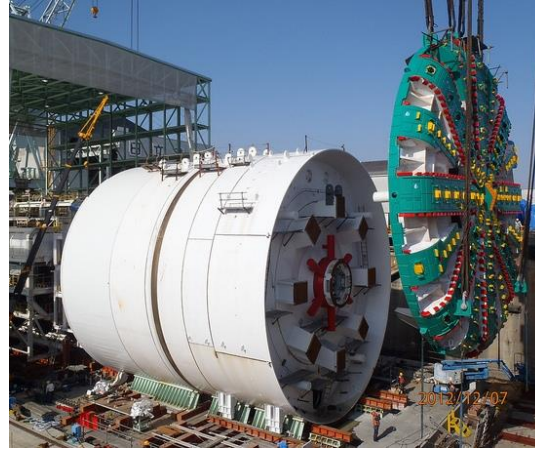


30 Years of Advances in Risk Management for Underground Projects



Dupont Circle Station, DC Metro 1974



Alaskan Way Seattle, TBM 2013



Lake Mead Tunnel Break-thru 2014

RETC Conference, Boston MA June 14th, 2023

John Reilly, Markus Spiegl, Philip Sander, Kevin Lundberg, Daniel Weinberger



Presentation Covers

1. Historical Background re Risk
2. Early Approaches to Risk/Probable Cost
3. Evolution, Risk Management 1990s - 2000+
4. International Megaproject Cost Problems
5. Implementation of Risk-Based Cost Estimating
6. Project Examples, US/European
7. TBM Enhanced Capability using Risk Evaluation
8. The CEVP-RIAAT Process
9. Digital Project Risk Twin Process / Simulation / Results
10. Summary: Risk-Based Cost Estimating Benefits

This presentation is John Reilly's presentation in the RETC Session.

For RiskConsult's presentation, on RIAAT and use of Digital Twin, See www.RiskCon.at

Risk – Historical Background

- The Code of Hammurabi is a well-preserved Babylonian code of ancient Mesopotamia dating back to about 1754 BC some sections relate to management of outcomes/risk
- Some historians believe the concept of risk arose through gaming.
- People in ancient civilizations played games with dice and bones – games that evolved into chess and checkers over 2000 years ago.
- Mutual aid societies have been documented from the earliest days of ancient Rome - considered precursors of modern insurance.
- Historical evidence that gaming gave rise to probability theory comes from writings by Dante and Galileo (many others).
- The mathematicians, Pascal and Fermat, wrote each other about games of chance in the 1600s - a correspondence that is believed to have given rise to modern probability theory.

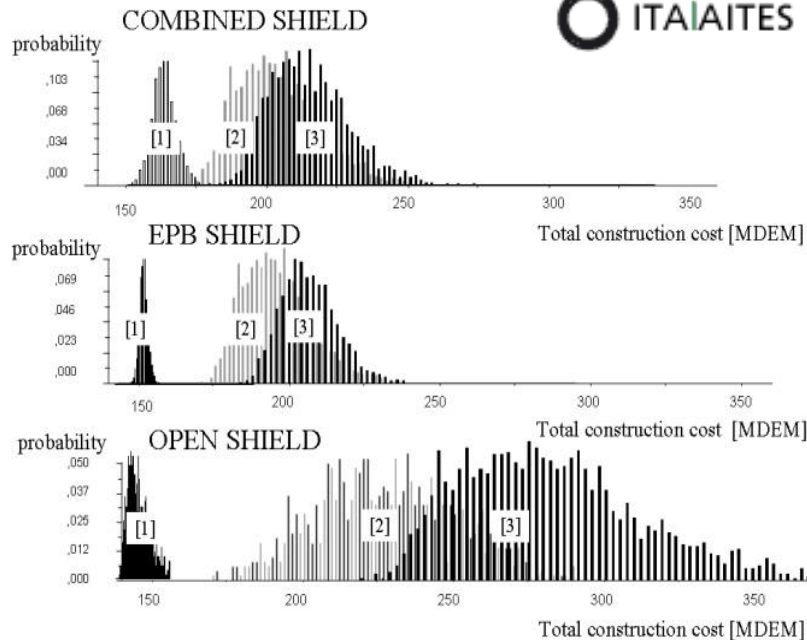
See: "Against the Gods: The Remarkable Story of Risk"

Peter L. Bernstein

Early Approaches to Risk/Probable Cost

Dealing with uncertainty and risk :

- Work on risk for Metro systems (Toronto 1993, LA 1995) and risk management processes with the International Tunneling Association (1997) led to papers on risk for underground construction – first presented 1998 in Melbourne, then in several international cities.
- A concept of base case plus uncertainty was developed in a study of the Grauholz TBM selection – a comparison of probable outcome if using a simple/less costly machine vs. a more sophisticated/expense one.
- Modeling showed that the probable outturn cost of a more expensive mixshield was significantly less than a basic machine.
- This formed the concept of base + probable risk cost as a process to better inform cost estimates for complex projects with substantial risk.



Base case + probable outcomes - cost and schedule for complex tunneling projects - Grauholz study, 1997

Evolution, Tunneling Risk Management 1990s - 2000+

DOCUMENTATION:

- ITA 2004 - Guideline, Tunneling Risk Management
- ITIG 2006 - Code of Practice
- UCA 2009 - Chapter on Risk
- UCA 2015 - Guidelines for Improved Risk Management, Tunnels & Underground



Recommended Contract Practices
for Underground Construction Edited by William W. Edgerton

SME



GUIDELINES FOR IMPROVED RISK MANAGEMENT ON TUNNEL AND UNDERGROUND CONSTRUCTION PROJECTS IN THE UNITED STATES OF AMERICA

Prepared by Joe O'Carroll, P.E., and Bob Goodfellow, P.E.

for and on behalf of the Underground Construction Association of SUE



1 May 2012

A CODE OF PRACTICE FOR RISK MANAGEMENT OF TUNNEL WORKS

2nd EDITION (May 2012)

2007-2014 Lake Mead intake tunnel - fully integrated owner/ contractor advanced risk management process



Risk – John Reilly’s Timeline

- 1996 Los Angeles Metro Green Line - risk workshop, readiness for operations
- 1998 Sir Adam Beck, Niagara Falls tunnel, TBM risk workshop
- 2001 Alaskan Way predesign risk workshops – risk profile
- 2002 WSDOT CEVP Process
- 2003 Brightwater risk-based alternatives
- 2003+ WSDOT Risk Management Planning
- 2003+ FHWA & FTA address cost-risk
- 2005 Alaskan Railroad cost-risk studies
- 2004+ Risk Chapter, UCA Better Contracting Practices
- 2006 Toronto Waterfront CEVP/Risk
- 2008 Mississauga LRT risk workshop
- 2009 Boston DCR Bridge Program
- 2017 FHWA eBook, risk-based costs
- 2017 Lima Peru Airport, integrated cost-risk process in program management
- 2021 Digital Twin



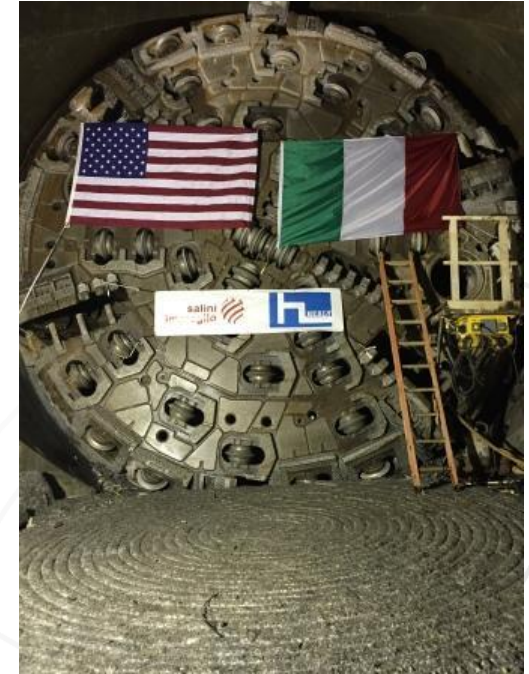
www.JohnReilly.us
“A short history of risk”



RET2023

Owner-Contractor Risk Management, Lake Mead

- Compliance with the ITIG Code
- Contractor and Owner (SNWA) were proactive to “work in partnership” and to use advanced risk management
- Engaged John Reilly to define risk process, risk workshop structure, risk compliance reports
- Advanced risk workshops for sensitive operations – e.g. final drive of TBM into sunken intake structure 330’ deep in lake – focus on inter-dependent risks and correlation of potential events.
- Successful contract from Owner and Contractor’s points of view.



Lake Mead Tunnel Break-thru
December 10 2014

See: Grayson, J., Nickerson, J. & Moonin, E. “Partnering through Risk Management: Lake Mead Intake No. 3. Risk Management Approach”, RETC June 2015 .

Major Cost Overruns Led to Risk-Based Cost Estimating

- Many large, complex transportation and underground construction projects have exceeded their budgets and schedules
- This has led to new management, contracting, cost and risk approaches

Percent = added cost over first announced budget.

Many examples.



London Jubilee Line
+67%



Channel Tunnel +80%



Boston Central Artery +80-100%



Sydney Opera House +1,400%



Golden Gate Bridge:
Cost \$35 million, completed ahead of schedule, under budget by \$1.3 million (3.5%)



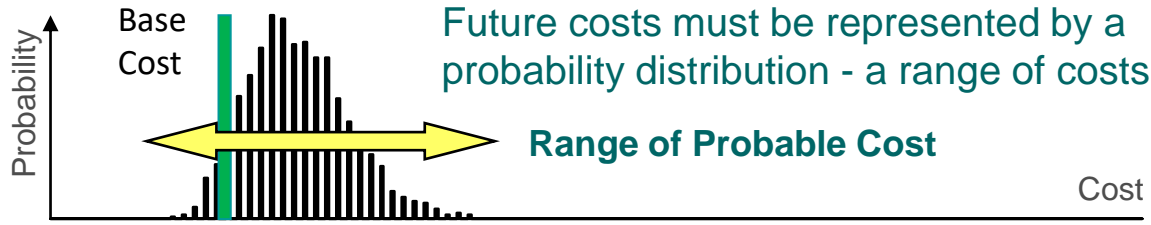
MBTA Boston, Orange Line:
Budget \$750m,
Cost \$743m,
Close to schedule.

Processes to Manage Cost of WSDOT Megaprojects 2002+

- WSDOT Secretary, Doug MacDonald, who had previously managed the successful \$3.8 billion Boston Harbor Project, was responsible for the delivery of several complex megaprojects – tunnels, floating bridges, highways.
- He understood the need for better cost estimating and program management.
- Mike McBride brought cost validation from the MWRA Metrowest Tunnel.
- John Reilly brought risk-based probability methods (US, International) to better estimate the range of probable cost.
- Led to the Cost Estimate Validation Process - CEVP® and a simpler scalable process called Cost-Risk Assessment (CRA).
- Related processes – Quantitative Risk Assessment (QRA) and Probabilistic Risk-Based Cost Estimating (PRBE - FHWA).
- Specifically defining and quantifying risk led to advanced risk management.

WSDOT CEVP Policy – “Range of Probable Cost”

- In the beginning there is a large potential range for a project’s ultimate cost - depending on events that may occur
- WSDOT decided never to use single-point numbers and communicate consistently in ranges of probable cost.



- A single cost number represents only one possible outcome, depending on circumstances and risk events that affect cost
- These circumstances and risk events are not directly controllable or absolutely quantifiable
- The risk events, if they occur, produce consequences which add cost/time to the project (sometimes opportunities)
- Therefore, cost estimation must include risk (i.e. account for uncertainty) using a logical, structured process

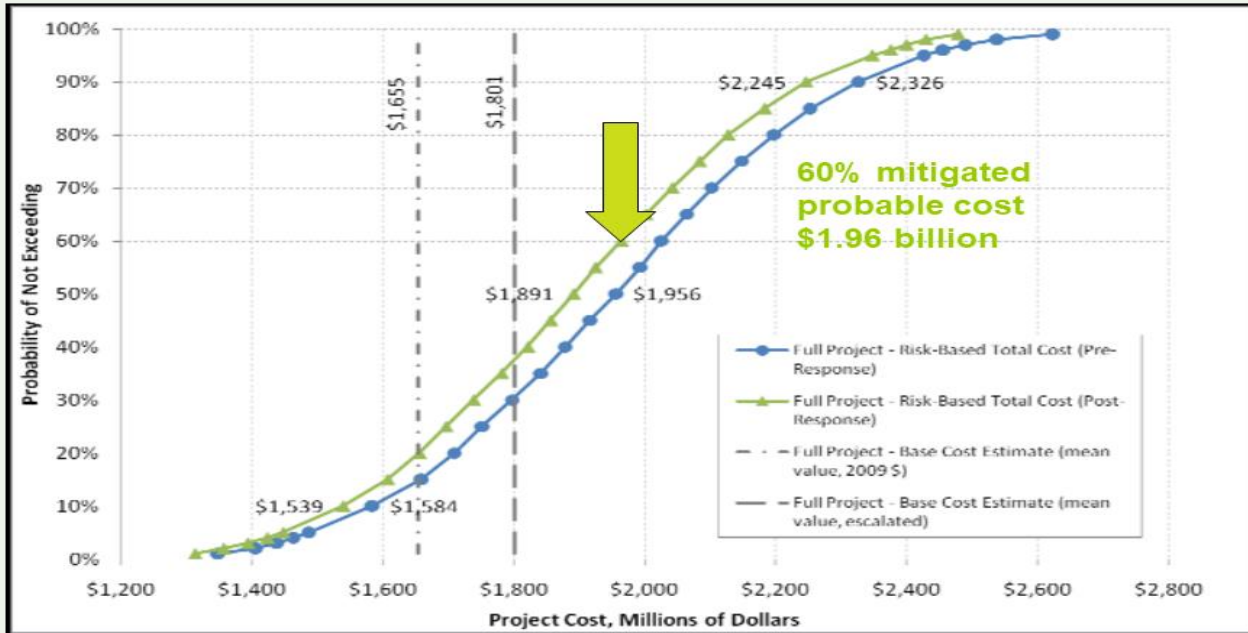
Advanced Implementation – Enhanced CEVP+ and VE

- Alaskan Way Tunnel – how did we shape the project to meet the authorized cost / budget?
- We used advanced CEVP, value engineering and a critical scope evaluation (2nd Avenue).
 - Initial CEVP workshop - recommended P80 CEVP of \$2.2b
 - Legislature authorized \$1.96b ~ 60% probable cost
 - Intensive CEVP+VE workshops to modify the project to meet a 60% probable cost of \$1.96b
 - Final outturn cost? – close to the 80%+ number after major TBM risks eventuated (reference CEVP risk register)

Advanced Implementation – Enhanced CEVP+ and VE

Alaskan Way Viaduct & Seawall Replacement Program

CEVP+ Results



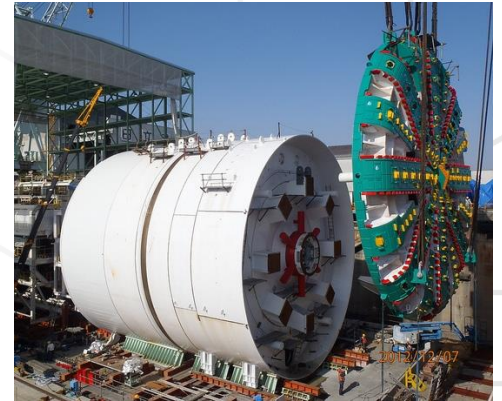
CEVP Examples – does it work?

➤ **Out-turn Performance:**

- WSDOT Alaska Way total program – CEVP 60% \$3.1b, actual \$3.2b (round numbers)
- WSDOT SR520 – CEVP 60% \$3.1b for Lake crossing + East side = actual cost
- WSDOT/ODOT evaluated outcomes for 28 smaller highway projects
 - comparing projects with a CRA vs. no CRA
 - Change order costs were reduced from +10.3% to +3.9% and
 - Schedule changes were reduced from +18.2% to +8.2%

➤ **Risk Identification - Low probability/high impact risks**

- Alaskan Way owner's risk register was extensive and included two risks related to machine breakdown with a combined impact of approximately \$125–180 million (most likely) and \$150–220 (high range) but with probabilities of less than 5%.
- These risks did occur.
- The issue of how to deal with high impact / low probability events is a continuing concern.



TBM - Enhanced Capability using Risk

- Using advanced risk evaluation to allow enhanced-capability TBMs to be considered in a competitive bid process was the subject of an article in TunnelTalk (*Reilly 2021*).
- A TBM manufacturer reported that commercial terms and cost limitations can often preclude the supply of a machine with the tunnelling capabilities and risk mitigation measures that they believe are necessary to reduce risk and result in a successful drive with good cost and schedule performance.
- It was proposed that the contract price could be increased above a defined base by the estimated value of risk mitigation measures.
- The TBM procurement could include a competitive base price for a TBM that meets the owner's prescriptive and performance specifications, with additional monies then authorized to fund additional TBM capabilities related to the estimated value of defined risk reduction measures, if implemented.

Summary

- Risk Management (RM) has advanced substantially in the US and Internationally – both in process & application
- RM process is well understood, guidelines are available
- Advanced RM models are available
- Industry is applying RM principles more extensively
- Federal Agencies and States are involved and active
- Better management processes include definition and quantification of risk (e.g. Lake Mead, Lima, US State Transportation Agencies FTA, FHWA)
- RM educational initiatives have/are being developed (FHWA/NHI eBook))
- We need construction contractors to advance risk management, improve processes and work more directly with owners – particularly for:
 - Interface and “shared risks”
 - To align risk processes to the benefit of owner, contractor and public
- RM should consider “best practices” from other countries (e.g. UK, Australia, NZ, Canada, Europe, Peru)