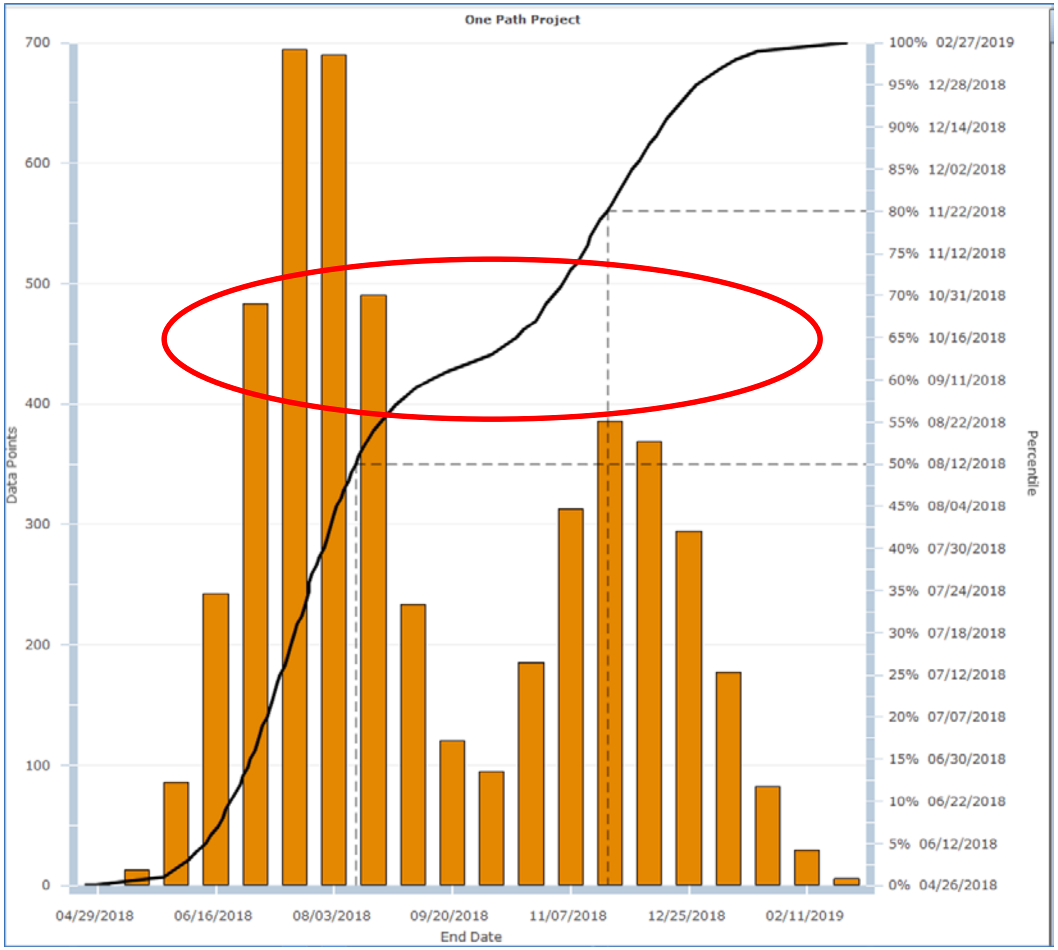
Give the New Activities Ranges of Impact, if they Happen



> Highlight the new activities in turn and give them uncertainties:

- Root Cause Analysis 20d – 40d – 60d
- Design the Fix - 10d – 20d – 40d
- Fix the Product - 10d- 30d- 50d
- Retest the Product - 20d – 30d – 50d

With the Probabilistic Branch in Place, Results may show Bi-modal Distribution



Probabilistic branch develops a shoulder at 60%

There can be more than one probabilistic outcome from a node. The probabilities need to sum to (40% + 60%) 100%.

Probabilistic branch can represent more planning than can be shown with a single probabilistic activity

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Review

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- Collecting risk data
- Introducing uncertainty to the model
- Introducing risks as Risk Drivers
- Risk drivers model correlation between activity durations
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