06-02 - Quantitative Risk Management

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Quantitative Risk Management - Outline

Review of key risk management concepts

Nature of uncertainty

Decision making

Probabilistic scheduling - PERT

Probabilistic scheduling - Monte Carlo

Risk Management - Definitions

- Project risk = ***uncertain*** event that, if it occurs, has a positive or negative ***effect on a project's objectives***
- Project Risk Management (PRM)= planning, identifying, analyzing, responding, and monitoring project risk

Risk Management - PRM Processes

Plan RM	Identify Risks	Perform Qualitative Risk Analysis	Perform Quantitative Risk Analysis	Plan Risk Responses	Monitor and Control Risks
Defines the **scope** and **objectives** and ensures that the **risk process is fully integrated** into wider PM	**Identifies** as many knowable risks as practicable	**Evaluates key characteristics** of individual risks enabling them to be prioritized for further action	**Evaluates the combined effect** of risks on the overall project outcome	**Determines appropriate response strategies and actions** for each individual risk and for overall project risk, and integrates them into a consolidated PM plan	**Implements agreed-upon actions**, reviews changes in project risk exposure, identifies additional RM actions as required, and assesses the effectiveness of the PRM process
• Tailored RM process • Risk thresholds • Process rules • Risk mgmt plan	• List of risks • Risk owners	• Probability • Impact • Root causes • Importance • Prioritized list	• Numerical models • Combined outcomes • Confidence limits • Sensitivity analysis • Prioritized list updates	• Strategies • Actions • Action owners • Timing • Analysis • Project plan updates	• Status and trends • Reporting • Trends in risk exposure

Nature of uncertainty

Project planning rests on **assumptions**

Risk is directly related to PM team knowledge about these assumptions.

The knowledge matrix helps in the classification of uncertainty as related to our identification of uncertainty vs the available knowledge.

Risk knowledge matrix

Project Team awareness \ Risk possible control	Known	Unknown
Known	Risk known and validated	Risk known but not validated
	Risk known, validated statistically	
Unknown	Risk not identified	Risk non identifiable

Risk Management - Statistical randomness

Risk variables are managed by:

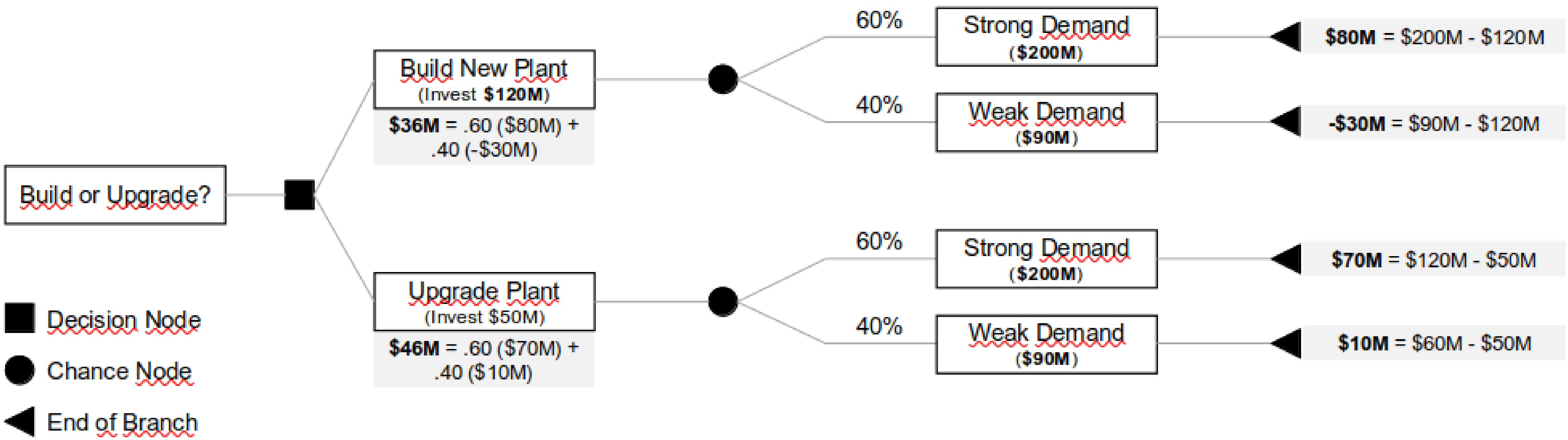
- discrete probabilities / frequencies in decision making
- three-point distribution in statistical planning methods

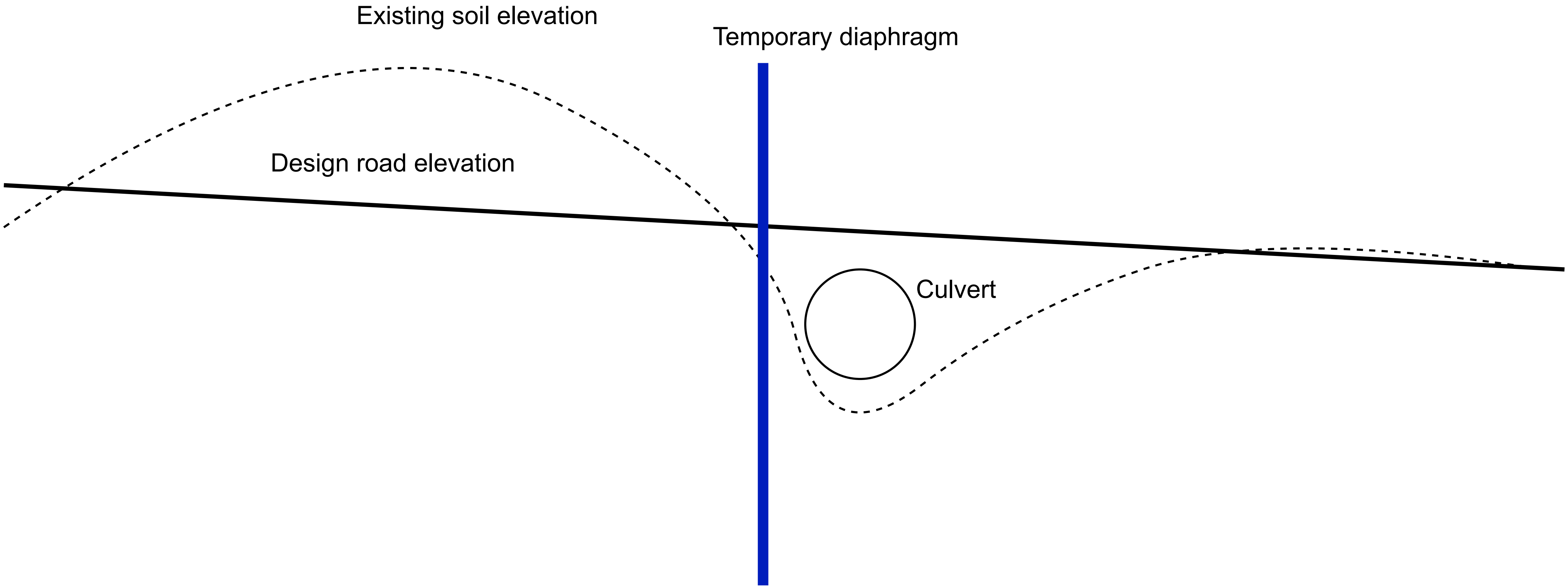
Decision making - Decision trees

We construct a tree chart detailing:

- decision nodes, where we branch different choices highlighting costs
- chance node, where we measure outcomes with different probability
- termination nodes, where we calculate probability weighted outcomes

Decision Definition	Decision Node	Chance Node	Net Path Value
Decision to be Made	**Input**: Cost of Each Decision **Output**: Decision Made	**Input**: Scenario Probability, Reward if it Occurs **Output**: Expected Monetary Value (EMV)	**Computed**: Payoffs minus Costs along Path

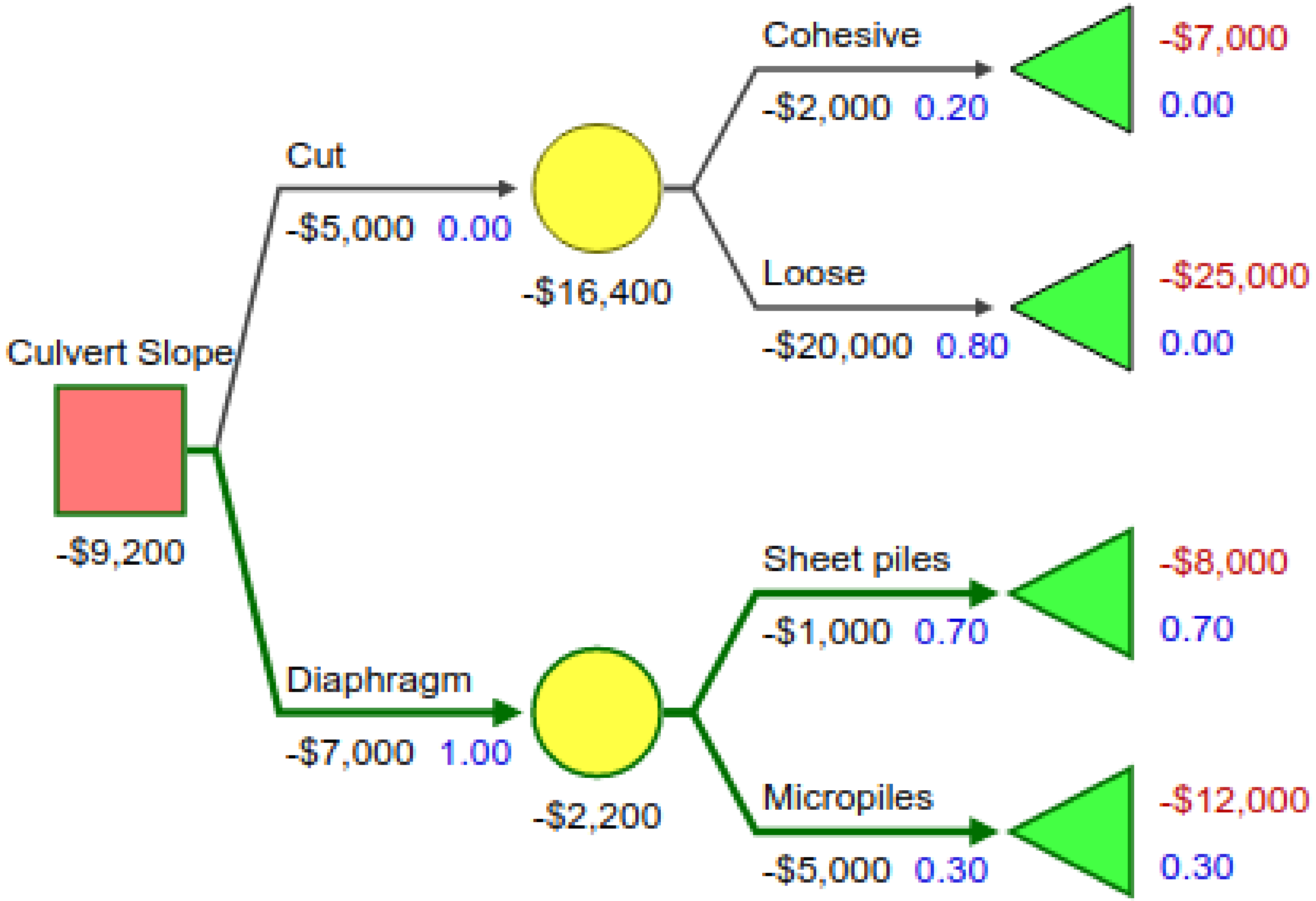



Existing soil elevation
Temporary diaphragm
Design road elevation
Culvert

Decision on temporary culvert excavation support

- Cost of cutting slope to safe angle = 5,000$
- Cost of diaphragm = 7,000$
- Assume that each day in duration cost 1,000$
- Cut in cohesive soil = 2days = 2,000$ with p=20%
- Cut in loose soil = 20days = 20,000$ with p=80%
- Diaphragm by sheet piles = 1day = 1,000$ with p=70%
- Diaphragm by micro piles = 3days = 3,000$ plus 2,000$ materials with p=30%

We must decide whether to execute a temporary diaphragm or to cut the slope to a safe angle.


Cohesive
-$2,000 0.20
-$7,000
0.00
Cut
-$5,000 0.00
-$16,400
Loose
-$20,000 0.80
-$25,000
0.00
Culvert Slope
-$9,200
Sheet piles
-$1,000 0.70
-$8,000
0.70
Diaphragm
-$7,000 1.00
-$2,200
Micropiles
-$5,000 0.30
-$12,000
0.30

Risk Management - PERT Probabilistic scheduling

Duration is assumed known by a three point distribution

- pessimistic a
- most likely m
- ottimistic b

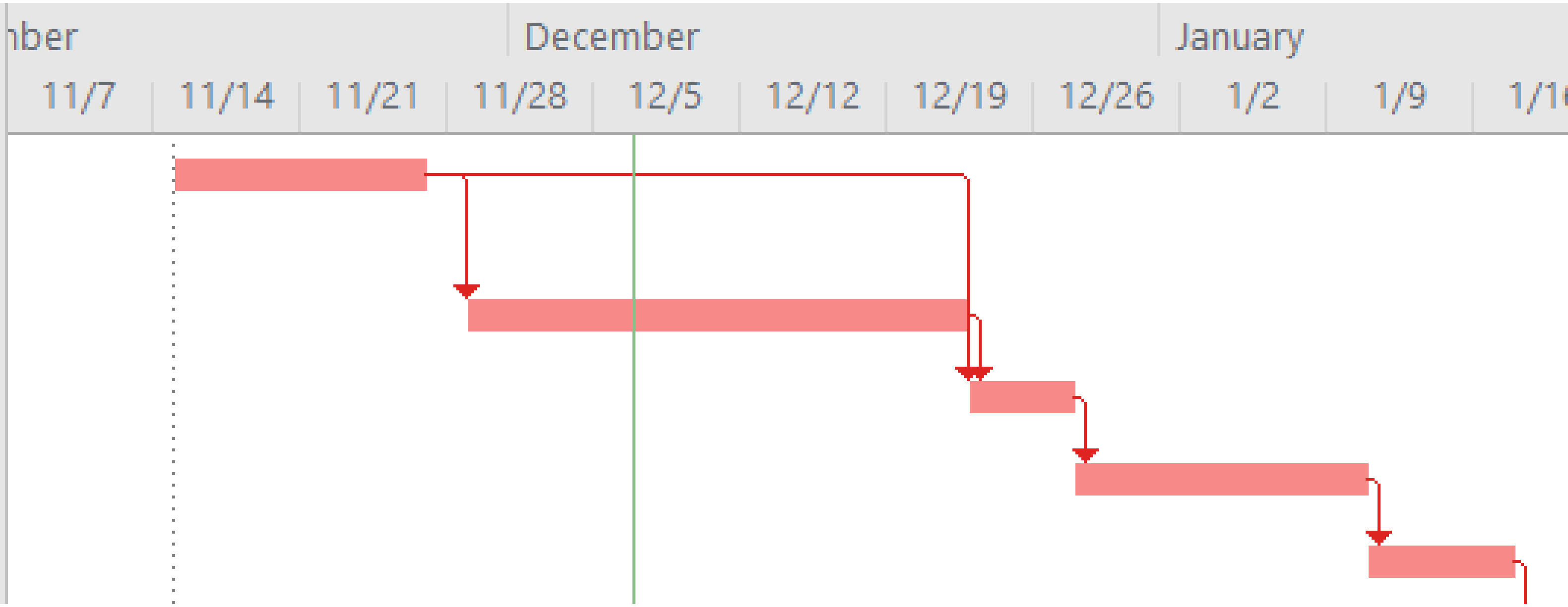
We deduce from β distribution:

- expected duration: $d = (a + 4m + b)/6$
- standard deviation: $S = (b - a)/6$
- variance: $V = S^2$

For each activity k in the path

1. Obtain a_k, m_k, b_k
2. Compute expected activity duration $d_k = (a_k + 4m_k + b_k)/6$
3. Compute activity variance $v_k = (\frac{b-a}{6})^2$
4. Compute expected path duration $D_e = f(d_k)$ using standard CPM algorithm
5. Compute path variance $V = \sum v_k$ as sum of critical path activity variance
6. Calculate the probability of path duration D as $P(Z = \frac{D-D_e}{\sqrt{V}})$, where P is obtained by a Normal distribution function

Task Name	Duration
Temp. Diaphgram- Contruct	10 days
Culvert - Excavation	18 days
Culvert - Liner install	3 days
Culvert - Selected b/fill	10 days
Temp. Diaphgram- Remove	5 days



	A	B	C	D	E	F	G	H	I
1	Task Name	Duration	a	ml	b	d_e	v		
2	Temp. Diaphgram- Contruct	10 days	8	10	15	10.500	1.361111		
3	Culvert - Excavation	18 days	17	18	25	19.000	1.777778		
4	Culvert - Liner install	3 days	3	3	10	4.167	1.361111		
5	Culvert - Selected b/fill	10 days	8	10	25	12.167	8.027778		
6	Temp. Diaphgram- Remove	5 days	1	5	7	4.667	1		
7						De	V		
8	Deterministic Duration D			46		50.5	13.52778		
9									
10	Prob of ending before or in D	z	-1.22349	P_D	0.110573	**11%**	*using NORM.DIST(C10,0,1,TRUE)*		

Risk Management - Monte Carlo numerical simulatiom

Replaces analytic solution with raw computing power - **specific software required!**

- Avoids need to simplify to get analytic solution
- No need to assume functional form of activity/project distributions

Allows determining the criticality index of an activity - Proportion of runs in which the activity was in the critical path

Hundreds to thousands of simulations needed

Set the duration distribution for each activity

- No functional form of distribution assumed
- Could be joint distribution for multiple activities

Iterate: for each “trial” (“realization”)

Sample random duration from each distributions

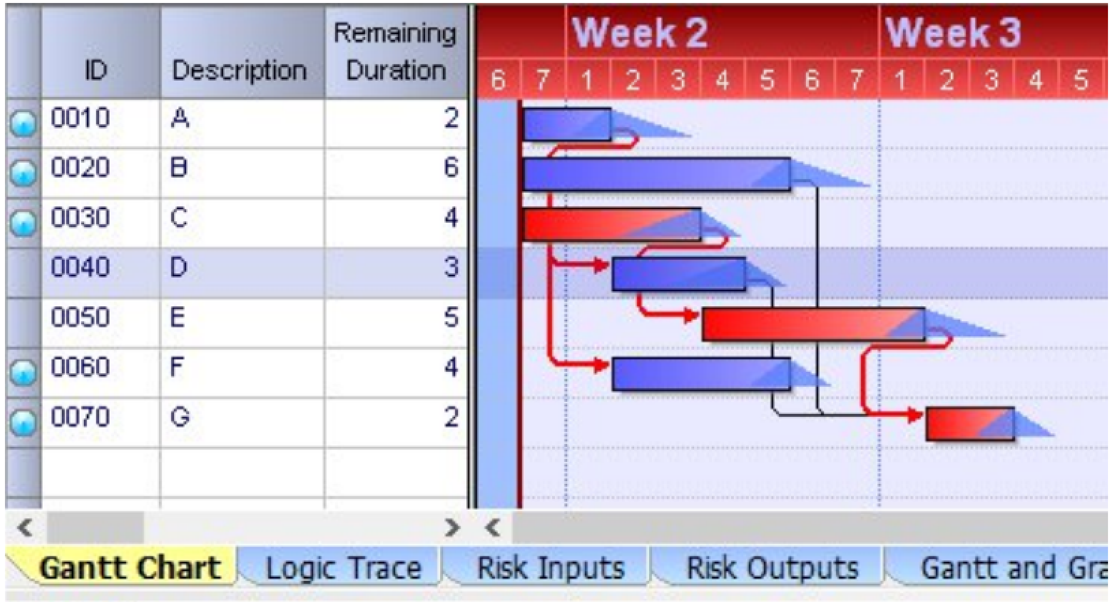
Find critical path and durations with standard CPM

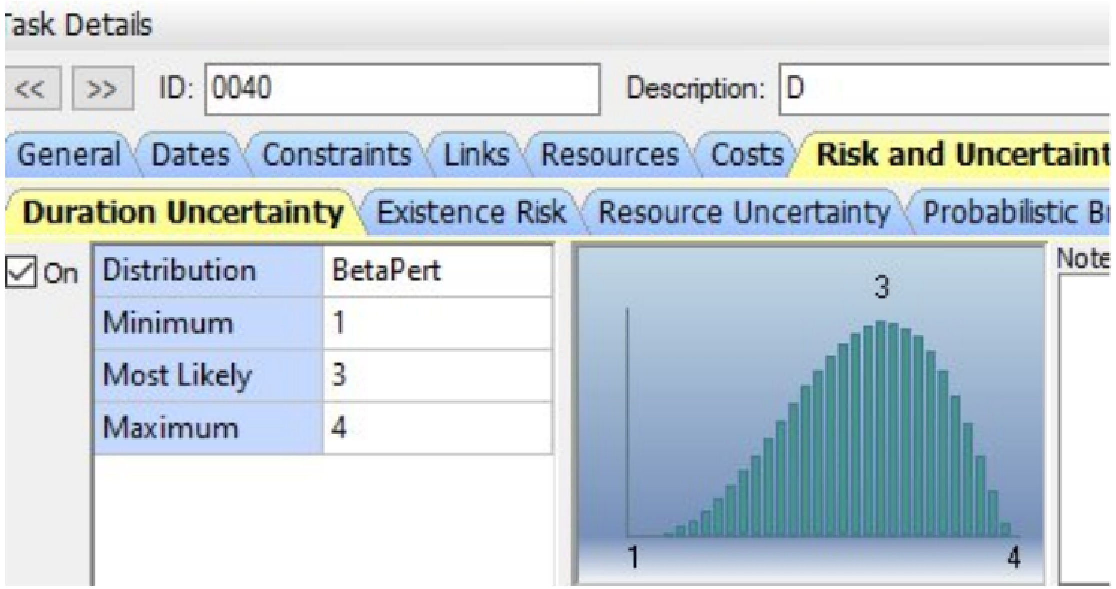
Record these results

Report recorded results

- Duration distribution
- Per-node criticality index (% runs where critical)

Simulation using Primavera Risk Analysis





Probability

$$\mathbb{P}\left[X \leq \tau\right] = \frac{\text{Number of times project finished in less than or equal to } t \text{ weeks}}{\text{Total number of replications}}$$

The probability that the project ends in 11 days or less is

$$\mathbb{P}\left[X \leq 11\right] = \frac{3267}{5000} = 65\%$$

Duration	Hits	Cumulative Hits
7	10	10
8	92	102
9	451	553
10	1181	1734
11	1533	3267
12	1133	4400
13	476	4876
14	116	4992
15	8	5000

Quantitative Risk Management - Reading

A. De Marco, Project Management for Facility Constructions, Second Edi. Springer International Publishing, 2018:

Part V – Uncertainty