Beyond A Tunnel Vision 2018

Application of an Integrated Cost and Schedule Analysis for Complex Tunneling Projects

Brussels, November 27th, 2018

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1. Introduction
2. Standard vs Integrated Approach
3. Integrated Cost and Schedule Model
4. Projects and the European Perspective

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RIAAT
Risk Administration and Analysis Tool

RiskConsult GmbH

Olympiastr. 39, 6020 Innsbruck, Austria
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Megaprojects follow different rules, thus tailored processes and tools are required.

- Cost and Risk Management
- Team Alignment
- RAMS Analysis
- Software Development
- Training

Experience with major infrastructure projects in Europe, North and South America.

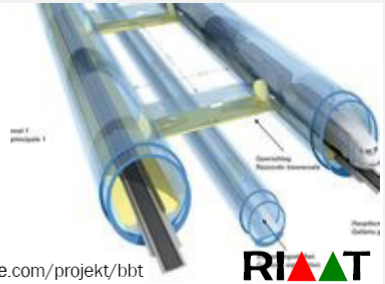
Selected Projects

Brenner Base Tunnel

The Brenner Base Tunnel is the main element of the new Brenner railway from Munich to Verona. At 64 km, it is the longest underground railway connection in the world, a pioneering work of engineering and it will markedly improve passenger travel and freight transport through the heart of Europe.

Services: Support and validation probabilistic risk assessment

Project costs: approx. $ 12 Billion



Source: http://www.bbt-se.com/projekt/bbt

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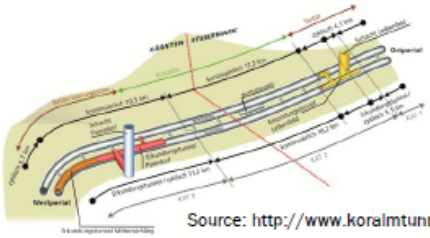
Koralm Base Tunnel



Source: http://www.koralmtunnel.eu

With a total length of 32.8 km and a maximum cover of 1,250 m the base tunnel will traverse the Koralpe mountain range and will connect the Austrian states of Styria and Carinthia.

Services: Probabilistic risk assessment, Moderation of the process during planning and construction stage

Project Cost: approx. $ 2.1 Billion

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Subway New York: Canarsie Tunnel

New York City Transit

Flooding caused by Superstorm Sandy inundated the Canarsie Tunnel with seven million gallons of salt water. The rehabilitation includes upgrading of the Canarsie Tunnel facilities from 1st Avenue Station in Manhattan to Bedford Avenue Station in Brooklyn and three substations.

Service: Risk assessment, identifying and quantifying risks for project cost and schedule, quantify potential reduction in risk through mitigation.

Source: New York Times

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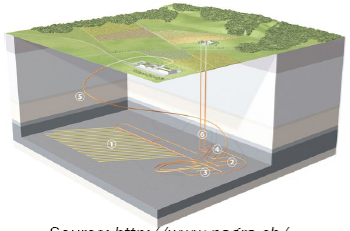
NAGRA - Swiss National Cooperative for the Disposal of Radioactive Waste



Source: http://www.nagra.ch/

Safe long-term disposal of radioactive waste in deep geological repositories is a challenging task that NAGRA has committed to implementing in the interests of man and the environment.

Services: Probabilistic cost estimation and risk analysis, software development, process development, staff training

nagra.

RIAAT

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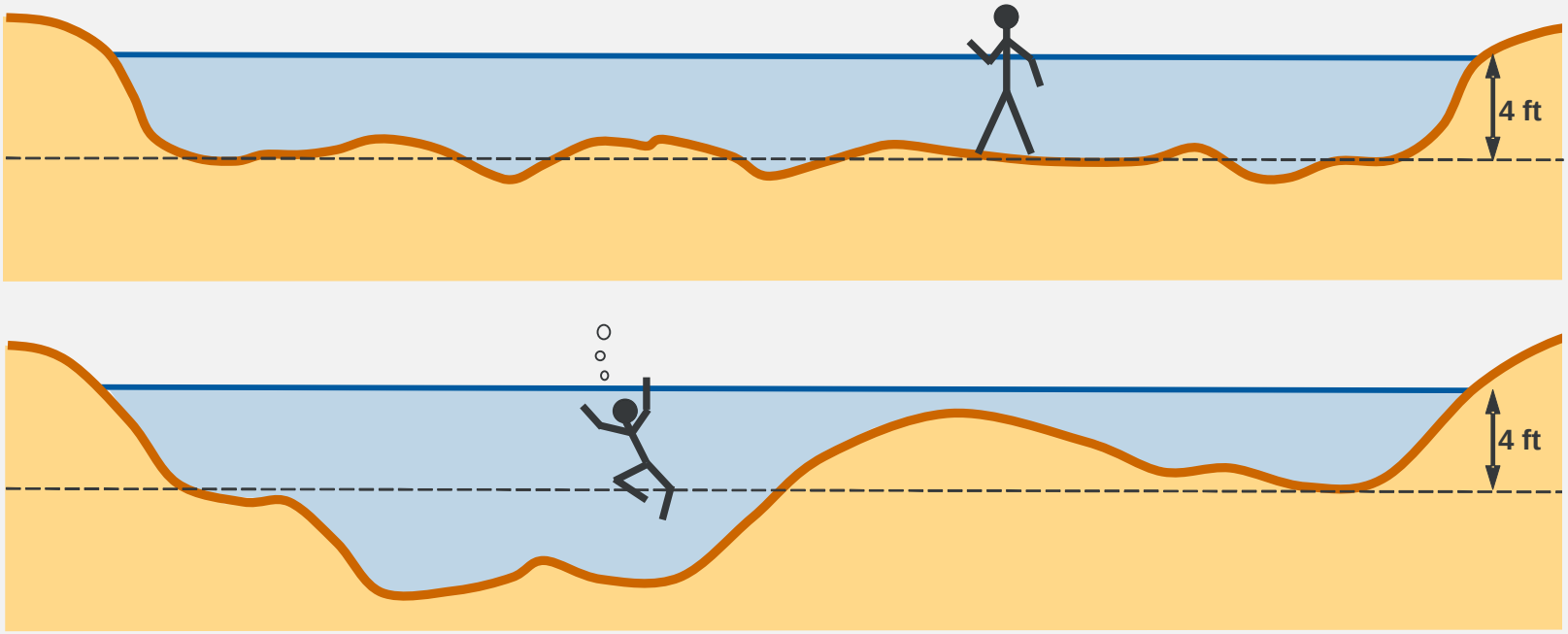
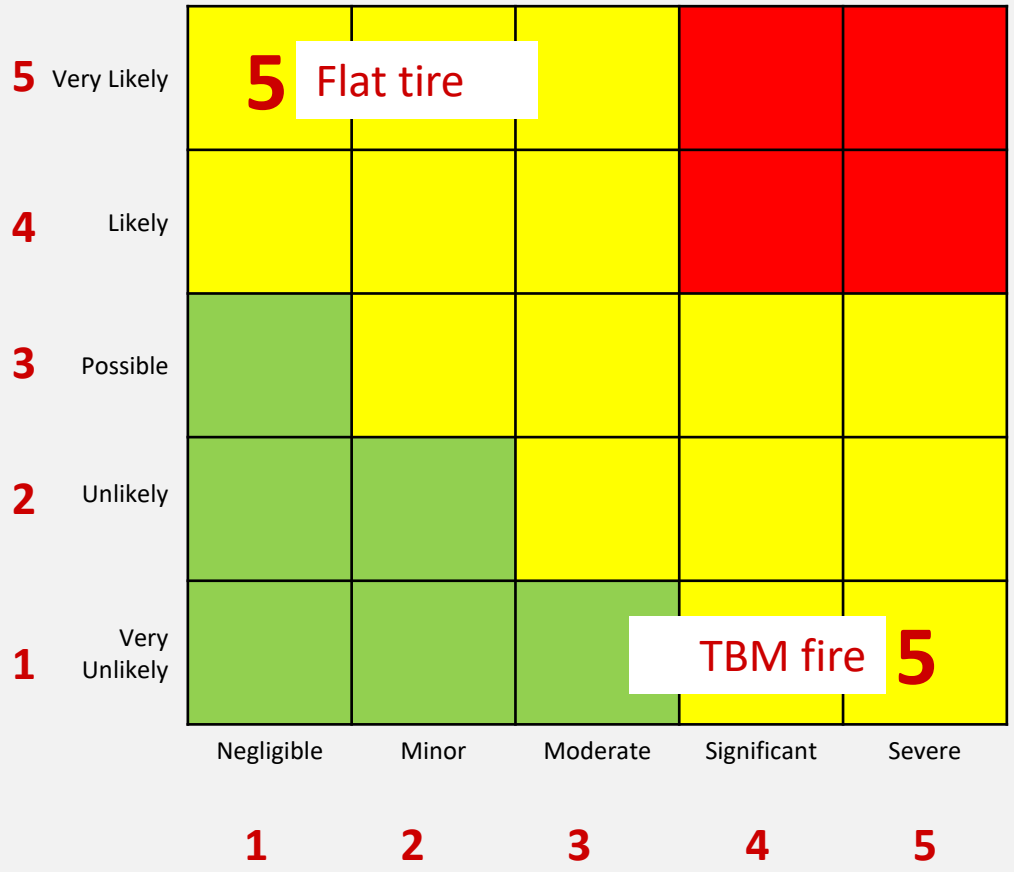
„Would you wade through a river 4 feet deep on average?"



Information about uncertainty is necessary!

Nassim Nicholas Taleb: The Black Swan

Fallacy of the Deterministic Approach

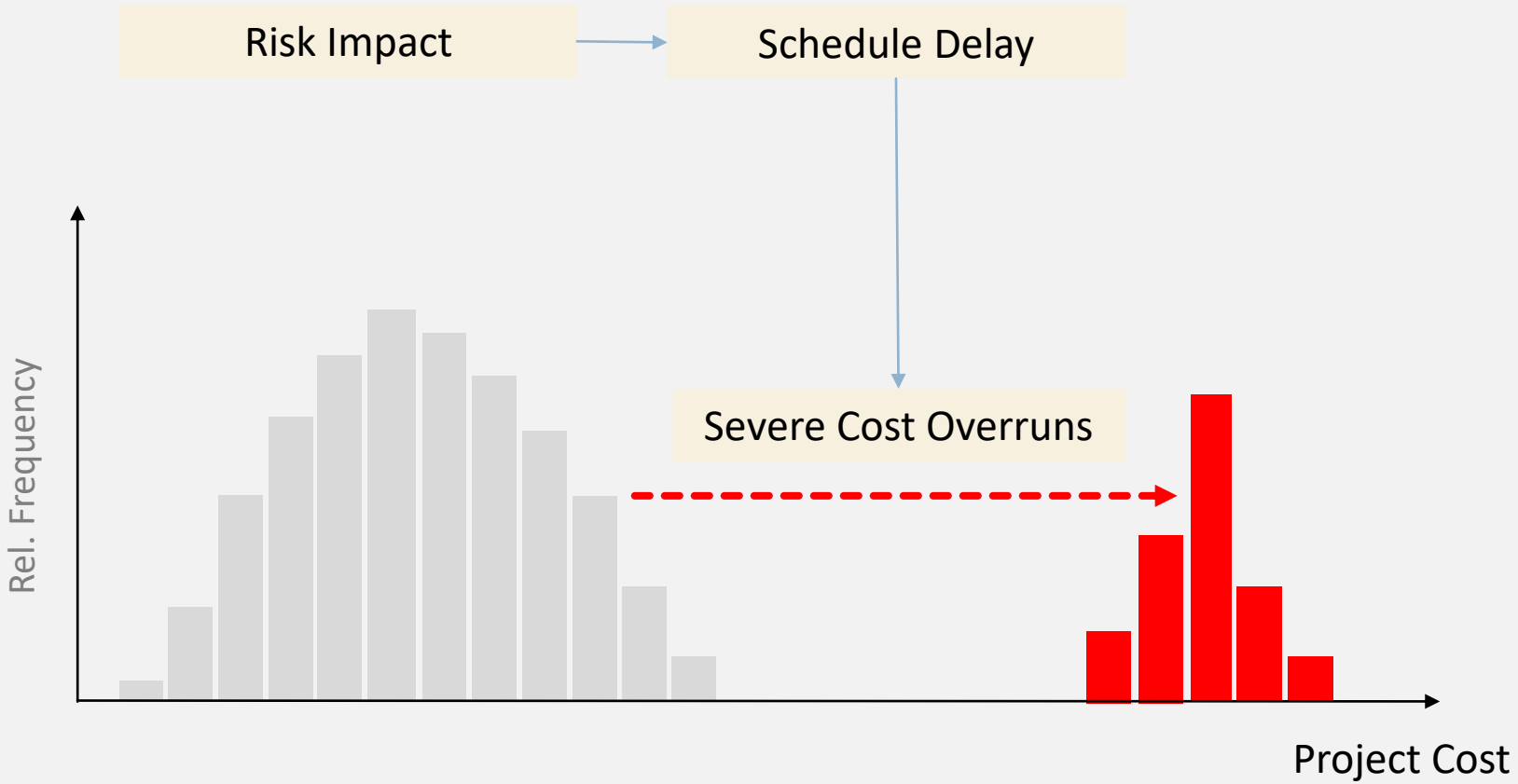


- Give equal weight to completely different scenarios.
- By multiplying the two elements of probability and impact, these values are no longer independent.
  - Loosing the probability information
  - Loosing the scenario impact information
- The actual impact will definitely deviate from the deterministic value (i.e., the mean) → see following example.

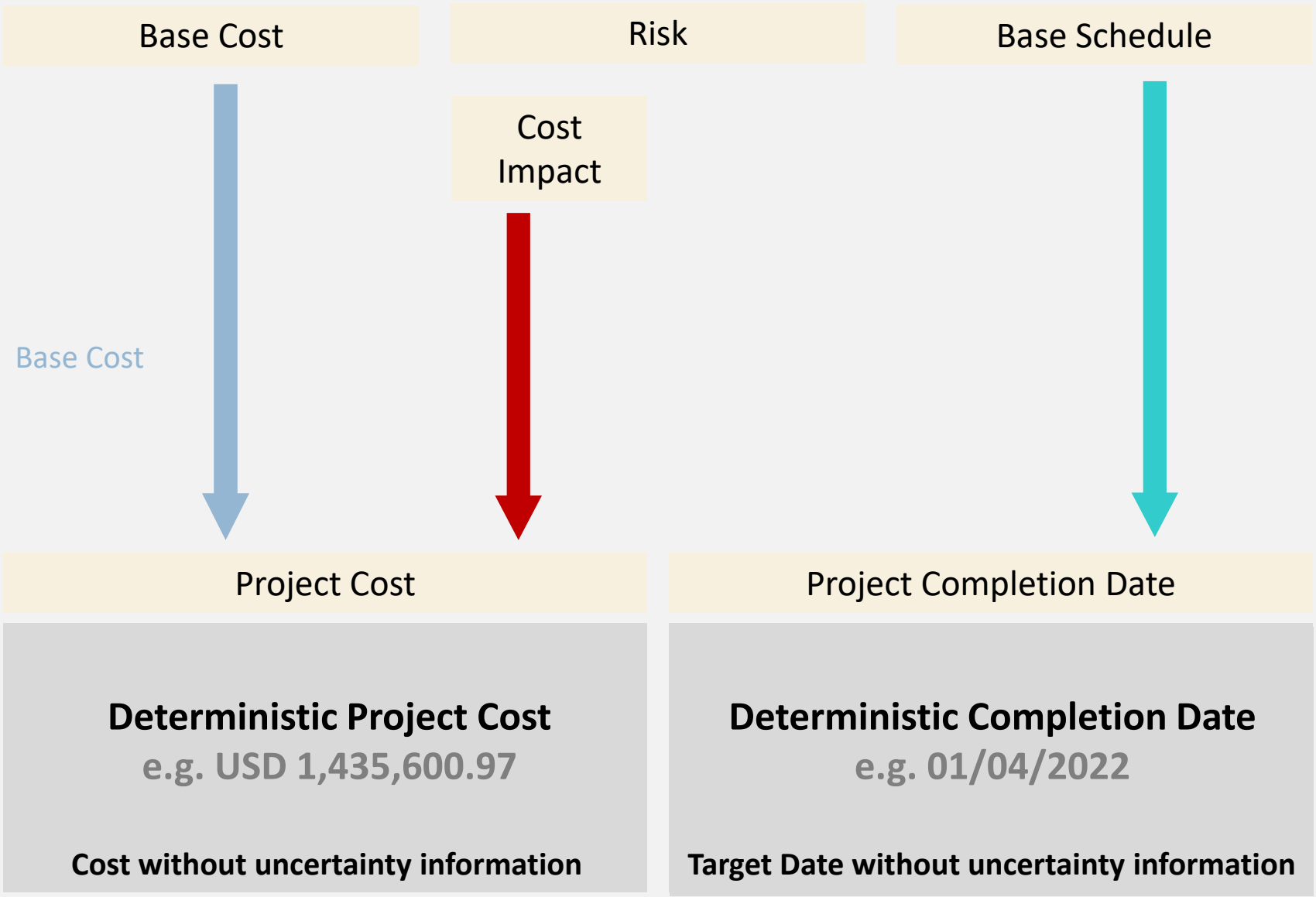
Example deterministic calculation:

Tire damage mine dumper:	80% x 10,000 $ = 8,000 $
TBM fire:	(1/500) x 4,000,000 $ = 8,000 $
NPP accident:	(1/10,000,000) x 80,000,000,000 $ = 8,000 $

Impact of Delays on Project Cost



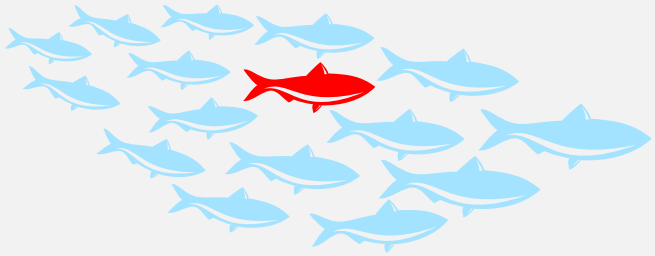
Standard Approach



Large-Scale Projects Follow Different Rules

→ Complex entities cannot be understood by breaking them down into independent parts.

Even at the simplest level, studying a fish cannot explain how a school of fish works.



complexity

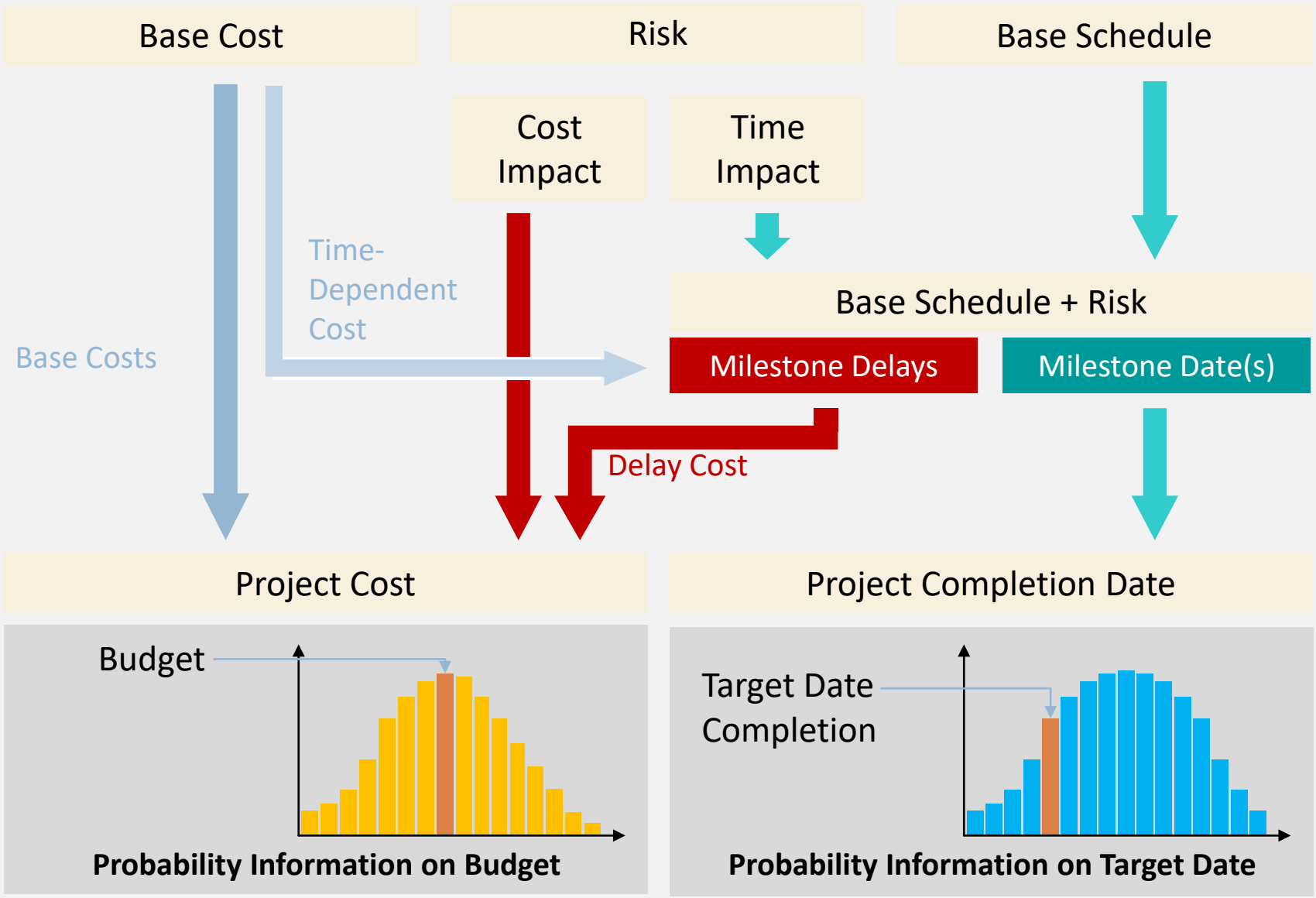
dynamics

Statement

→ **Integrate cost and schedule.**

→ Consider **uncertainties.**

Integrated Cost & Schedule Model



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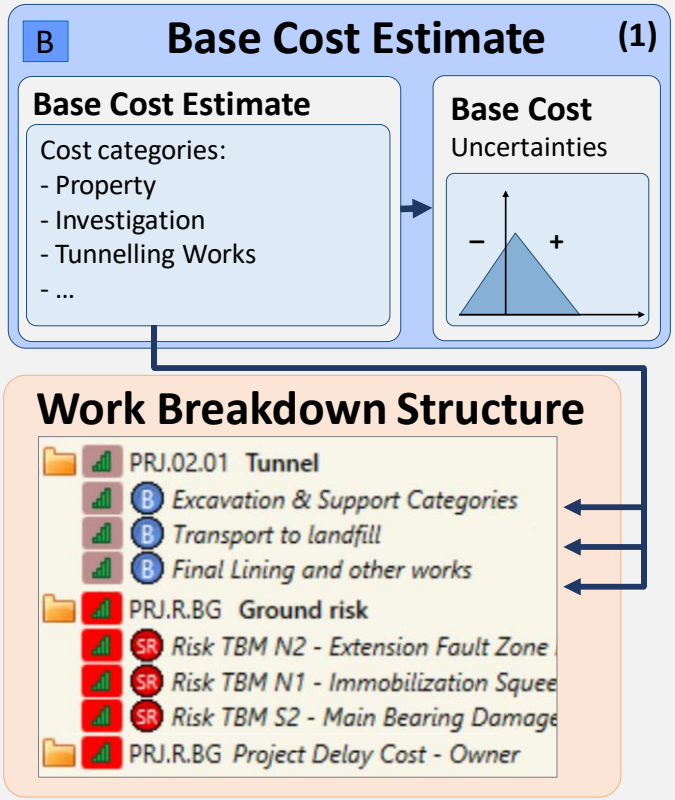
Integrated Cost and Schedule Analysis - Process



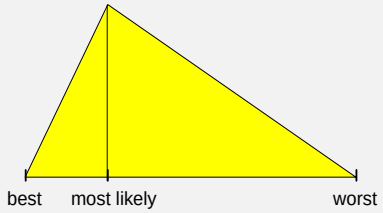
Validation of Base Cost Estimate

- Assign cost elements to WBS structure
- Review relevant Base Cost elements (quantities, prices, completeness)
- Add Base Cost variabilities (uncertainties)

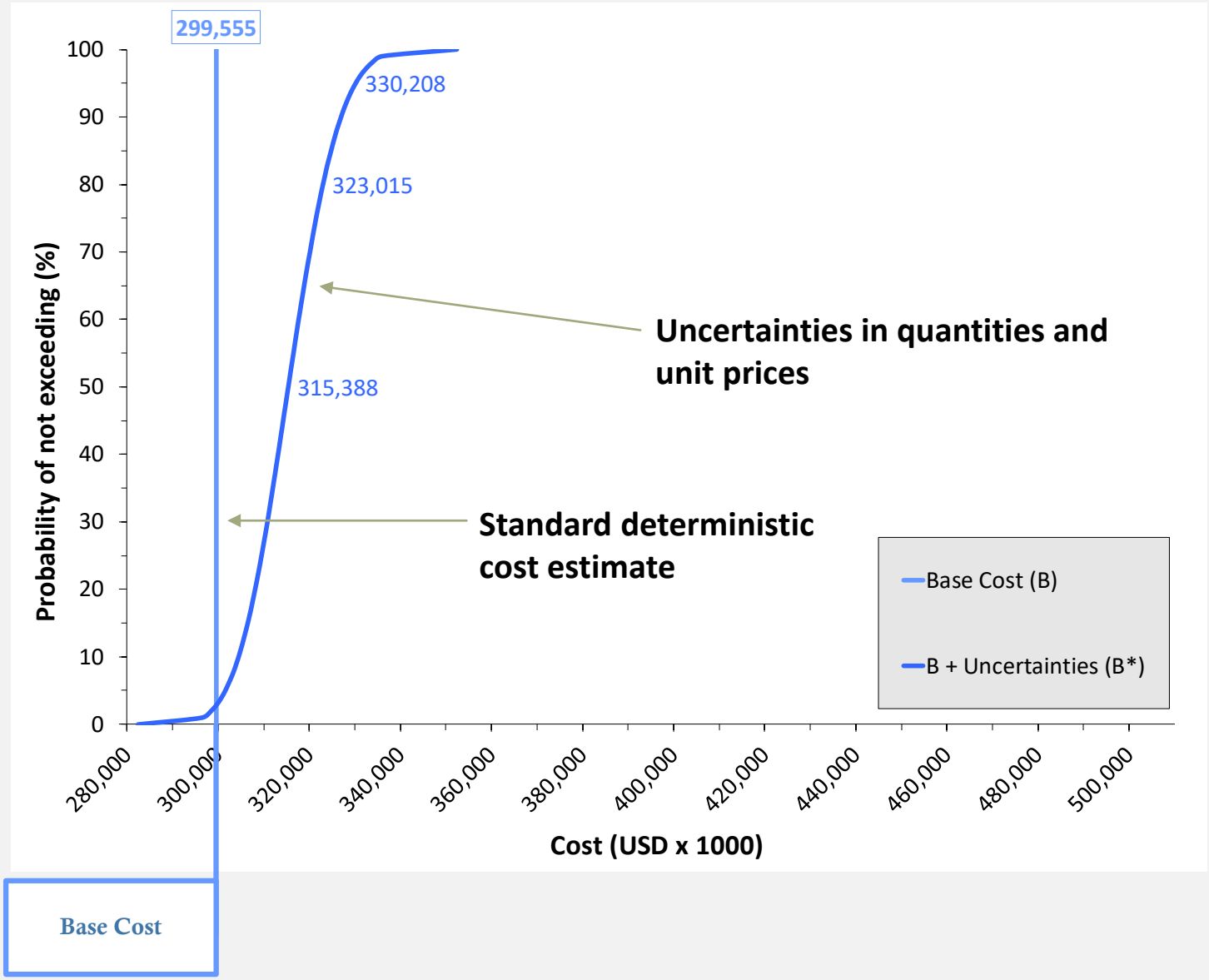
3-Point Estimate

- Reality can be described much better with bandwidths than with single numbers.
- Triangle or Beta-Pert distribution is easy to understand.
- More complex modeling is possible at any point in the process.

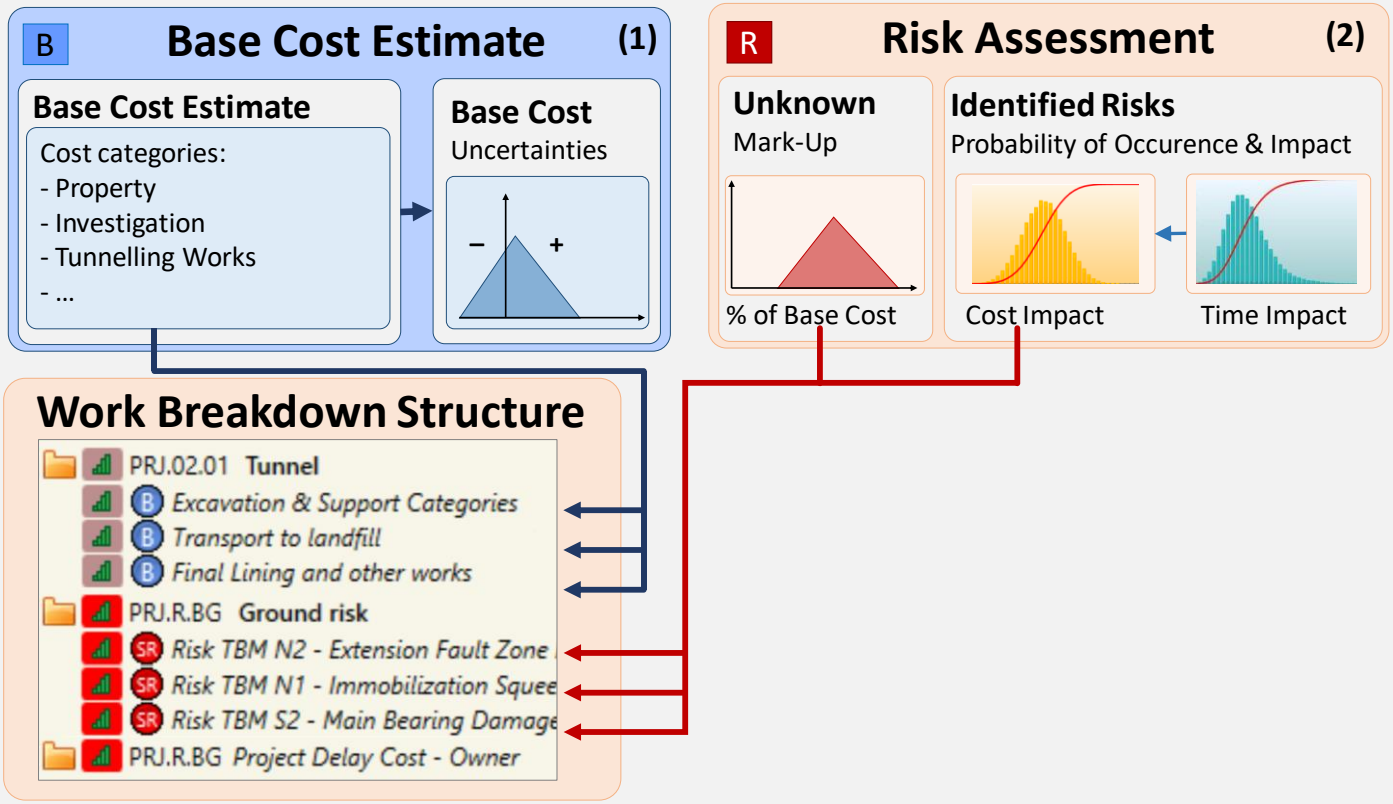
Triangle Distribution



Base Cost + Base Cost Uncertainty



Integrated Cost and Schedule Analysis - Process

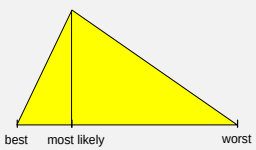


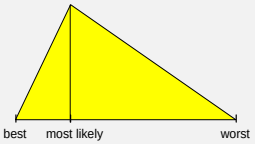
Identified Risks - Risk Assessment Workshops

- Facilitated interdisciplinary workshops
- Identification and quantification of risks
- Populate risk register
- Supported by appropriate tools

Probability of occurence (%) or expected occurrence rate (multiple occurring risks)

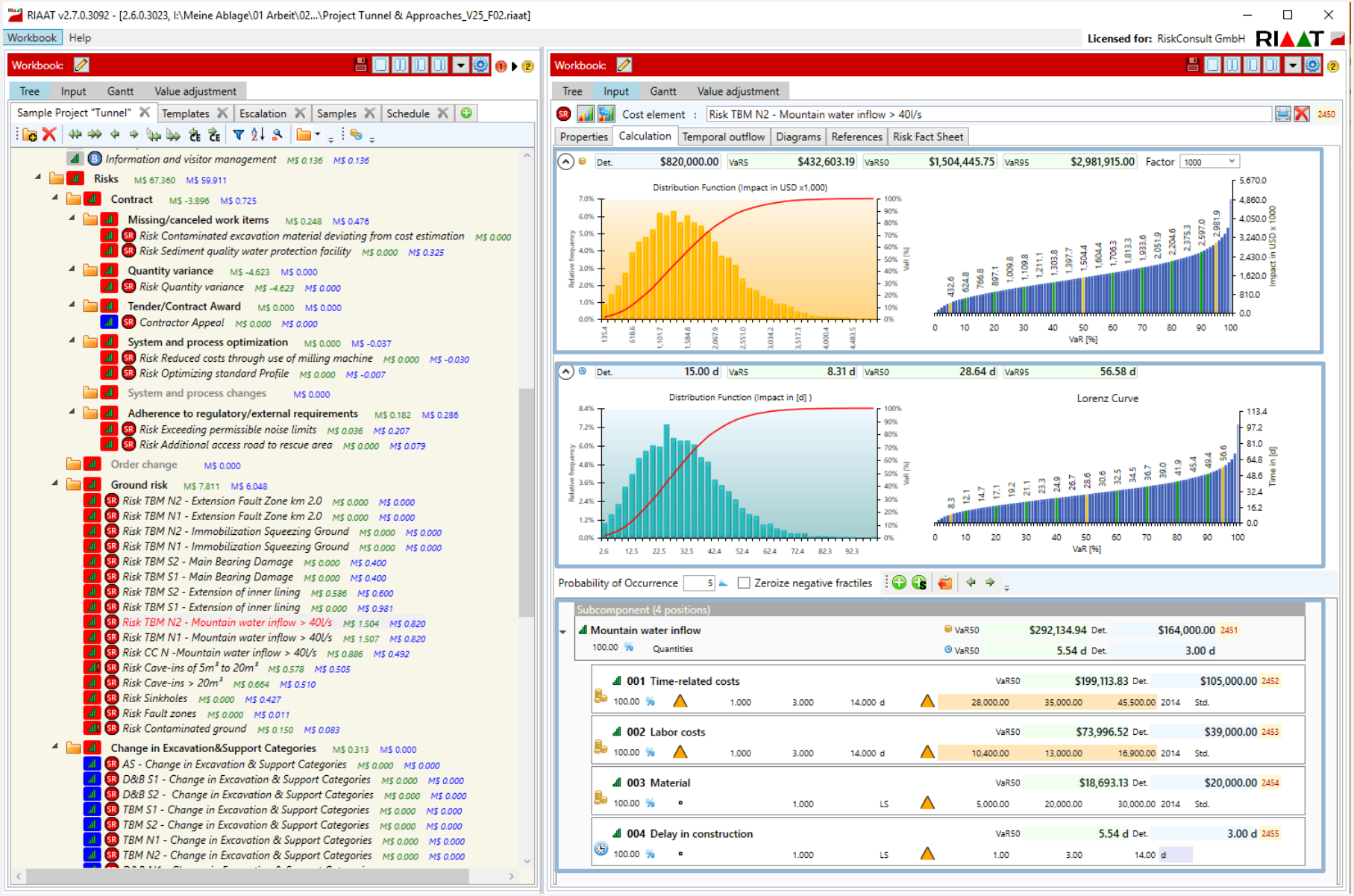
Impact (cost and time)





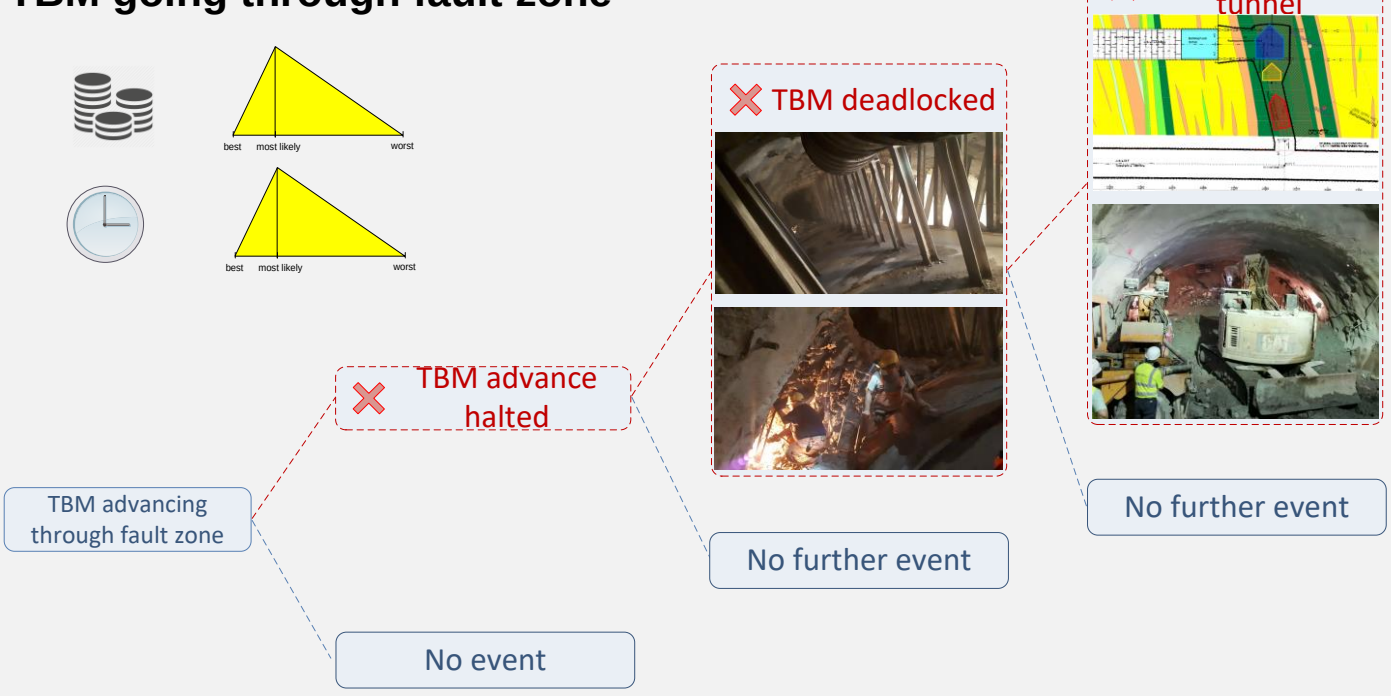
#	Identified Risk	Probability of Occurence	Rate of Occurence	cost impact (USD x 1000) best	cost impact (USD x 1000) most likely	cost impact (USD x 1000) worst	time impact (d) best	time impact (d) most likely	time impact (d) worst
1	TBM S2 - Main Bearing Damage	20%	-	1000	2000	3000	90	180	400
2	TBM N1 - Change in Exc.&Sup. Categ.	70%	-	500	3000	4500	20	120	180
3	TBM N1 - Immobilization Squeezing	25%	-	1500	3000	5000	60	120	200
4	Contractor Appeal	50%	-	-	-	-	30	90	180
5	No Release of Design	30%	-	225	900	1350	30	120	180
6	TBM N - Delay installation	25%	-	400	1200	2000	20	60	100
7	Extension Fault zone km 2.0	80%	-	0	840	1660	0	42	83
8	TBM S2 - Extension of inner lining	-	3	150	200	250	5	10	20
9	Logistic Problems Crosscut S (13-25)	30%	-	150	375	600	20	50	80
10	CC N - Mountain water inflow >40l/s	-	3	222	886	1782	1	3	14

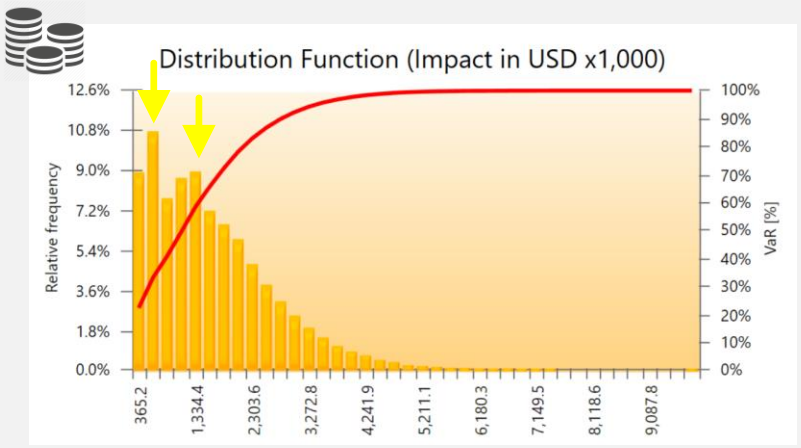
Integrated Cost and Schedule Analysis

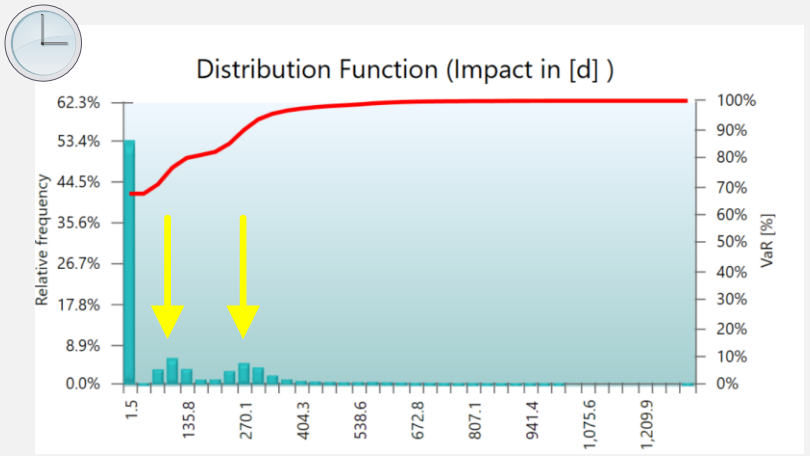


Identified Risk: TBM going through fault zone

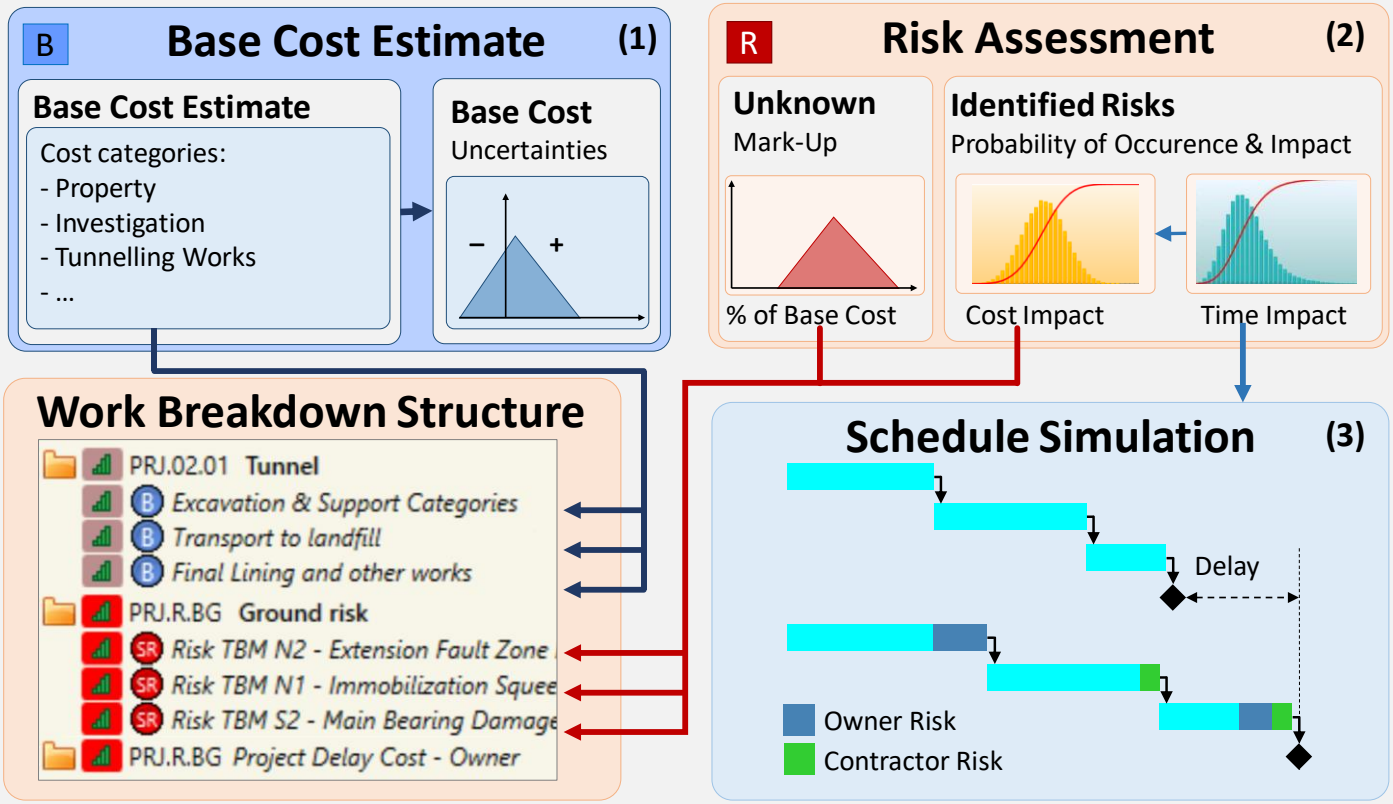
For every “leaf”:







Integrated Cost and Schedule Analysis - Process



Scheduling – To not see the forest for the trees

1. **Condense Schedule**

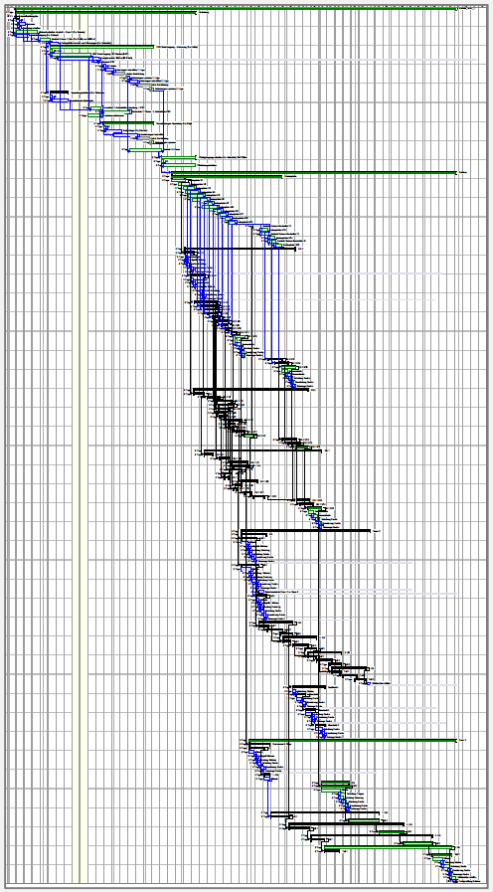
   Convenient level of detail, keep important dependencies, seek for clarity

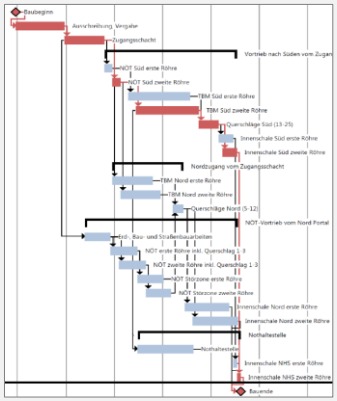
2. **Ongoing dynamic adaptions**

   Reproduce actual current situation

3. **Uncertainty**

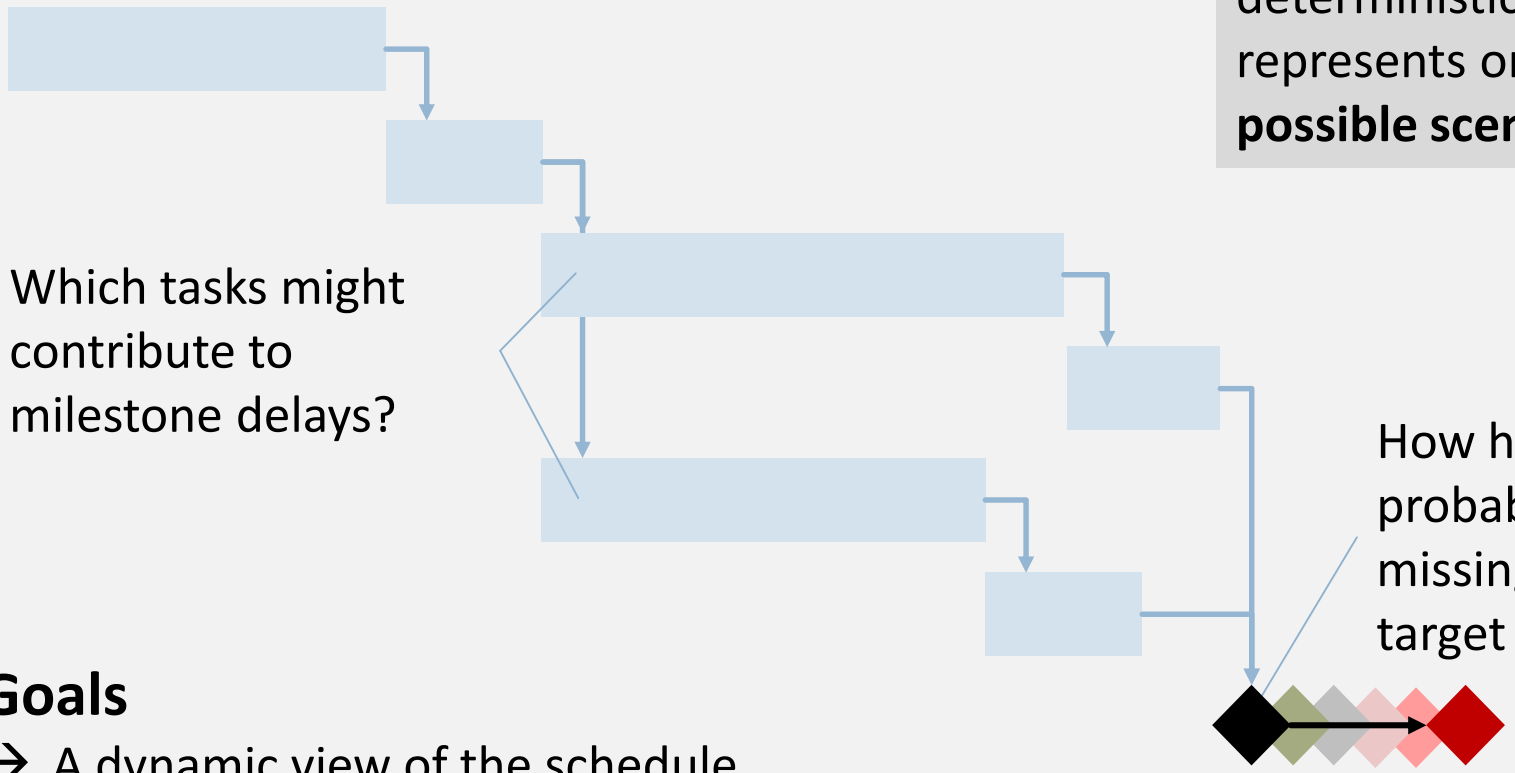
   Incorporate uncertainty and risk to understand the impact on your milestones.





Deterministic Schedule Approach

The classic deterministic schedule represents only **one possible scenario**.



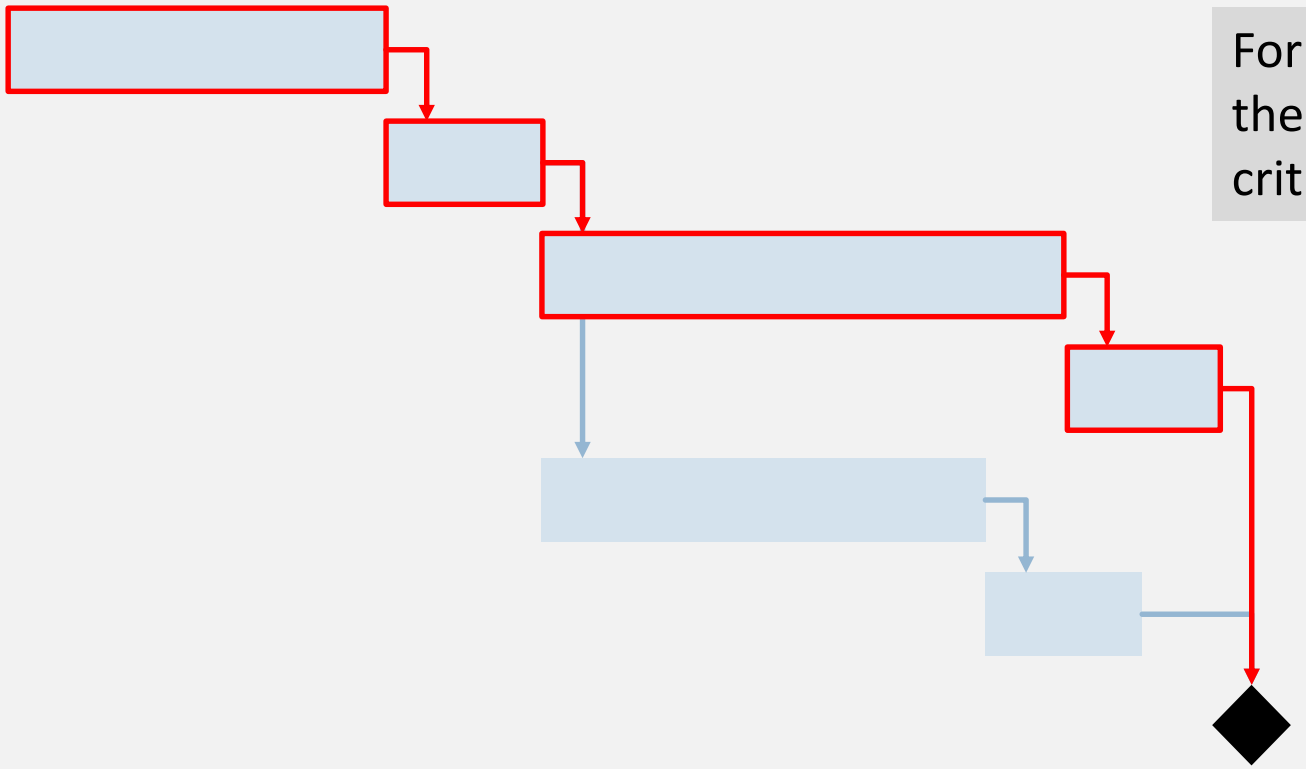
Which tasks might contribute to milestone delays?

How high is the probability of missing the target date?

Goals

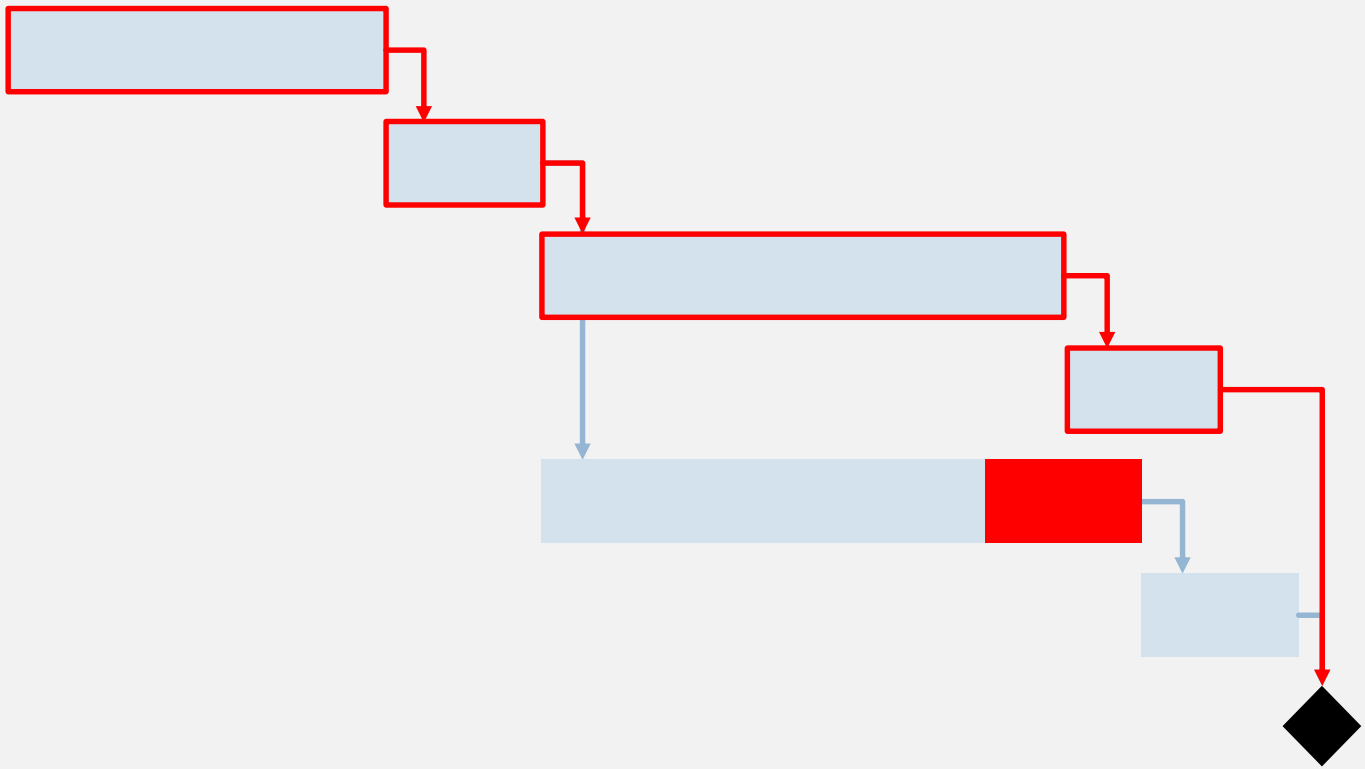
→ A dynamic view of the schedule
→ Integrate risks – link them to tasks
→ Implement risk mitigation measures based on results of the schedule analysis
→ Optimize construction processes

CPM in Deterministic Schedule



For **one** scenarios there is only **one** critical path.

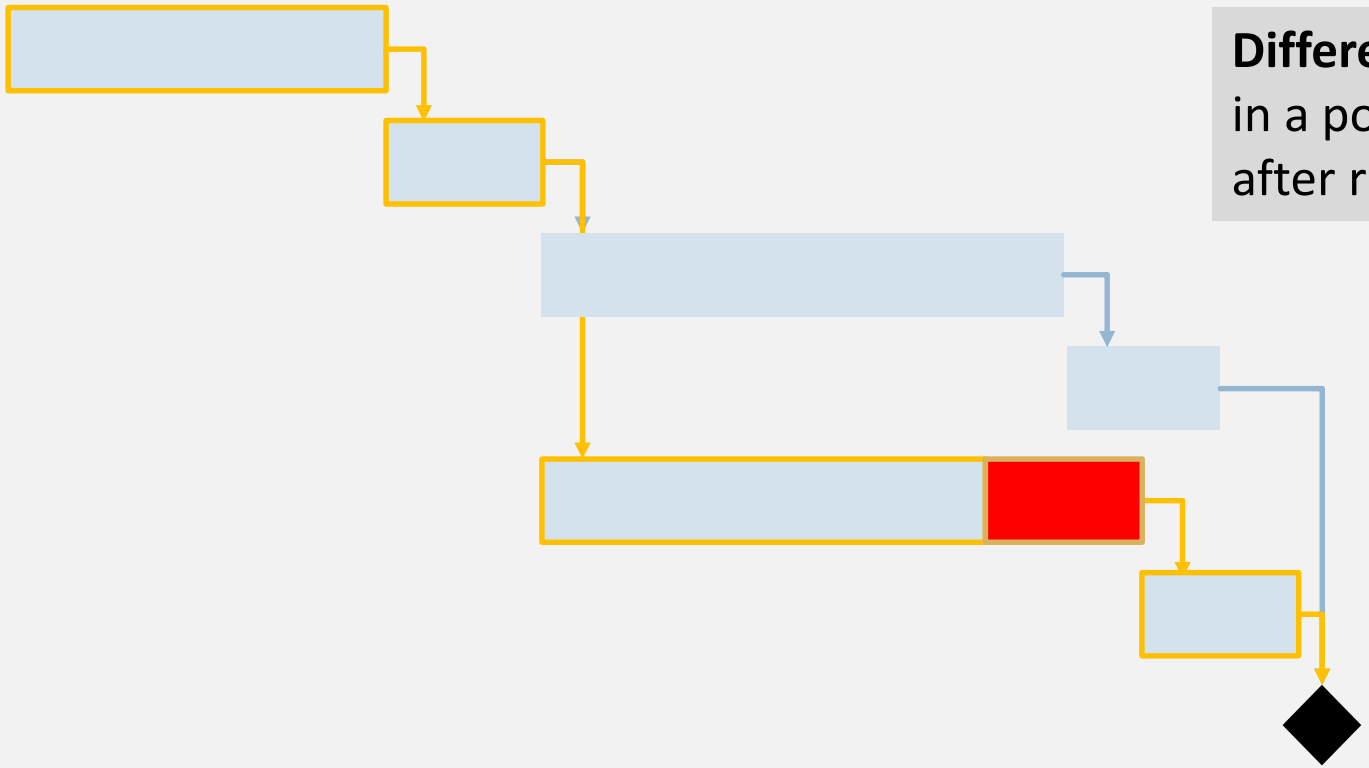
Critical Path Shifting due to Risk Impact



What If

risk impacts change task durations?

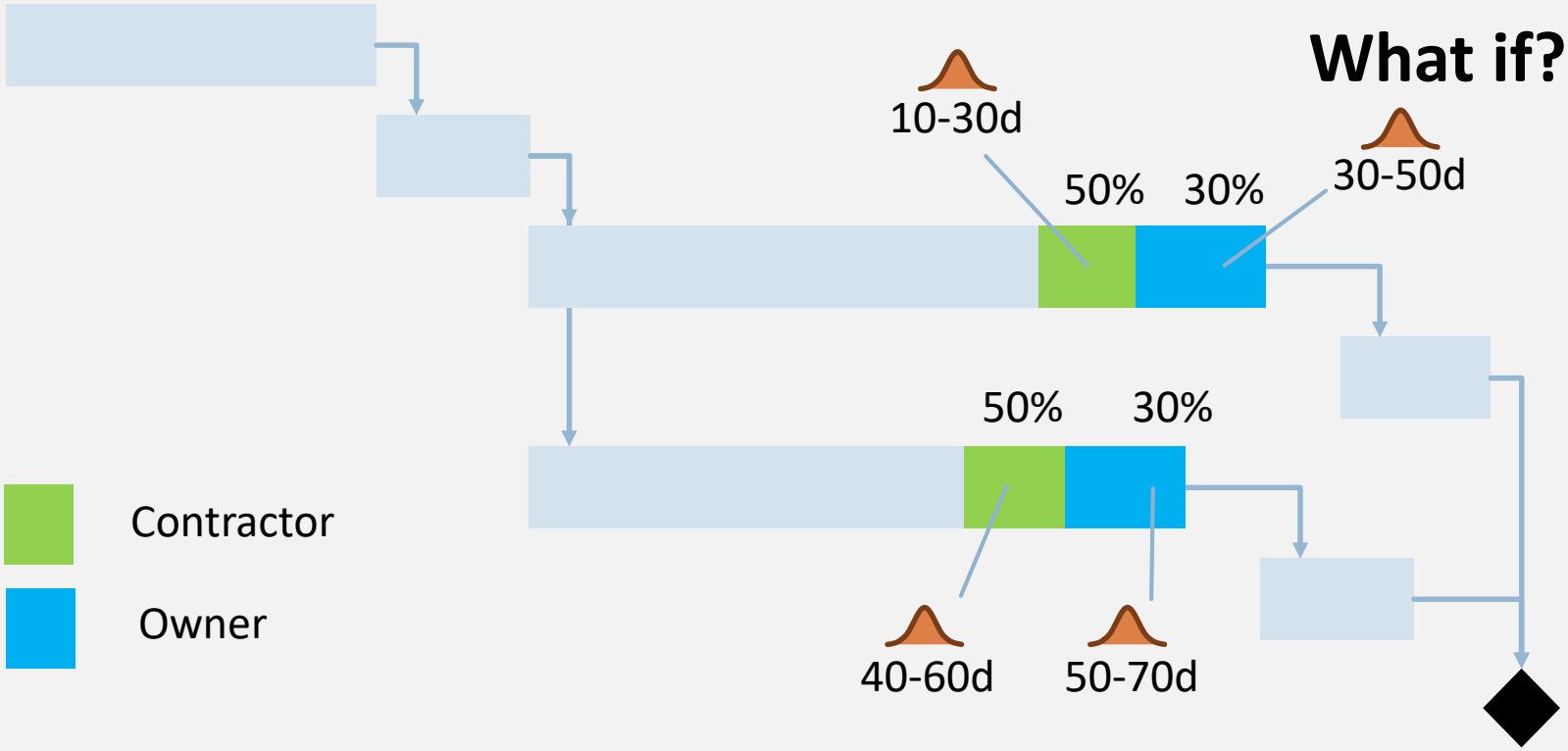
Critical Path Shifting due to Risk Impact



Different critical path in a possible scenario after risk impact(s).

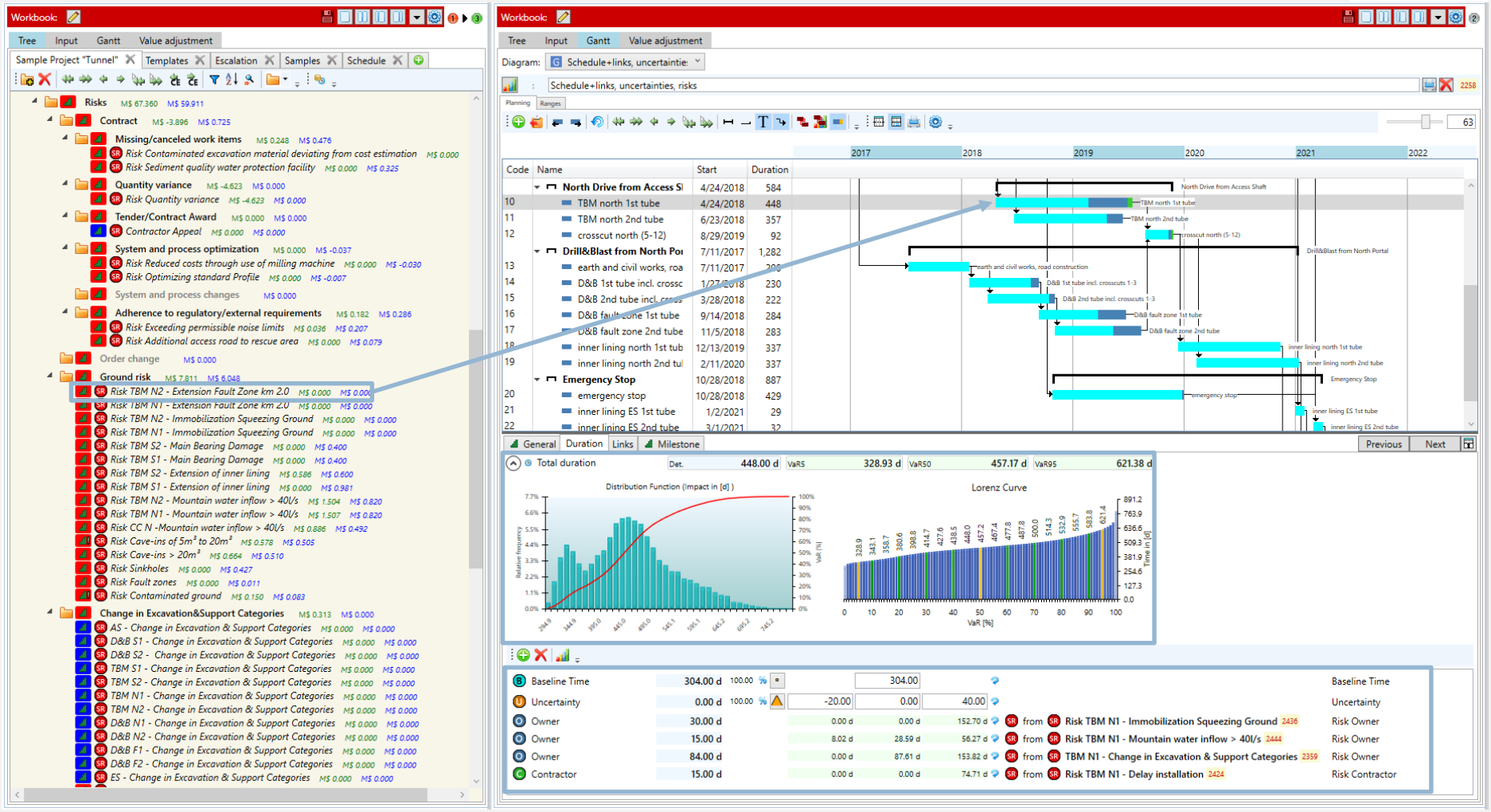
Assigning Risks to Tasks

#	Identified Risk	Probability of Occurence	Rate of Occurence	time impact (d) best	most likely	worst
1	TBM S2 - Main Bearing Damage	20%	-	90	180	400

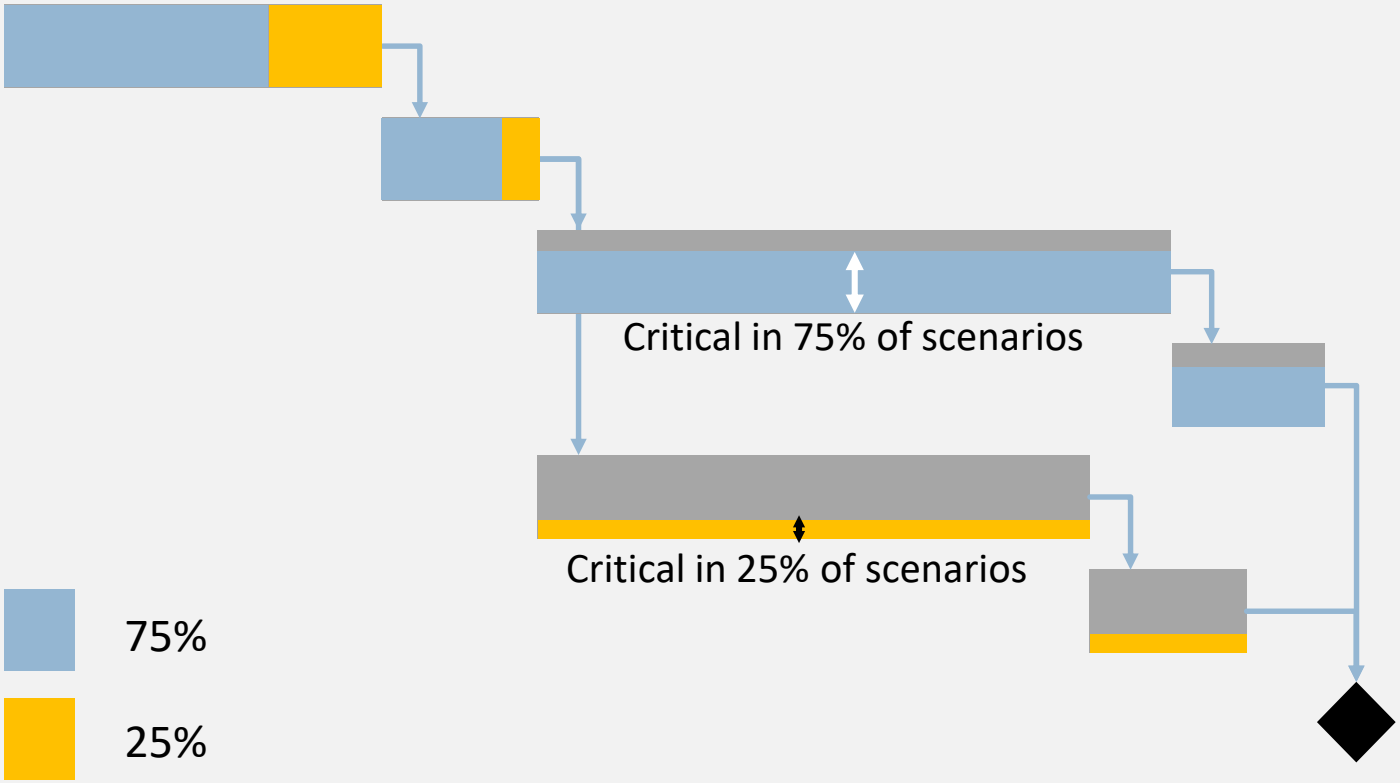


→ Monte Carlo simulation will generate thousands of realistic scenarios, each depicting a possible project outcome.

Application: Assigning Risks to Schedule Activities



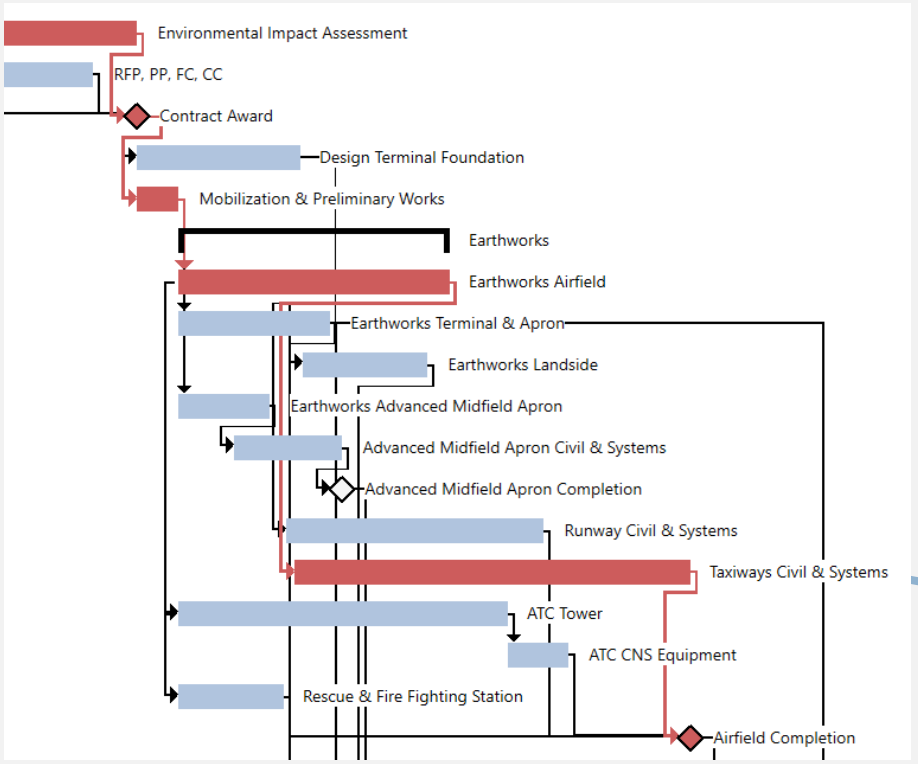
Critical Paths after Monte Carlo Simulation



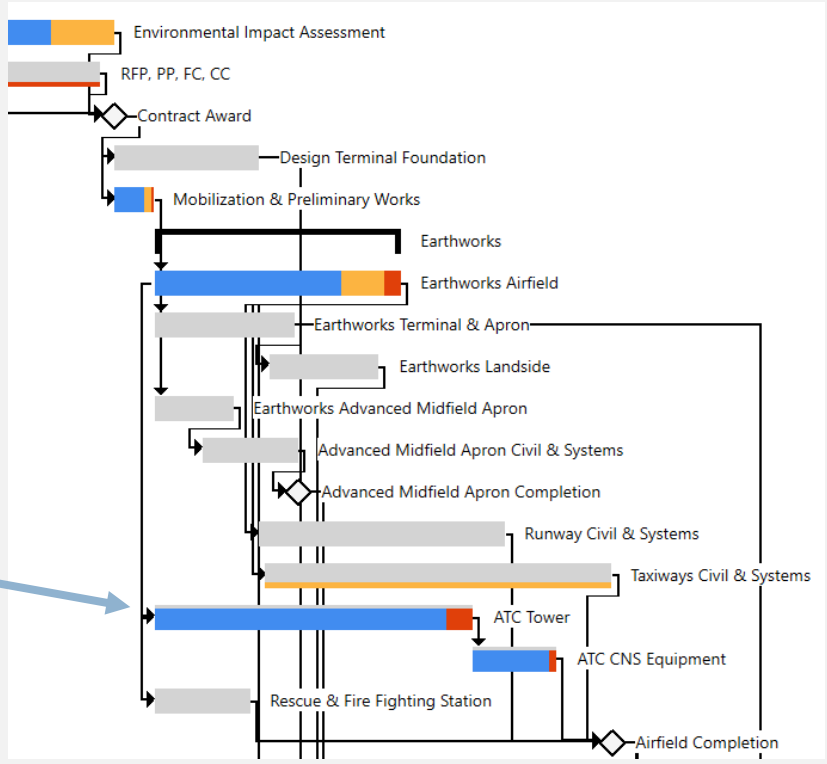
→ Due to uncertainties, **numerous** critical paths become possible, each with a different probability.

Example: Lima Airport Extension Project

Base Schedule



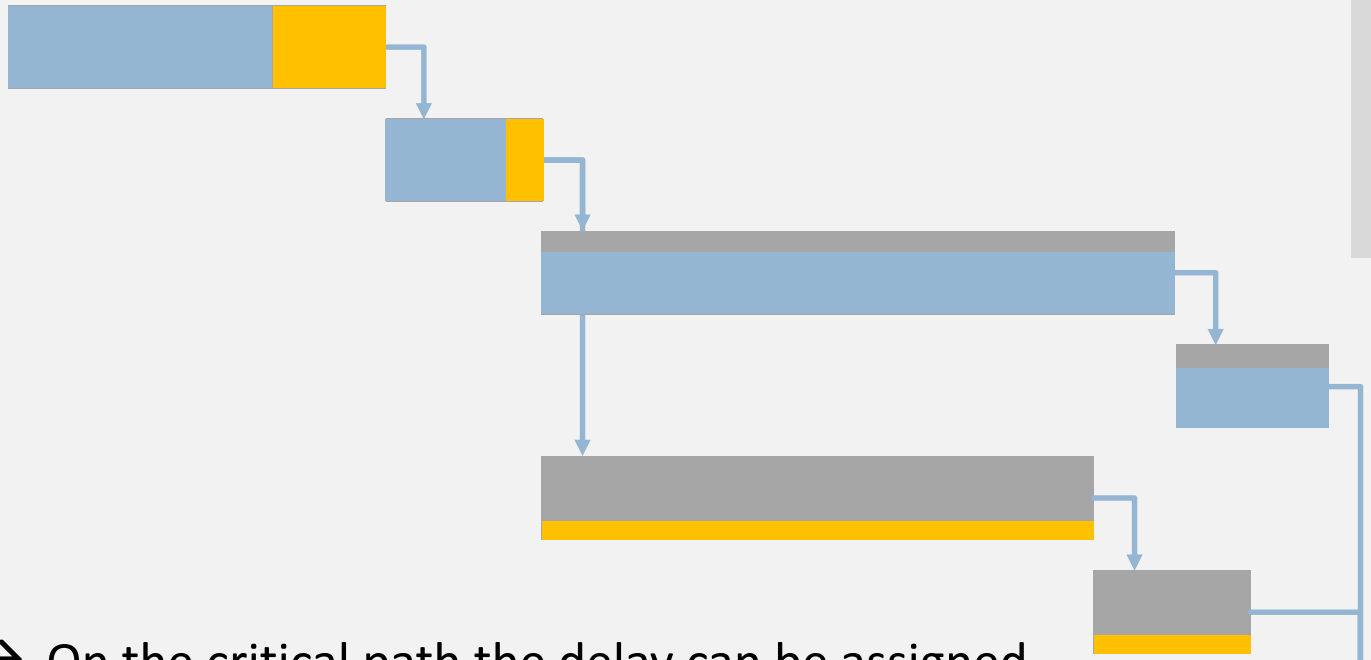
Base Schedule + Risk

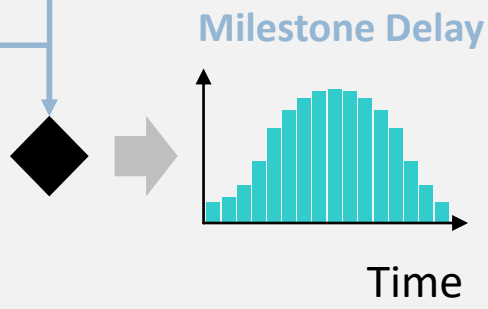


Main critical path is changing to ATC tower due to risk impact

Milestone Results after Monte Carlo Simulation

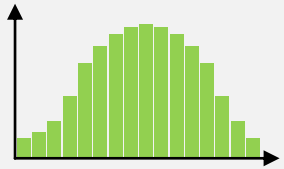
Each simulated scenario yields a different milestone delay, with respect to a given target date.



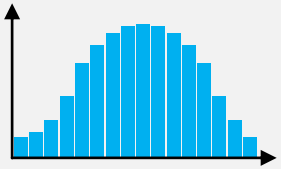


→ On the critical path the delay can be assigned to different responsibilities (cost components):

Contractor Delay



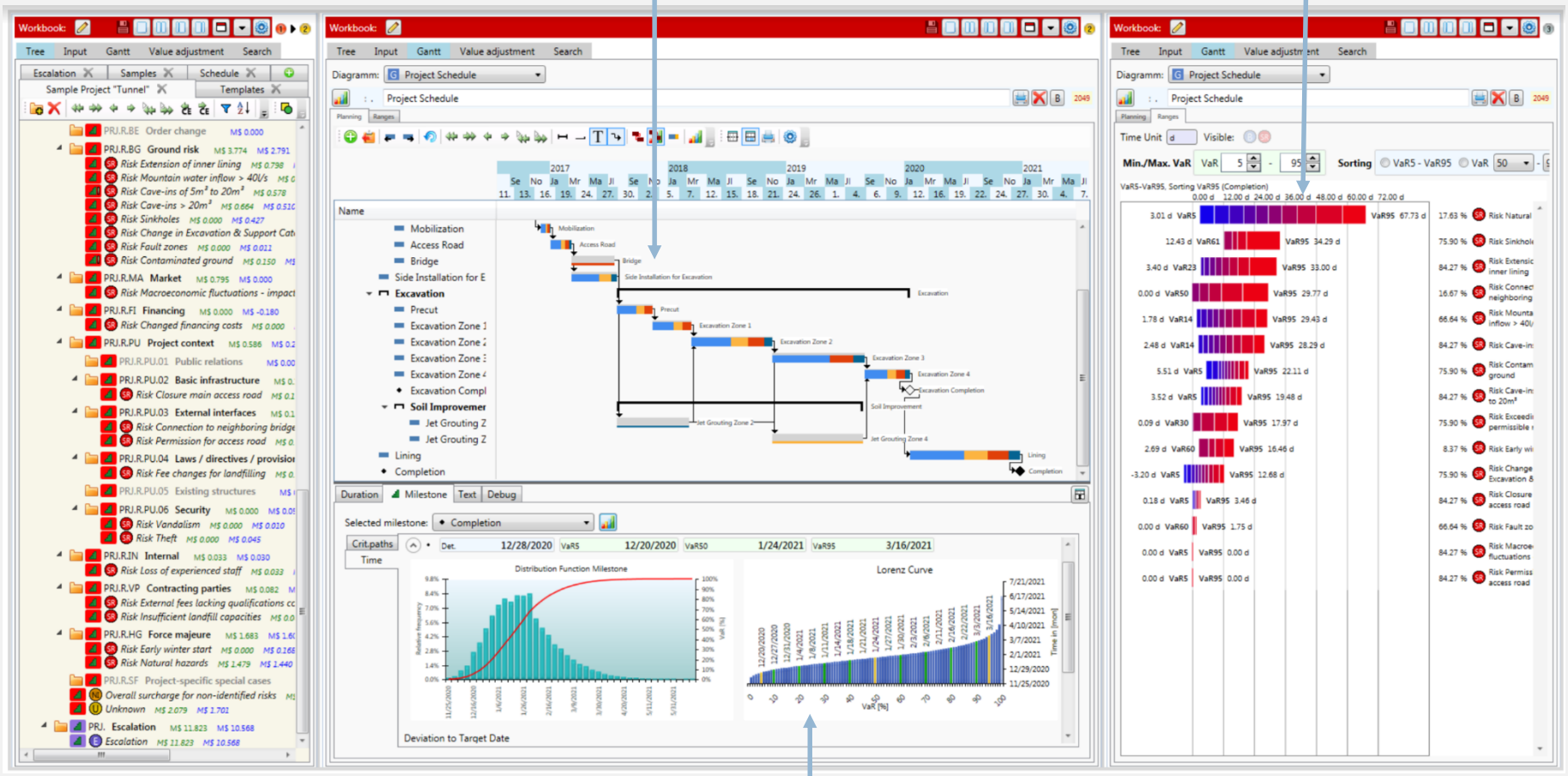
Owner Delay



Milestone Delay and Risk Impact on Critical Paths

Critical paths view

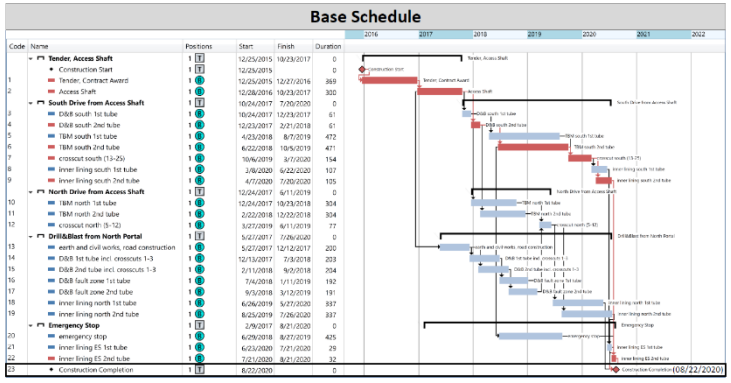
Potential risk impact on critical paths



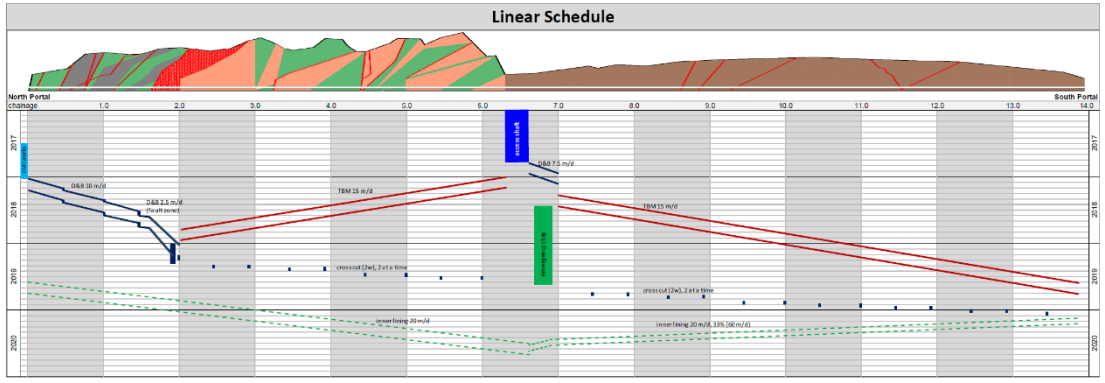
Range for project completion date

Summary Integrated Schedule Model

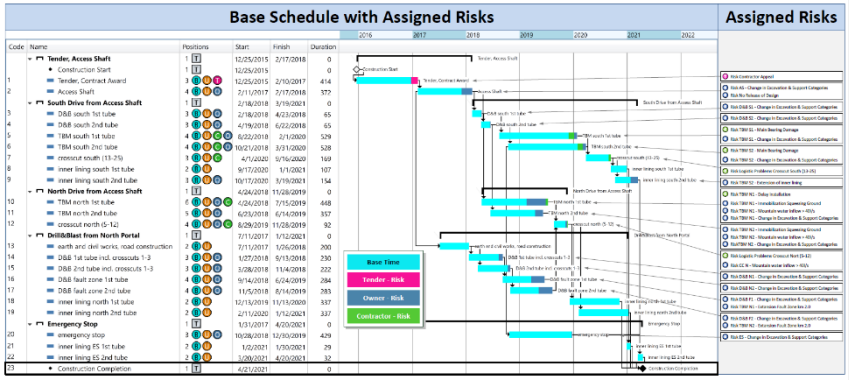
Base Schedule



Linear Schedule

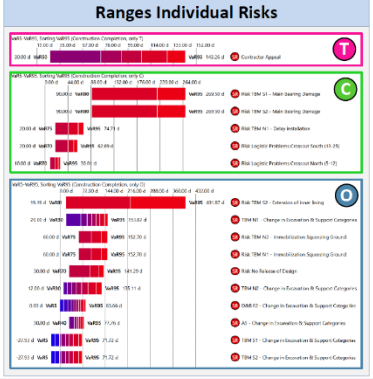


Base Schedule with Assigned Risks

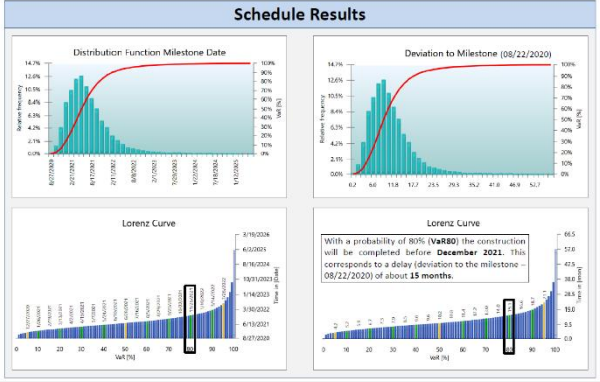


Assigned Risks

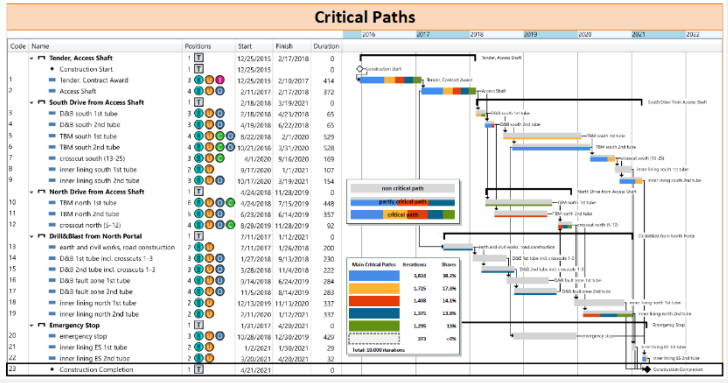
Ranges Individual Risks



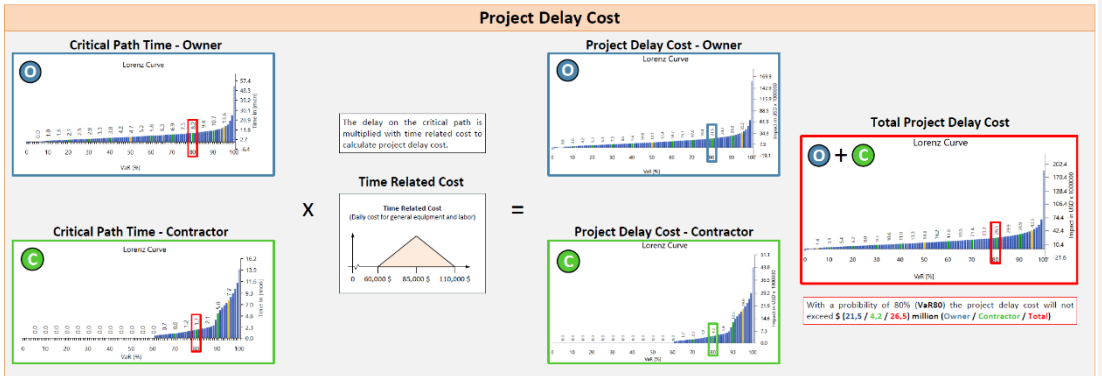
Schedule Results



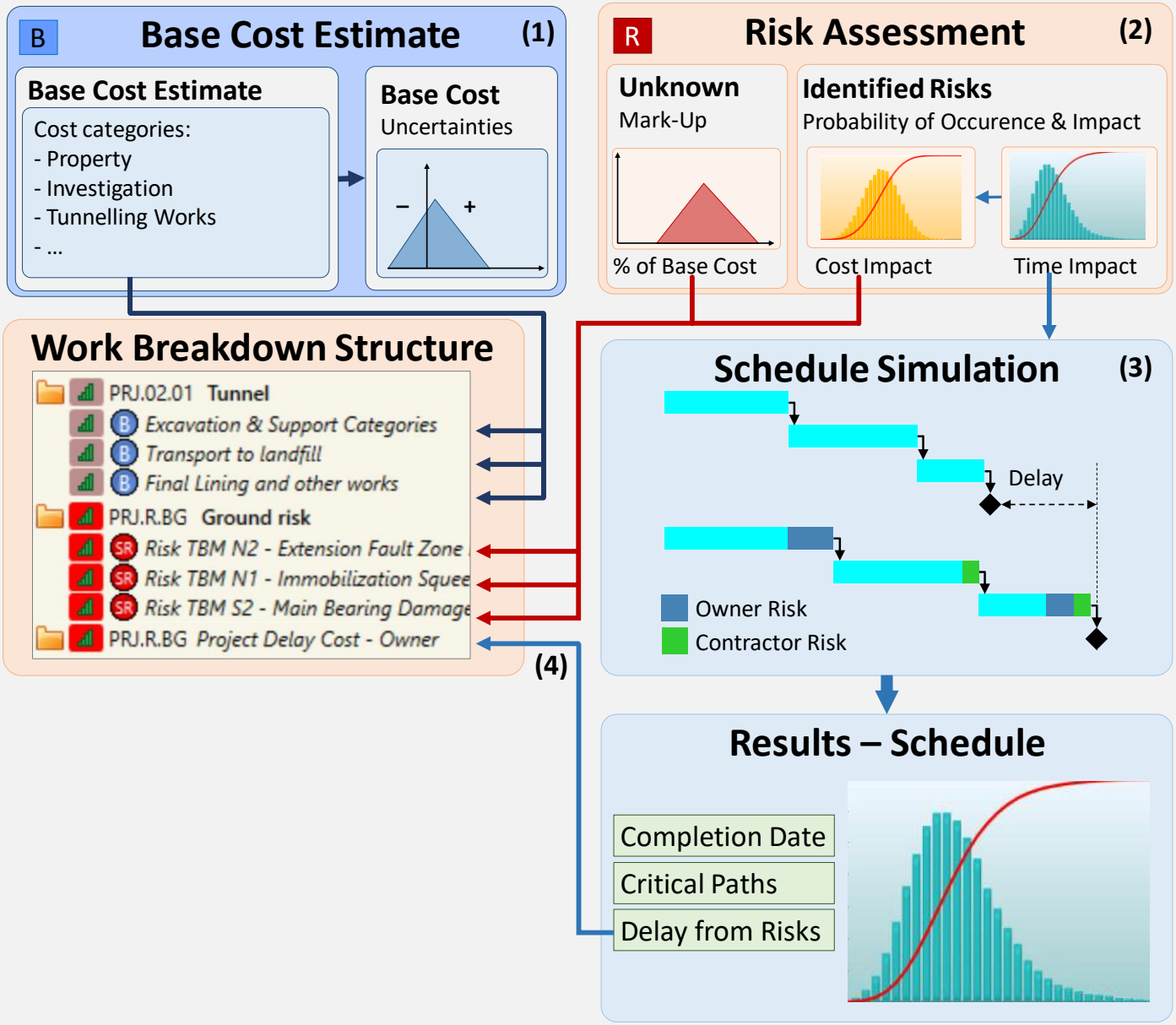
Critical Paths



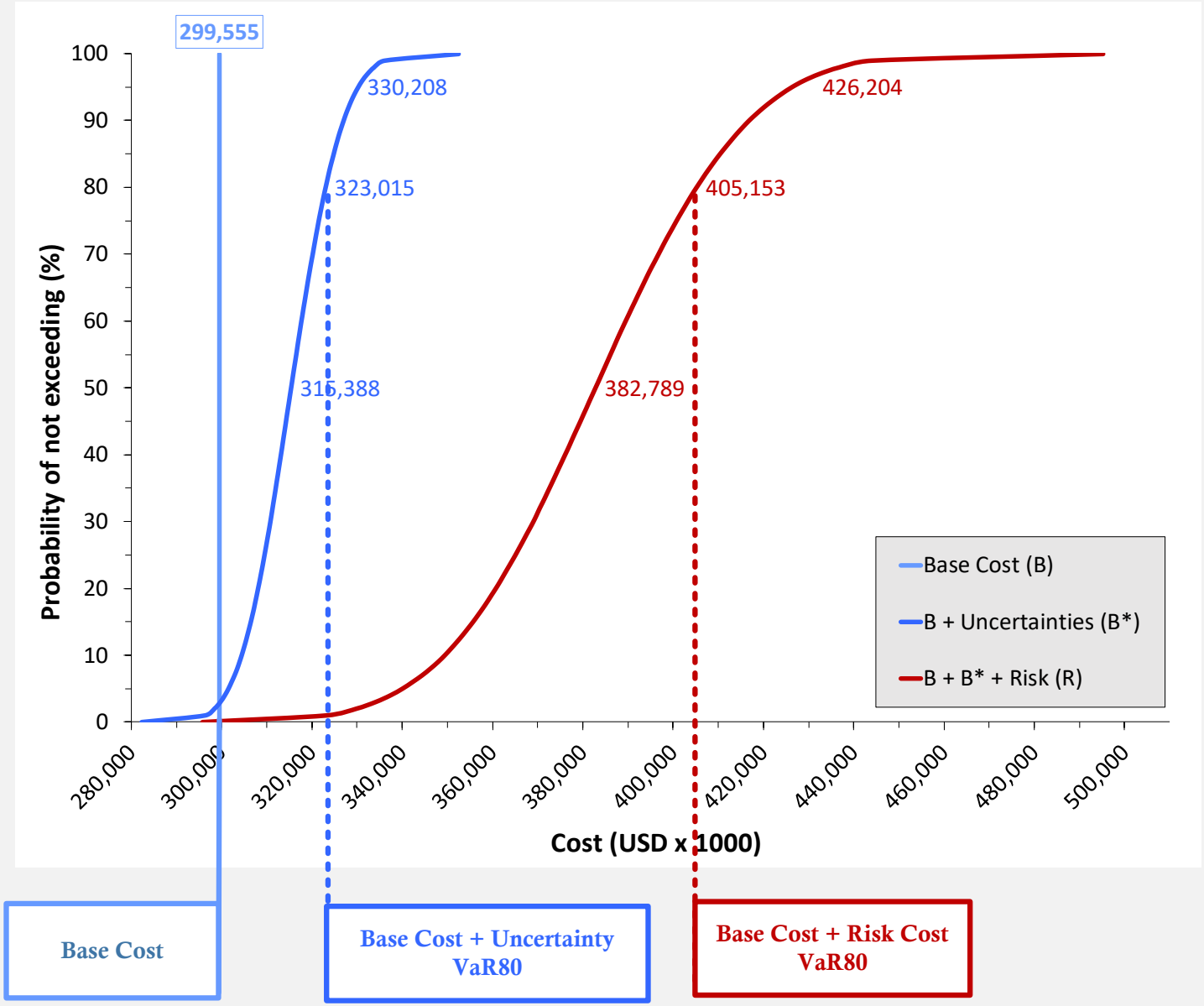
Project Delay Cost



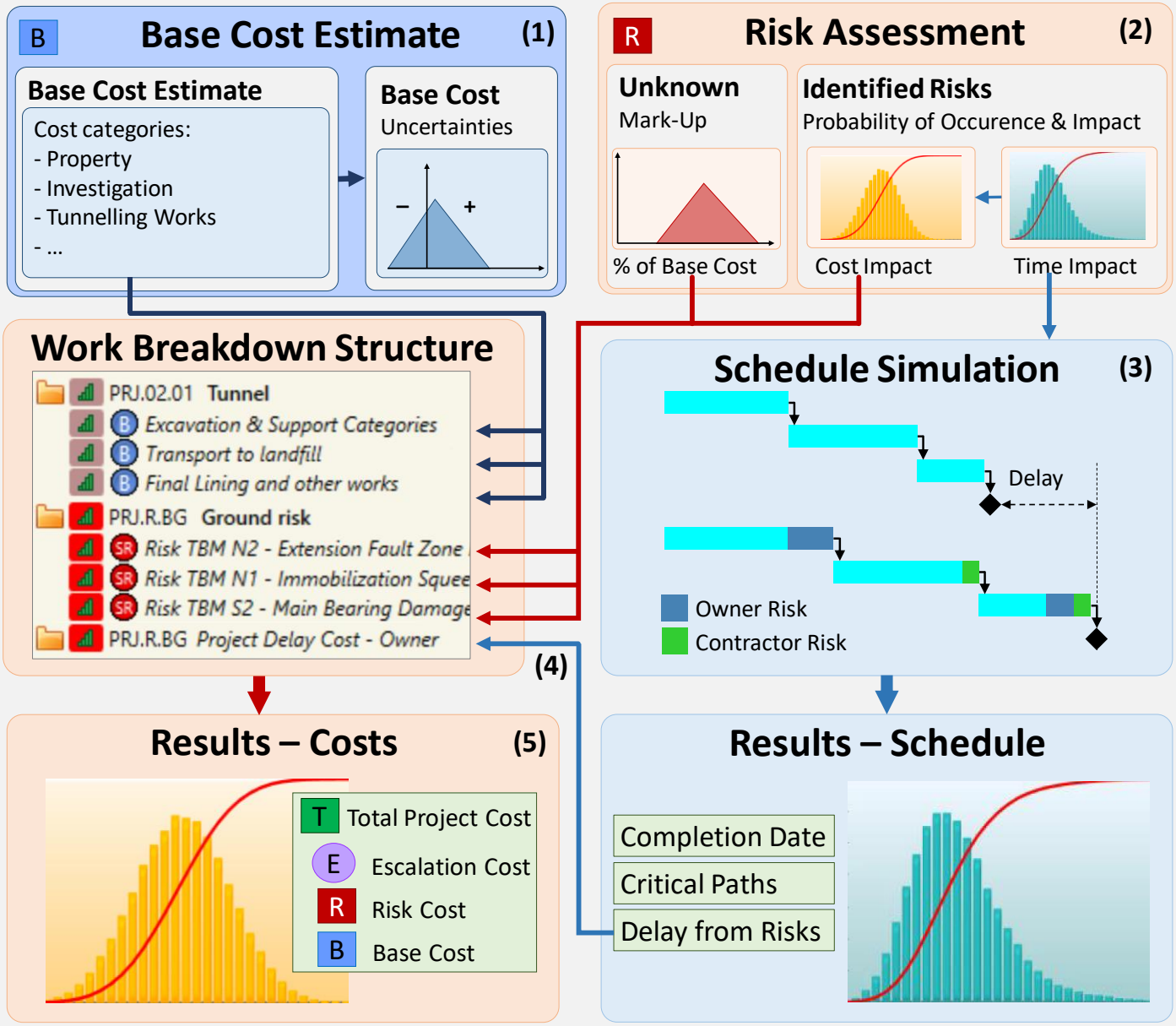
Integrated Cost and Schedule Analysis - Process



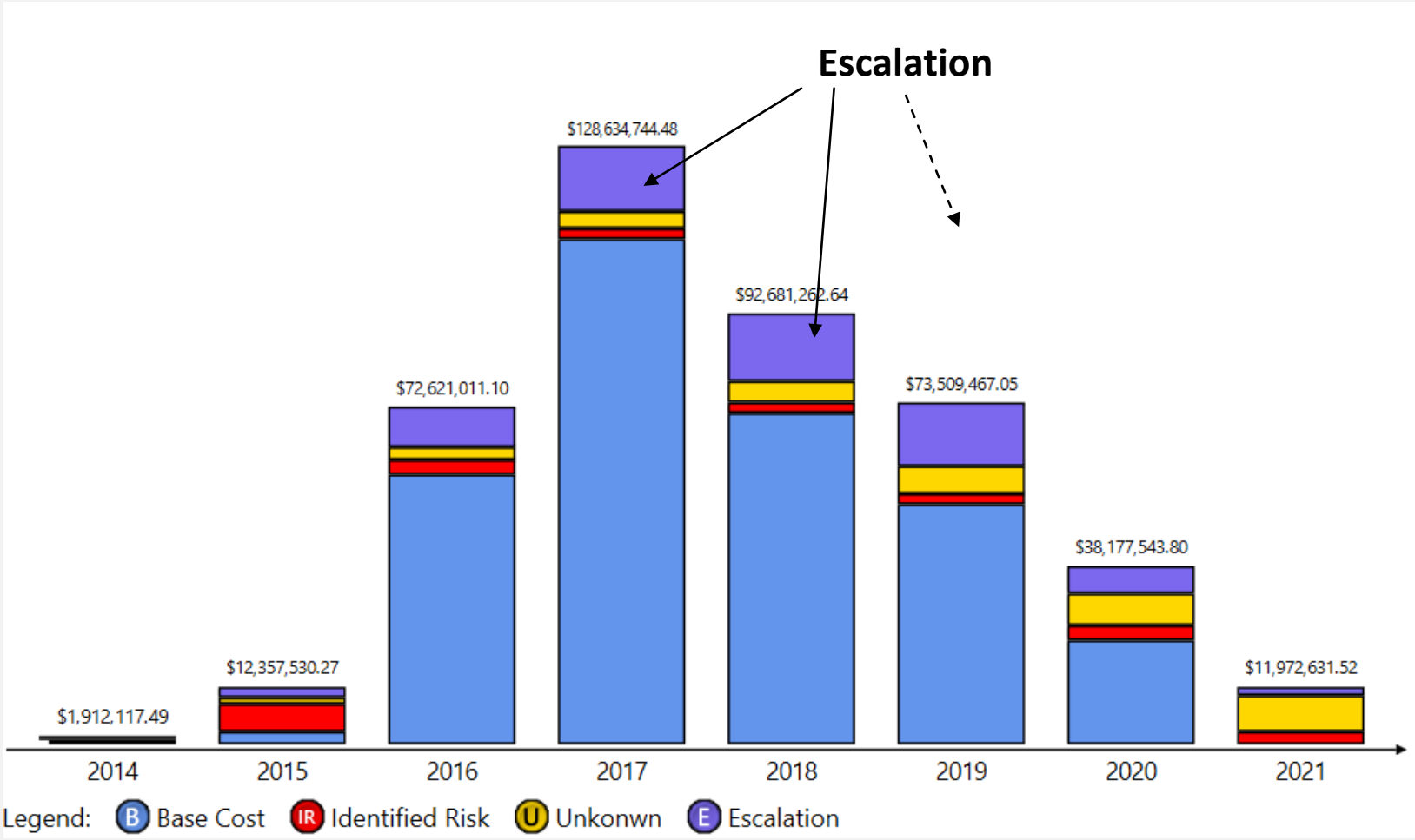
Base Cost + Base Cost Uncertainty + Risk



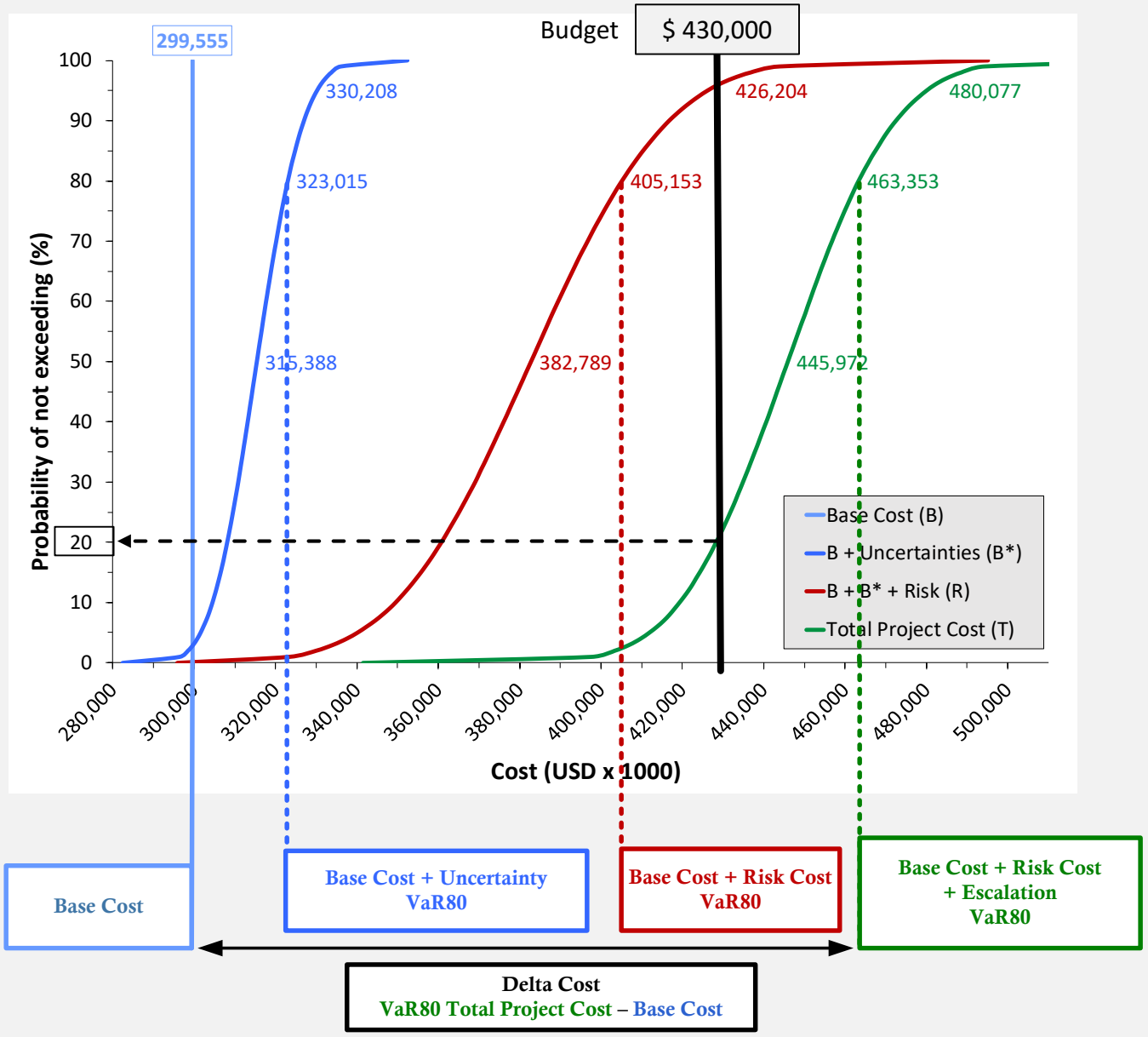
Integrated Cost and Schedule Analysis - Process



Escalation calculated from Cash Flow



Total Project Costs



1. Introduction
2. Standard vs Integrated Approach
3. Integrated Cost and Schedule Model
4. **Projects and the European Perspective**

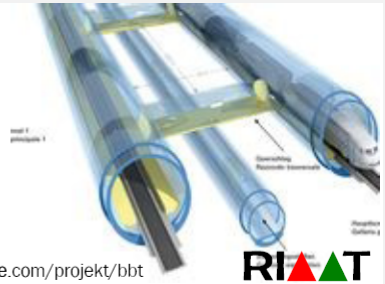
Selected Projects

Brenner Base Tunnel

The Brenner Base Tunnel is the main element of the new Brenner railway from Munich to Verona. At 64 km, it is the longest underground railway connection in the world, a pioneering work of engineering and it will markedly improve passenger travel and freight transport through the heart of Europe.

Services: Support and validation probabilistic risk assessment

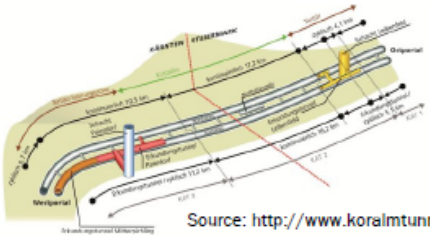
Project costs: approx. $ 12 Billion



Source: http://www.bbt-se.com/projekt/bbt

RIAAT

Koralm Base Tunnel



Source: http://www.koralmtunnel.eu

With a total length of 32.8 km and a maximum cover of 1,250 m the base tunnel will traverse the Koralpe mountain range and will connect the Austrian states of Styria and Carinthia.

Services: Probabilistic risk assessment, Moderation of the process during planning and construction stage

Project Cost: approx. $ 2.1 Billion

RIAAT

Subway New York: Canarsie Tunnel

New York City Transit

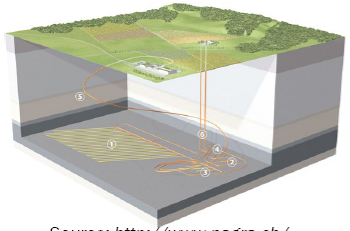
Flooding caused by Superstorm Sandy inundated the Canarsie Tunnel with seven million gallons of salt water. The rehabilitation includes upgrading of the Canarsie Tunnel facilities from 1st Avenue Station in Manhattan to Bedford Avenue Station in Brooklyn and three substations.

Service: Risk assessment, identifying and quantifying risks for project cost and schedule, quantify potential reduction in risk through mitigation.

Source: New York Times

RIAAT

NAGRA - Swiss National Cooperative for the Disposal of Radioactive Waste



Source: http://www.nagra.ch/

Safe long-term disposal of radioactive waste in deep geological repositories is a challenging task that NAGRA has committed to implementing in the interests of man and the environment.

Services: Probabilistic cost estimation and risk analysis, software development, process development, staff training

nagra.

RIAAT

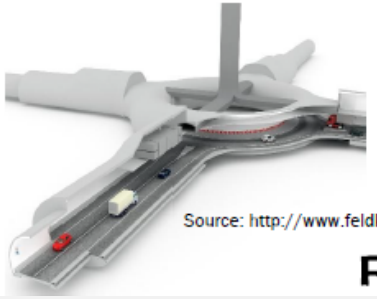
Different Tunnel Project Types

Citytunnel Feldkirch

The heart of the project is the 4-arm underground roundabout with a diameter of 58 m, which connects the 4-section city tunnel underneath Feldkirch.

Services: Probabilistic cost estimation
Verification of the existing cost estimation and schedule

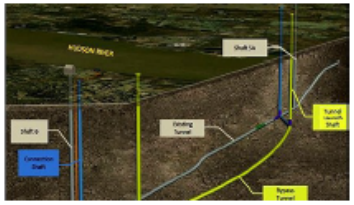
Project Cost: approx. $ 330 Million



Source: http://www.feldkirch.at/stadt

RIAAT

Delaware Aqueduct, New York City



Source: http://www.water-technology.net

Construction of the Delaware Aqueduct (Aqueduct) commenced in 1939 and was completed in 1944 to span 85 miles from upstate New York watersheds to New York City. The Delaware Aqueduct supplies approximately 60% of New York City's 1 billion gallons per day of drinking water supply.

Services: Under the Delaware Leaks and Tunnel Assessment (LTA) contract, the known leaks and condition of the Rondout-West Branch Tunnel (RWBT) will be monitored to determine risk of failure of the tunnel prior to and during unwatering for the new bypass connection.

RIAAT

Lower Inn Valley Railway Corridor

The project includes the construction section 1 (Kundl-Baumkirchen) of the Lower Inn Valley railway corridor. The railway track has an approximate length of 40 km, 32 of which are subsurface.

Services: Conception and moderation of the risk-management-process to identify and evaluate every individual risk. To estimate the whole risk potential (2013-2018) the risks for all 25 contract sections have been documented by a master plan for budgeting (using RIAAT).

Project Cost: approx. $ 2.5 Billion

Source: http://www.unterinntalbahn.at

RIAAT

GKI - Projekt Cost Control

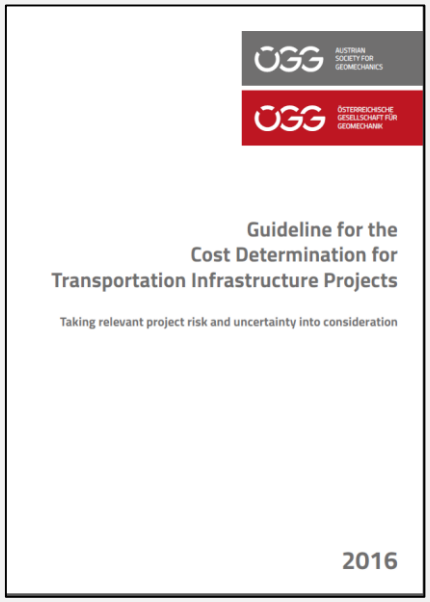
The joint venture power generating plant "Gemeinschaftskraftwerk Inn" (GKI) in the Upper Inn region at the Swiss-Austrian border represents the largest new construction of a hydroelectric power plant in the Alpine region in this millennium. The power plant has undergone a comprehensive examination in both Austria and Switzerland.

Services: Cost control with the company's own software tool RIAAT. Initiation and implementation of a cost controlling structure and concurrent services.

Source: http://www.gemeinschaftskraftwerk-inn.com

RIAAT

Guideline for the Cost Determination for Transportation Infrastructure Projects

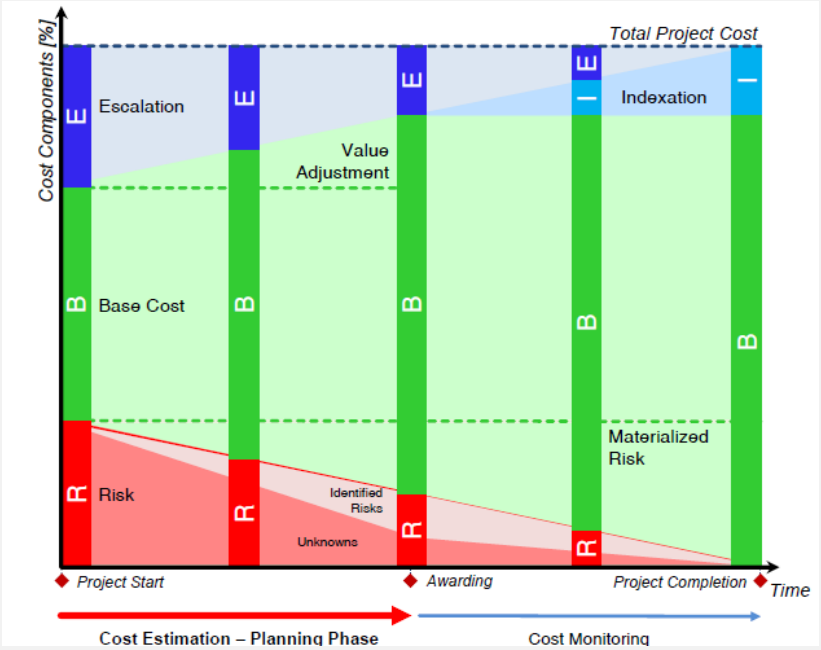


Guidline for state-of-the-art cost estimation and risk management

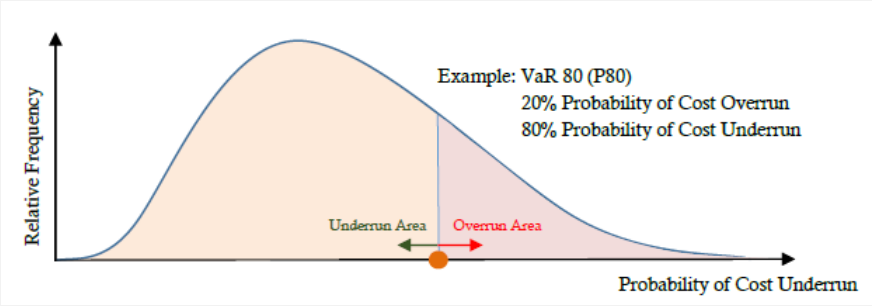
Applied in projects in:

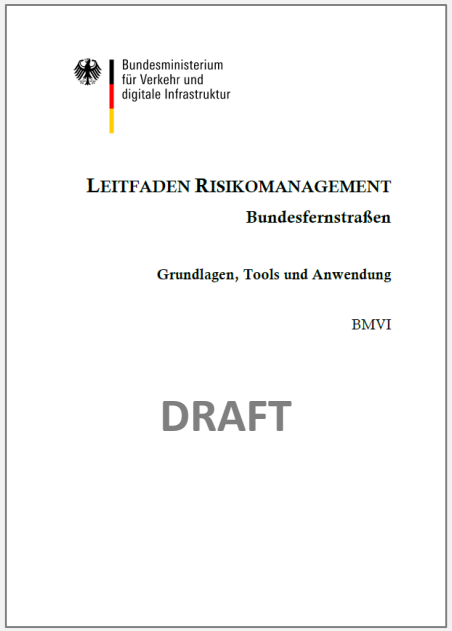
Austria, Germany, Switzerland, Italy, Slovenia, USA, Canada, Peru

Cost Component Structure



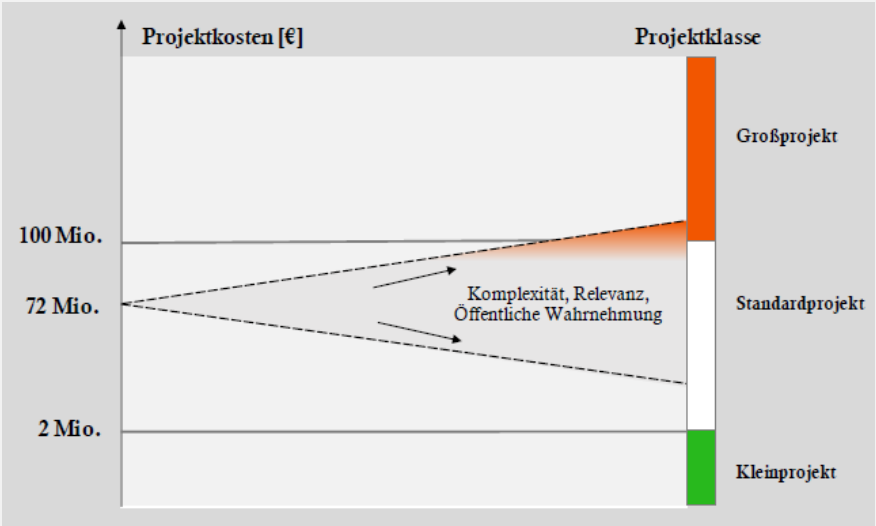
Probabilistic Approach



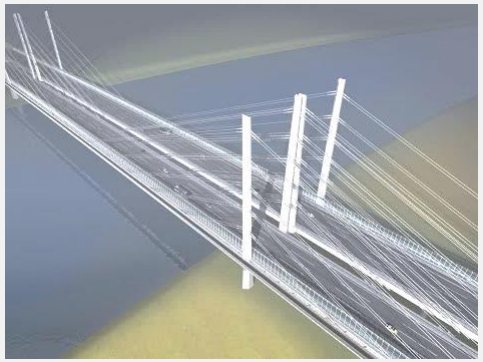


Guideline Risk Management for Federal Roads and Freeways

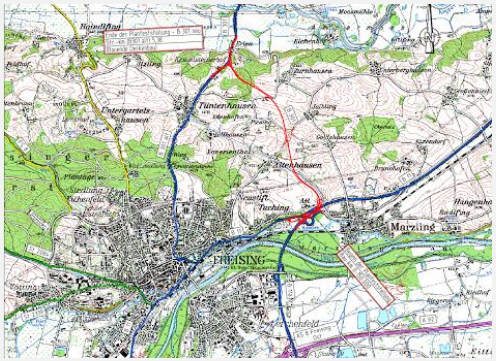
Scalable RM Approach dependent on project type



Rheinbrücke Duisburg A40



Umfahrung Freising B301



Rader Hochbrücke A7