Outline

- Probabilistic, Risk-Based Integrated Cost and Schedule RA/RM Concepts
- Project Examples
- Summary
Uncertainty in Project Cost and Schedule

- Cost & schedule estimates for large or unique projects are often significantly inaccurate, with corresponding consequences (e.g., Flyvbjerg et. al. 2002)

- A project can be affected by a number of technical and policy variables

- These variables cause uncertainty in cost and schedule:
  - Variations in project conditions assumed for estimates (e.g., in average unit rates, progress rates, escalation rates)
  - Uncertain impacts from unplanned events (deviations from assumptions)

- During project development, information on these variables is typically limited
Probabilistic Cost and Schedule
RA / RM: Objectives

Help mitigate these problems by:

- Quantifying project cost and schedule uncertainty
- Identifying and prioritizing critical risks and key opportunities
- Increasing confidence in the cost and schedule estimates
- Increasing project team understanding and communication
- Enabling Risk Management and Value Engineering studies

Probabilistic Cost and Schedule
RA / RM: Philosophy

- Take a comprehensive look at the project (i.e., not just construction)
- Quantify uncertainty in key project assumptions
- Utilize independent perspective (for validation)
- Employ a collaborative, team approach
- Achieve consensus (and reduce controversy)
- Focus on the key issues
- Identify and evaluate risk-management strategies to improve project performance
- Update as the project changes significantly
Probabilistic Cost and Schedule RA / RM: Concept

Total \approx \text{"Base" } + \text{"Risk"}

Replace contingency with explicit risk and opportunity events (may or may not occur)

Quantify “risk” and uncertainty in “base” to determine uncertainties in total

Integrated Cost and Schedule Model

Activity “Base” Costs and Uncertainties
Activity “Base” Durations and Uncertainties
Risk Events (likelihood of occurrence, and uncertainty in activity cost and duration changes if the event occurs)
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Example Applications

- Transportation:
  - Highways (WSDOT)
  - Bridges (WSDOT)
  - Rapid transit (Pittsburgh, NY PATH, Dallas)
  - Rail (Pittsburgh Maglev, Denmark-Storebaelt)
  - Ports / Airports (SeaTac, Transbay)
  - Tunnels (San Vicente, Caldecott)

- Other Infrastructure:
  - Water supply (San Diego Co)
  - Sewer systems (King Co WA, Hong Kong)
  - Electrical substations (SEPTA)
  - Buildings (NY PATH)
  - Mines / LNG plant (Freeport, Trinidad)
  - Landfills (Cleanaway, RDOS)

100 projects, totaling US $70B capital cost
Floating Highway Bridge

- Old bridge with multiple fixed spans and long floating span
- Carries 115,000 vehicles per day
- Owner considering 3 bridge re-build alternatives, two with additional improvements beyond the ends of the bridge:
  - 4 lanes with “full” improvements (bridge and beyond)
  - 6 lanes with “full” improvements
  - 6 lanes with bridge improvements only (“6 lane partial”)
- Owner wanted to compare cost and schedule for the alternatives, considering uncertainties and risks
- Policy dictates budgeting for the 80th percentile
Floating Bridge – Cost Uncertainty (for the 6-Lane Full alternative)

- Base Cost (No Risk or Opportunity); Unescalated
- With Cost and Schedule Risk and Opportunity; Unescalated
- With Cost and Schedule Risk and Opportunity and Escalation

Impacts on Target Confidence Level or Reliability (80th percentile)

From Risk and Opportunity
$225M

From Inflation
$510M

Floating Bridge – Comparison of Alternatives

Comparison of Alternatives

- 6-Lane Partial
- 4-Lane Full
- 6-Lane Full

Cumulative Probability

Total Project Cost (US$M)

Total Project Cost (YOE US$M)

Project Completion Date

- 18 months (full vs. partial)

- 800M
- 700M
- 600M
- 500M
- 400M
- 300M
- 200M
- 100M
- 0

- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- 100%

- Nov 2013
- Jun 2014
- Dec 2014
- Jul 2015
- Jan 2016
- Aug 2016
- Mar 2017
- Sep 2017
- Apr 2018
- Oct 2018
- May 2019
Floating Bridge – Updating and Risk Management

Impact of Risk Management

Floating Bridge – Uncertainty in Cash Flow of Expenditures

Annual - Mean
Annual - 10th Percentile
Annual - 90th Percentile
Cumulative - Mean
Cumulative - 10th Percentile
Cumulative - 90th Percentile
Water-Supply Tunnel

San Diego, California (US)
alternative shaft locations

Water-Supply Tunnel – Comparison of Alternatives

Difference in cost at 80th percentile as determined from risk assessment. Before RA, costs were assumed to be the same for shallow and deep.

80%

$40M

0% 20% 40% 60% 80% 100%

total escalated cost ($M) or duration (mos after June 2002)

probability of non-exceedance

shallow cost
shallow duration
depth cost
depth duration
Power Substations – Impact of Delayed Funding

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Summary of Benefits

- Clarify and evaluate project delivery strategies
- Validate and improve project estimates
- Quantify uncertainties in project estimates to ensure more realistic expectations
- Quantify key cost and schedule risks and opportunities → provide basis for Risk Management, Value Engineering, and Strategic Planning
- Improve communication (360 degrees)

⇒ save time and money

Summary of Challenges

- Interim validation: the approach appears to be performing better (on average) than traditional estimating, but may still be underestimating the uncertainty

- Challenges:
  - Difficulty convincing owner to include all significant uncertainties and risks (excluding them constrains results)
  - Removing optimism and/or “management bias,” even when they’re known to exist
  - Making results understandable and more useful to owner

⇒ Careful implementation is required to ensure accurate and defensible results