Canadian Society of Value Analysis

Toronto - Markham Holiday Inn

Risk Analysis of Major Transit Investment Costs: Approach and Case Studies

October 24 - 25, 2006

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HDR|HLB Decision Economics

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Cost-Risk Analysis

What is a Cost-Risk Analysis?

A Tool for Management and the Project Team to Use to Control Cost and Risk on Complex Infrastructure Projects

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What are the Expected Results of Holding a Cost-Risk Workshop?

- A better estimate for the project presented as a range of potential costs
- A quantified risk management plan for project planning
- More reliable project cost forecasts for budgeting and bonding

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Cost-Risk Analysis

- To be accountable, we must meet our schedule and budget, however…
  - *Most project budgets and expectations get set early in the planning stage*
  - *A project's final (future) cost is difficult to estimate in the beginning*
  - *Early in a project, event and risk factors that could increase project costs are rarely available to help set and manage budgets*

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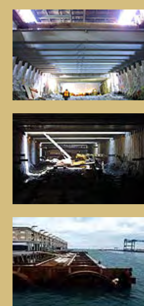
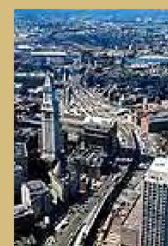
Cost and Budget Problems

- Many large, complex projects have exceeded their budgets and schedules

London Jubilee Line Metro





Boston
Central Artery / Tunnel

Cost growth = final cost compared to cost estimate at time of decision to proceed with project

Many other examples!

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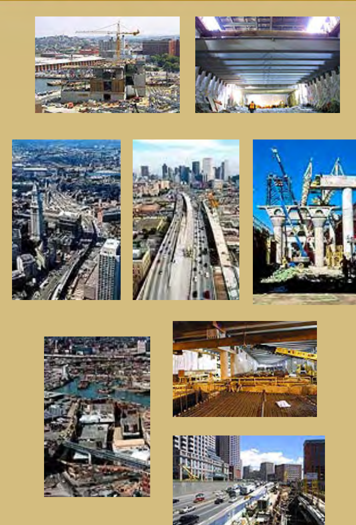
Central Artery/Tunnel Cost $12B More than Original Estimate

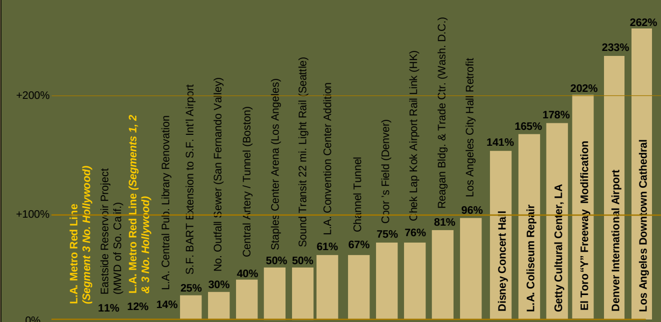
- Complex tunneling and urban road project in the heart of Boston
- Significant "mitigation" requirements added as project developed (new scope?)
- Difficult to manage the project as the budget grew
- Long time period involved, many political changes
- Client change from MHD to MTA



Is this a Unique Example? No, Many Projects Exceed their Budgets!

Examples of Project Cost Growth, US(*)

Percent Over Budget - presented at AUA Conf. Seattle, May 2001



Reference	M 1-31-01	E 1-11-99	M 7-1-98	D 9-6-94	E 3-1-99	D 9-6-94	I 4-3-98	L 3-19-99	E 1-8-01	A 10-12-93	E 1-3-94	X 5-92	U 2-14-96	L 1-25-98	L 12-8-99	L 12-16-94	L 12-97	E 4-24-95	O 6-7-91	E 10-19-98	L 3-5-98
Orig. Est. (in $mil.)	1311	1970	4007	109	1200	19	8000	250	2400	310	9210	123	1560	362	153	110	35	360	55	1500	45
Current Est. or Actual (in $mil.)	1311	2190	4502	125	1500	25	11200	375	3600	500	15350	215	2750	656	300	274	93	1000	166	5000	163

(*) Similar examples exist world-wide

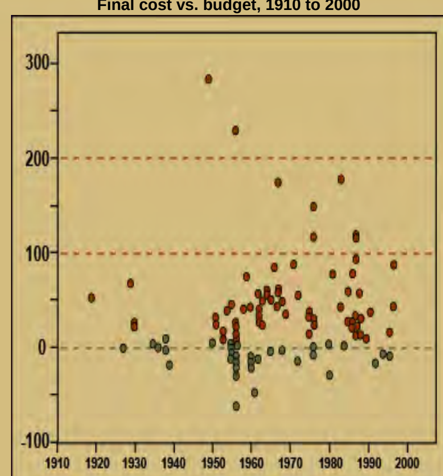
Prepared 2-26-01 by LACMTA Construction Div. Program Mgmt.

Flyvbjerg Study, June 2002 - 258 International Projects

- Cost estimates** have been "systematically misleading"
- A wide range of projects has this problem
- This condition has existed for a very long time (70 years)
- This cannot be explained by normal errors / random results
- Best explained by "strategic misrepresentation"
- <u>How to correct this problem</u>?

** at time of decision to implement

Final cost vs. budget, 1910 to 2000



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Project Management Basics

- Managing a project within an established budget means two things:
  - The budget and schedule must be realistic in terms of the project, its environment and its characteristics.
  - Management must have procedures to control the project with respect to the budget.

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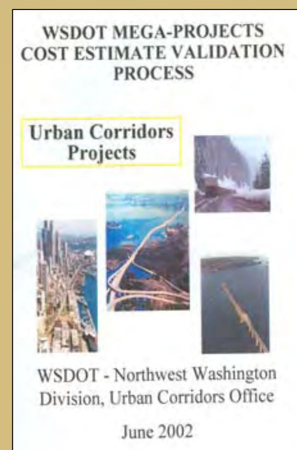
Traditional Estimating/Budgeting Approach

- Quantity takeoffs and unit prices applied to create a base estimate
- Traditional procedures deal with risk by relying on the addition of "contingencies".
- Contingencies usually lump together the consequences of an unspecified number and type of possible problems.
- While based on the "expert" judgment of the estimator or policy of the owner, these contingencies do not allow for explicit identification and management of uncertainties and risk.

Developing a New Way

- In 2002, WSDOT, with accountability to the public in mind, decided there had to be better ways to identify and manage the cost of a project.
- WSDOT asked Michael McBride (then with MWRA), John Reilly of John Reilly Associates, and others to help develop a better cost estimating process, that included identification and management of risk.
- What resulted WSDOT calls the Cost Estimate Validation Process (CEVP®).



Developing a New Way

- Questions that we asked:
  - *How are estimates usually done?*
  - *What is needed to have more confidence in that estimate?*
  - *How would one validate that estimate?*
  - *Are there other ways that project estimates can be presented?*
- Key conclusions:
  - *We need to examine the project team's cost assumptions using independent experts to "validate" the base cost estimate.*
  - *We need to include risk (i.e., uncertainty) using statistical risk and decision analysis methods.*
  - *We need to introduce the concept of a "range of probable cost".*

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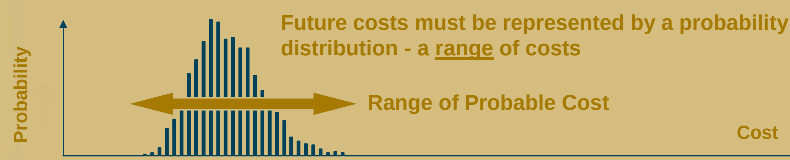
A Key Concept – "Range of Probable Cost"

- A single cost number represents only *one possible result,* 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 and when they occur, produce impacts which add cost or time to the project.
- There is a large potential range for a project's ultimate cost - depending on events that may occur.



- Therefore, cost estimation must include risk (i.e., account for uncertainty) using a logical, structured process.

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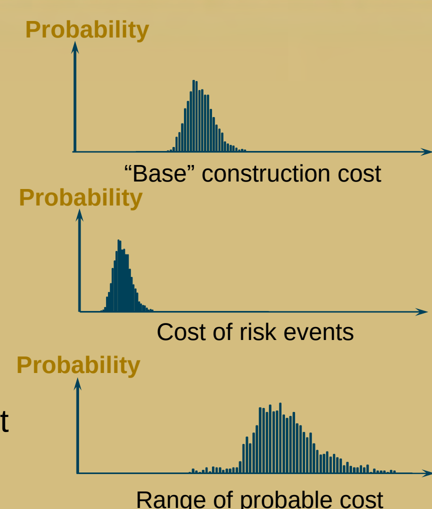
A Logical Approach – Base Cost + Risk Cost * = Range of Probable (Future) Cost

* Risk cost is normally called "contingency"

1. Determine the "Base Cost" (normal cost with variance)
2. Add Cost for risk events (risk = probability x consequences)
3. Range of probable project cost



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Determining the "Base Cost" by Doing a "Due Diligence" Review

- Concept developed based on a comprehensive program estimate review on a $700+ million, 17.6-mile water supply tunnel program in Boston, MA.

Photography by Regina Villa Associates

Metrowest Water Supply Tunnel
Michael McBride, Project Director

- Subject Matter Experts (SME's), including those with Contractor Experience, who have estimating and project delivery experience, gathered to conduct a due diligence review with the project team and adjust as necessary.

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Base Cost Determination

- Consider the basis of the estimate at the particular stage of the project.
  - Is it a construction estimate or a project/program estimate?
  - Does it include planning, design, construction (escalated to midpoint), services during construction, startup costs?
  - Is the Project Team's proposed schedule realistic?
  - What are our assumptions? Where do they come from?
  - How valid are they? How do we know?
  - What do we know we know some sense of certainty? (components, units, prices)

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Base Cost Determination

What do we know but can't quantify? (allowances)

What is in the estimate to cover what we know that we don't know? (normal uncertainty)

What is in the estimate to cover what we don't know that we don't know? (gross uncertainty)

} Contingencies

- Work with the project team and adjust the estimate as necessary
- Remove all contingency, i.e., provision for unknowns
- Determine the "Base" cost – the most probable cost that can be expected <u>if the project goes exactly as planned</u>.

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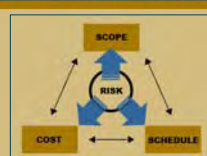
The Context – Risk Exposures



Risk Causes

- Technical issues
- Geological uncertainty
- Environmental requirements
- Funding uncertainty
- Pricing uncertainty
- Strategic issues
- Contractual conditions
- Staff capability
- Available resources
- Location problems
- Political requirements
- Public acceptance
- Historical factors
- Cultural factors

Risk Impacts

- Budget Risks
  - *Risk that budget elements (unit prices, quantities) will deviate from the estimate.*
- Event Risks
  - *Risk of internal or external events that force the project team to work beyond the estimate just to meet the Project Scope and SOW.*
- Scope Risks
  - *Risk of significant changes to project scope due to external pressures.*

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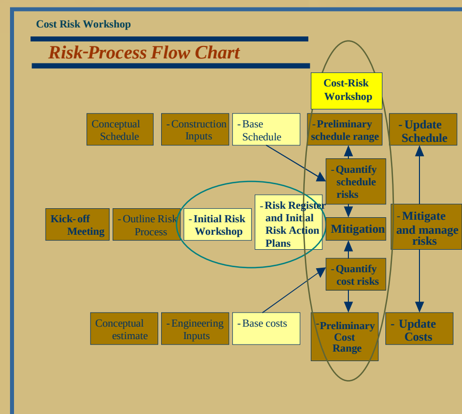
Cost-Risk Modeling Process

1. A kickoff meeting is held with the project team to introduce the process. The project scope, estimate and schedule are presented and discussed with the cost-risk consultant, the subject matter experts and the project team.
2. Discussions are then held between the cost review lead, the subject matter experts and the project team to review the estimate, make adjustments if any, and develop the base estimate.



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Cost-Risk Modeling Process

3. The initial risk workshop is held with the expert panel to:

   a. Develop a project flow chart considering durations, links and constraints

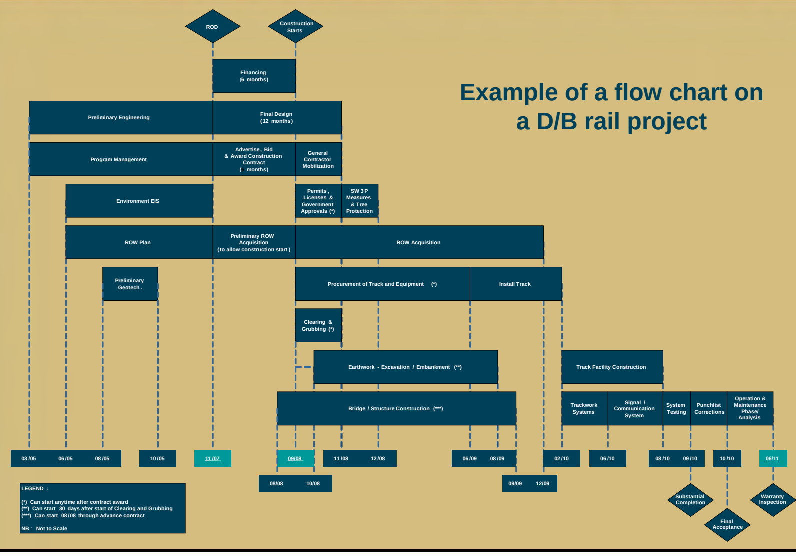
   b. Develop the initial risk register and the initial opportunity register – events, benefits and probabilities

   c. Quantify the risks and opportunities and identify where they occur in the flow chart.

4. Using the RAP® Process, run the first cost-risk model and the Monte Carlo Simulations to develop the initial range of probable cost for the project.

5. Develop report and input to the Risk Management Plan.

Develop Project Flow Chart and Duration



Example of a flow chart on a D/B rail project

Identify Risk and Opportunity Events

Example:

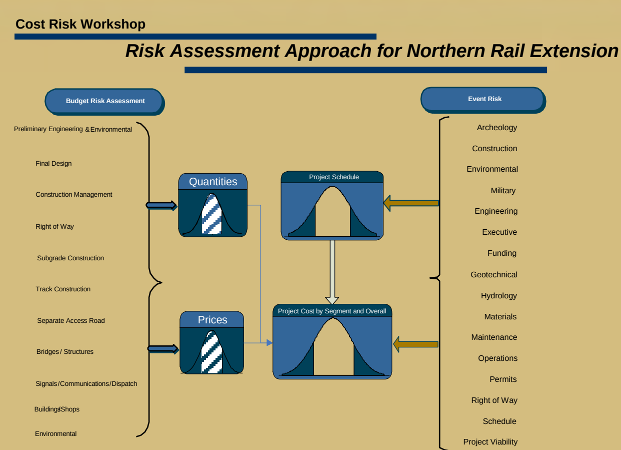
Risk Event	Risk Description	Type of Risk	Probability	Cost Impact ($)	Schedule Impact
Construction Resources - people	Currently, the construction market in this part of the state is booming, skilled labor and materials are in short supply. Contractors attracted to higher profit, lower risk projects such as gas pipeline.	Cost and Schedule	75.0%	$25,000,000	6.0
Embankment impacts on permafrost	Permafrost degradation could lead to high O&M. Understanding the variability in load capacity of the subgrade will dictate engineering design parameters.	Cost	50.0%	$28,000,000	0.0

Identify Risk and Opportunity Events

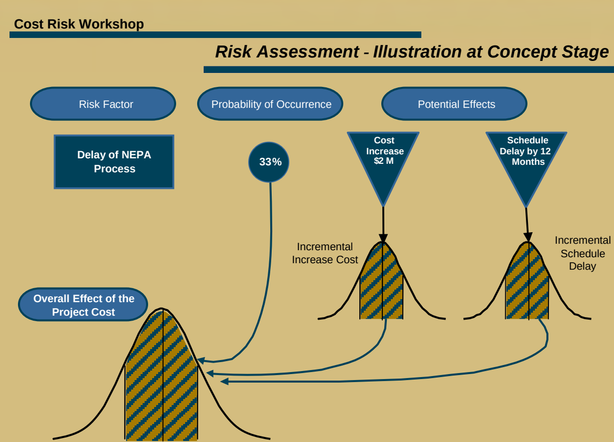
Example:

Opportunity Description	Probability	Cost Benefit ($)	Schedule Benefit
Eliminate Access Road	50.0%	$45,000,000	6 mo
Contract Term (Incentives)	40.0%	$40,000,000	8 mo
Change Control from CTC to DTC	20.0%	$13,000,000	2 mo

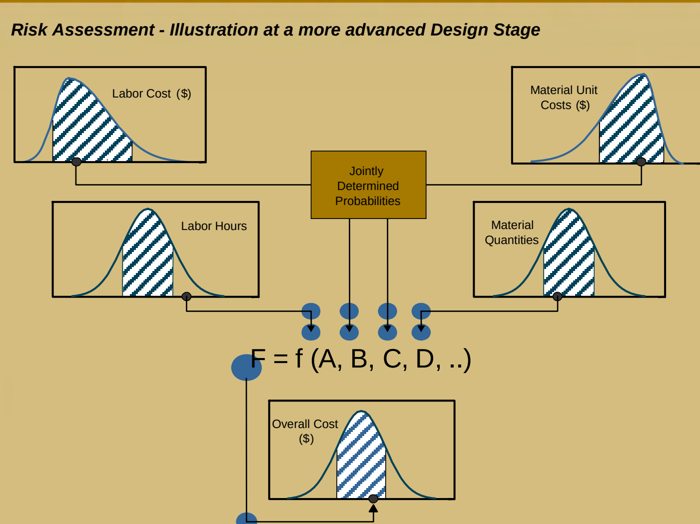
Incorporating Event Risks and Opportunities



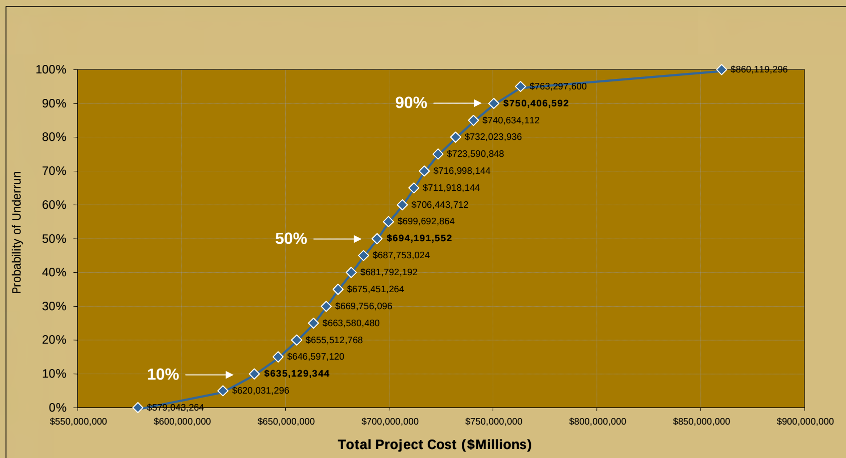
Applying Event Risks and Opportunities



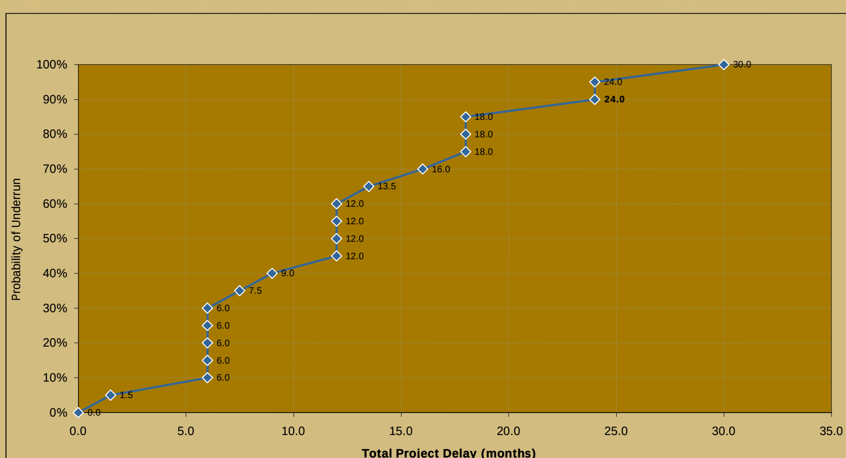
Monte Carlo Simulations and Risk-Adjusted Cost Outcomes



Products of the Workshop: Range of Probable Costs



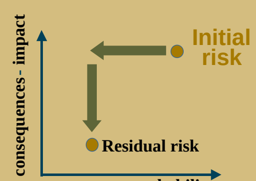
Products of the Workshop: Range of Potential Schedule Impacts



Risk Mitigation

Risk Mitigation

"No construction project is risk free. Risk can be managed, minimized, shared, transferred, or simply accepted, but it cannot be ignored."
(Managing Geotechnical Risk, C.R.I. Clayton, 2001)



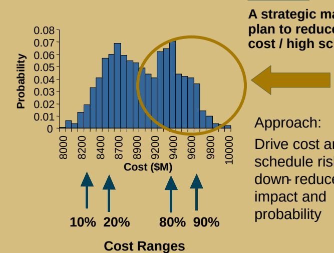
Impact The effect on the project or its objectives, measured in terms of safety, cost, schedule delay, quality of construction or other requirement.
Probability Chance of an event occurring
Risk Combination of impact and probability
Residual risk risk remaining after primary risks are mitigated

Risk Mitigation

Cost-Risk Process: FTA/WSDOT [(1)]

Cost & Schedule Models

We can, however, develop strategies to manage risk through design and construction to force the ultimate project costs towards the lower ranges.



NEXT STEP:
A strategic management plan to reduce the high cost / high schedule risks

Approach:
Drive cost and schedule risk down- reduce impact and probability

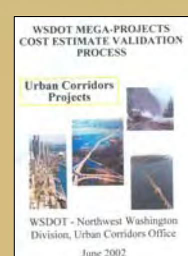
[(1)] WSDOT's CEVP process led to FTA's Risk Assessment Policy

Examples of Risk Mitigation

- Modified contract packages and terms
- Early purchase of critical or long-lead items
- Early purchase of Right-of-Way or lease of staging areas
- Additional geotechnical investigation to better define risk
- Enhanced public participation
- Negotiating community agreements upfront

The Expanding Use of Cost-Risk Analysis

- WSDOT initially applied the CEVP® Cost-Risk process on 9 large, complex projects with a collective value of $25 billion, for approximately 0.01% of project costs.
- More realistic cost ranges led to decisions about what could be built within the available budget.
- Better communication with political decision-makers and the public regarding realistic cost ranges.
- Risk mitigation plans are being used as a management tool.
- WSDOT found the expert review very valuable and adopted the CEVP process for other major projects.
- WSDOT holds CEVP updates as the projects progress through planning and design.


WSDOT MEGA-PROJECTS
COST ESTIMATE VALIDATION PROCESS

Urban Corridors Projects

WSDOT - Northwest Washington Division, Urban Corridors Office

June 2002

"Shocking or not, the Department of Transportation has performed an unprecedented public service with these latest cost estimates. It is a much-needed dose of fiscal reality."

Seattle Post Intelligencer
June 9, 2002

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The Expanding Use of Cost-Risk Analysis

- MWRA used a Cost-Risk Analysis to establish a program budget for the $310 million North Dorchester CSO Tunnel Program.

- Cost-Risk Analysis following CEVP have been adopted by the U.S. Federal Transit and Federal Highway Administration. Policy memoranda have been issued to this effort.

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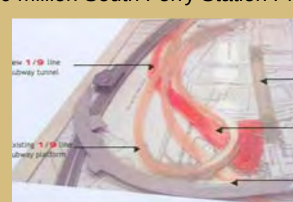
HDR Projects Using Cost-Risk Analysis

- HDR|HLB currently provides risk analysis services to the Lower Manhattan Recovery Office of the Federal Transit Administration. Recent projects include risk assessments of:

$750 million construction of the Fulton Street Transit Center

$400 million South Ferry Station Project



"MTA Digs for Train Station, but Crew Hits a Wall Again."
New York Times
January 23, 2006

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Project Overview

Initial Schedule:

$750 million FTA Grant Awarded - December 2003

Completion of Environmental Review Process - November 2004

Start of Construction - July 2005

Completion of Construction - June 2009

Fulton Street Transit Center:

Multi-level complex of stations to serve 12 different subway lines and over 275,000 daily commuter trips.

Direct link to the new PATH Terminal and the World Trade Center site.

"The existing maze of narrow ramps, stairs and platforms will be transformed into a more spacious and rational configuration, allowing for easier transfers and better access from street level."

http://www.fta.dot.gov/regions/LMRO/regional_offices_929.html

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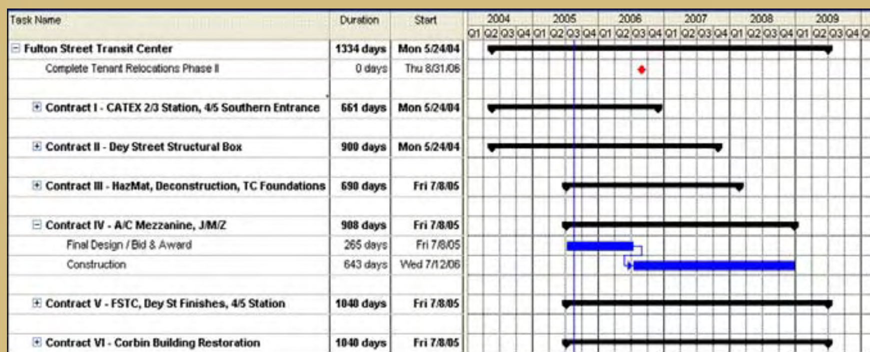
Baseline Cost Estimates
(Including Escalation and Contingencies)

DESCRIPTION	Contract I - 2/3 Station Rehabilitation and 4/5 South Entrances	Contract II - Dey Street Concourse Structural Box	Contract III - Deconstruction, Hazmat and Foundations	Contract IV - a/c Mezzanine and J/M/Z	Contract V - FSTC, Dey Street (Finishes), 4/5 Rehabilitation	Contract VI - Corbin Building Restoration	Project Costs (No Specific Contract)	Total Project Estimate
BID COST (ESCALATED)	$ 33,987,000	$ 133,189,664	$ 44,026,839	$ 61,265,930	$ 187,935,798	$ 16,576,324	$ -	$ 476,981,555
EIS WORK	$ 320,623	$ 1,256,471	$ 415,336	$ 577,964	$ 1,772,929	$ 156,376	$ -	$ 4,499,699
EIS WORK UPDATE	$ -	$ -	$ -	$ -	$ 300,000	$ -	$ -	$ 300,000
DESIGN COST - CONSULTANT PE DESIGN SERVICES	$ 2,885,399	$ 11,307,422	$ 3,737,753	$ 5,201,302	$ 15,955,212	$ 1,407,282	$ -	$ 40,494,370
DESIGN COST - NYCT PE DESIGN SERVICES	$ 572,648	$ 2,244,115	$ 741,809	$ 1,032,271	$ 3,166,534	$ 279,295	$ -	$ 8,036,672
DESIGN COST - CONSULTANT FINAL DESIGN & PHASE III DESIGN SERVICES	$ -	$ -	$ 2,706,052	$ 4,038,526	$ 19,255,545	$ 1,060,057	$ -	$ 27,060,180
DESIGN COST - NYCT FINAL DESIGN SERVICES	$ -	$ -	$ 304,876	$ 419,493	$ 1,182,276	$ 550,491	$ -	$ 2,457,137
CONSTRUCTION ADMINISTRATION - NYCT	$ 1,734,969	$ 2,814,669	$ 517,218	$ 1,993,636	$ 5,873,239	$ 1,630,320	$ -	$ 14,564,051
CONSTRUCTION ADMINISTRATION AND CONTINGENCY - CONSULTANT CONST. MGMT TEAM	$ 1,587,907	$ 6,124,785	$ 2,041,595	$ 2,948,970	$ 7,259,004	$ 907,376	$ -	$ 20,869,637
TA LABOR	$ 4,487,201	$ 13,774,461		$ 3,678,278	$ 3,971,598			$ 25,911,538
PROPERTY COSTS & RELOCATION COSTS FOR 140 TENANTS		$ -			$ -		$ 123,225,000	$ 123,225,000
UTILITY FEE ALLOWANCE	$ 2,205,000	$ 2,703,750		$ 3,125,000	$ -			$ 8,033,750
ARTWORK ALLOWANCE	$ -				$ -		$ 1,635,000	$ 1,635,000
CONTINGENCY (AWO'S) - 5% OF BID COST W/ AFI	$ 1,699,350	$ 6,659,483	$ 2,201,342	$ 3,063,297	$ 9,396,790	$ 828,816	$ -	$ 23,849,000
PA INTERFACE AT THE WEST END OF THE DEY STREET PROJECT	$ -				$ -		$ 1,000,000	$ 1,000,000
NYCT PURCHSED EQUIPMENT (IE TURNSTILES, HEETS, ETC.)	$ -				$ -		$ 3,000,000	$ 3,000,000
SENIOR MANAGEMENT / MTA PROJECT RESERVE	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,082,411	$ 3,082,411
PROJECT COST	$ 49,480,097	$ 180,074,820	$ 56,692,820	$ 87,344,667	$ 256,068,925	$ 23,396,338	$ 131,942,411	$ 785,000,000

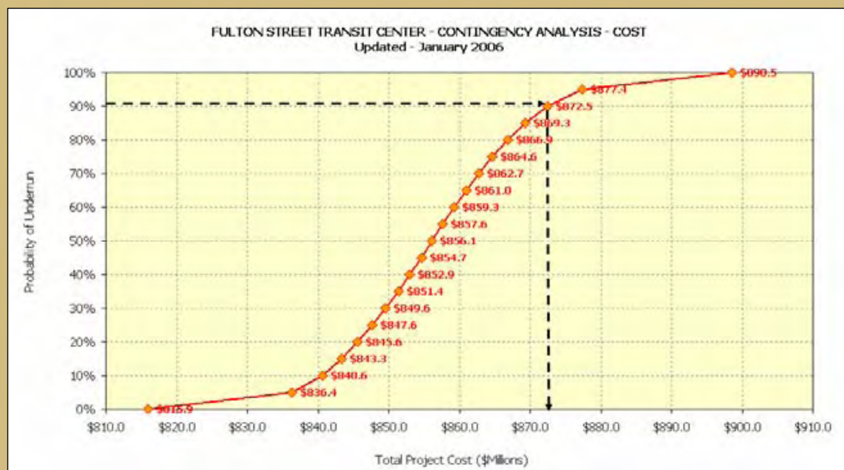
Project Flowchart
(Baseline Durations and Project Completion)



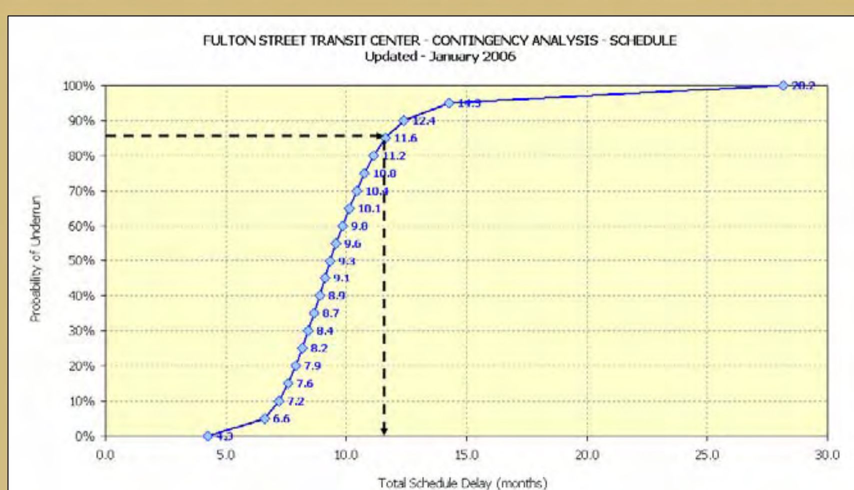
Risk Register
(Examples of Event Risks and their Cost Impacts)

Contract Impacted	Risk Type	Risk Description	Probability of Occurrence	Distribution	Cost Impacts ($ thousands)		
					Low	Most Likely	High
PKG1	Construction	Decking	75%	Triangular	$0	$100	$250
PKG1	Construction	Design changes during construction	100%	Triangular	$750	$1,100	$1,500
PKG1	Utilities	Unforeseen additonal work	100%	Triangular	$0	$250	$500
PKG1	Signal	Signal cabinet	5%	Discrete	$0	$0	$1,000
PKG1	Scope changes	Deletion of A/C to 2/3 Stair	100%	Triangular	-$1,000	-$500	$0
PKG2	Construction	Structural damage to project/adjacent properties - contractor assumes any monetary impact - reflected in bid.	5%	Discrete	$0	$0	$250
PKG2	Construction	Impacts to local businesses	20%	Pert	$0	$0	$50
PKG2	Construction	Design changes during construction - Owner-Driven	100%	Triangular	$100	$300	$500
PKG2	Construction	Additional Utility Work Scope (all utilities)	50%	Triangular	$0	$50	$100
PKG2	Construction	Differing field or latent conditions - AWOs	50%	Triangular	$350	$700	$1,400
PKG2	Construction	Stabilizing the Corbin Building	50%	Triangular	$0	$500	$1,000
PKG2	Construction	Differing field/subsurface conditions	50%	Triangular	$100	$300	$500
PKG5	Construction	Structural damage to project/adjacent properties (Corbin, 144 Fulton, etc.)	5%	Discrete	$0	$0	$1,000
PKG5	Construction	Changes to Account for Difficulties (Dome..etc.)	25%	Pert	$0	$500	$1,000
PKG5	Construction	Sequencing of work among sub-contractors	10%	Discrete	$0	$150	$250
PKG5	Construction	Design changes during construction	100%	Triangular	$1,250	$2,500	$5,000
PKG5	Construction	Unexpected potential damage to existing A/C tunnel structure	5%	Discrete	$0	$0	$1,000
PKG5	Construction	Differing field or latent conditions - AWOs	50%	Triangular	$700	$1,400	$2,800
PKG6	Environmental - Historical	Corbin Building - Historic	50%	Triangular	$500	$1,000	$2,000
PKG6	Site risk	Hazardous materials	10%	Discrete	$0	$0	$150
PKG6	Construction	Undiscovered/latent conditions in Corbin Building	50%	Triangular	$0	$750	$1,500
PKG6	Construction	Differing field or latent conditions - AWOs	50%	Triangular	$170	$350	$700

Project Cost Distribution



Schedule Delay Distribution



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Identification of Key Risks

Top Five Cost Risks and Mitigation Strategies:

- Corbin Building integration: The extended PE effort includes more comprehensive designs for adaptive re-use of the Corbin Building.
- Complex construction of Dome/Oculus: MTACC is developing procurement strategies to mitigate risks related to the complexities of the dome/oculus design.
- Property acquisition and relocation delays: MTACC is developing a comprehensive property acquisition and relocation plan and integrating it with the new construction packages.
- Differing field/subsurface conditions: Borings and utility test pit investigations are being performed on the site. The results of this work may provide a better understanding of the potential impacts of this risk.
- Interference with other Lower Manhattan projects: MTACC is coordinating with other agencies to develop a plan to manage access to construction sites and minimize the impact of short and long term street closures.

Top Five Schedule Risks and Mitigation Strategies:

- Property acquisition and relocation delays: MTACC is developing a comprehensive property acquisition and relocation plan.
- Delays in the environmental review process: The ROD has already been delayed 3 months resulting in Extended PE costs and a request to further extend PE. MTA must ensure that there is no further delay in obtaining the ROD.
- Complex construction of Dome/Oculus: MTACC is developing procurement strategies to mitigate risks related to the complexities of the dome/oculus design.
- Corbin Building integration: The extended PE effort includes more comprehensive designs for adaptive re-use of the Corbin Building.
- Environmental compliance (Section 106): The MTACC is developing an MOA, in consultation with the SHPO, to address properties protected under Section 106, including the Corbin Building.

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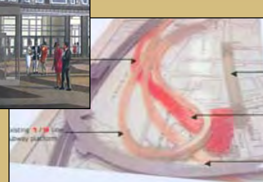
Project Overview



Initial Schedule:

$420 million FTA Grant Awarded - December 2003

Completion of Environmental Review Process - August 2004

Start of Construction - March 2005

Completion of Construction - May 2008

South Ferry Terminal Station:

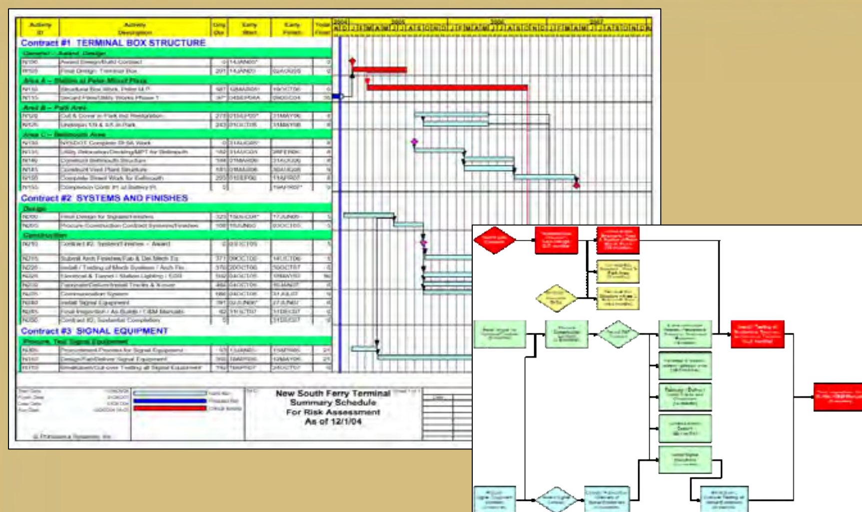
Last station at the southern end of the 1/9 subway lines in Manhattan.

Terminal will replace the functionally obsolete station under Battery Park that serves Staten Island Ferry riders.

Project will convert the single track, five-car loop station into a three-track, 10-car, stub end two-platform terminal with new access for disabled riders and better connections to the renovated Staten Island ferry terminal and the R and W subway lines.

http://www.fta.dot.gov/regions/LMRO/regional_offices_929.html

Project Flowcharts
(Baseline Durations and Project Completion)



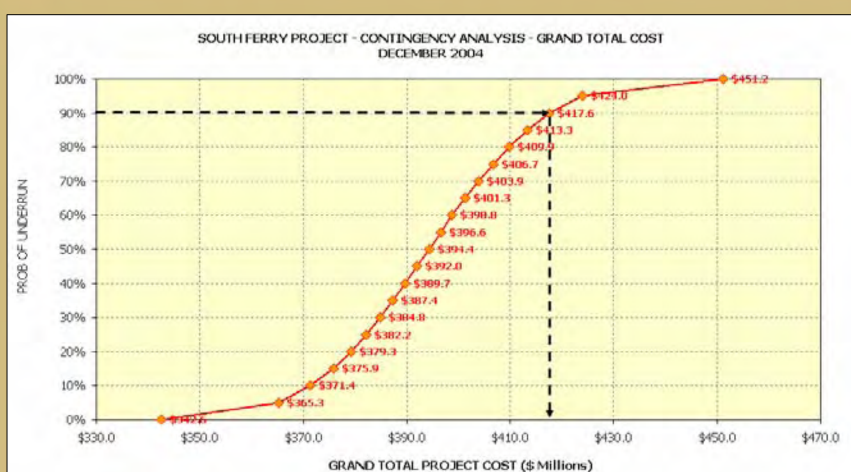
Baseline Cost Estimates
(Including Escalation and Contingencies)

DESCRIPTION	STRUCTURAL BOX CONTRACT EAC	FINISHES CONTRACT EAC	SIGNAL EQUIPMENT PURCHASE CONTRACT EAC	SECANT PILING WORK - EDC	REPHASING WORK - EDC	PARK MITIGATION WORK	ROUTE 9A - TRANSIT PORTION	TOTAL (FTA FUNDING PORTION)
BID COST	$ 231,600,000	$ 71,000,000	$ 12,500,000	$ 9,418,513	$ 1,950,230	$ -	INCL W / STRUCT. BOX EAC	$ 326,468,743
AFI	$ 10,000,000	$ 5,000,000	$ 625,000	$ -	$ -	$ -	$ -	$ 15,625,000
ENVIRONMENTAL REVIEW	$ 500,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 500,000
DESIGN COST - PE	$ 6,500,000	$ 1,000,000	$ -	$ -	$ -	$ -	$ -	$ 7,500,000
DESIGN COST - FINAL DESIGN	$ -	$ 4,000,000	$ -	$ -	$ -	$ -	$ -	$ 4,000,000
CONSTRUCTION ADMINISTRATION	$ 7,800,000	$ 8,000,000	$ -	$ 982,025	$ -	$ -	$ -	$ 16,782,025
TA LABOR	$ 10,000,000	$ 2,000,000	$ -	$ -	$ -	$ -	$ -	$ 12,000,000
CONTINGENCY (AWOS)	$ 12,080,000	$ 3,800,000	$ -	$ 892,750	$ -	$ -	$ -	$ 16,772,750
UTILITY FEE	$ 1,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,000,000
ARTWORK ALLOWANCE	$ -	$ 1,000,000	$ -	$ -	$ -	$ -	$ -	$ 1,000,000
PARKS MITIGATION RESERVE	$ -	$ -	$ -	$ -	$ -	$ 15,076,000	$ -	$ 15,076,000
SENIOR MANAGEMENT / MTA PROJECT RESERVE	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL PROJECT COST	**$ 279,480,000**	**$ 95,800,000**	**$ 13,125,000**	**$ 11,293,288**	**$ 1,950,230**	**$ 15,076,000**	**$ -**	**$ 416,724,518**

Risk Register
(Examples of Event Risks and their Cost Impacts)

Contract Impacted	Risk Type	Risk Description	Probability of Occurrence	Distribution	Cost Impacts ($ thousands)		
					Low	Most Likely	High
Box	Construction	Underpinning Existing Subway Lines	40%	Triangular	$0	$0	$3,500
Box		Undiscovered utilities	50%	Triangular	$0	$0	$3,500
Box	Construction	Fan Plant - relocate Fan Plant on top of Tunnel	30%	Triangular	-$15,000	$0	$0
Box	Construction	Actual conditions vary from assumed conditions during box construction (water)	5%	Discrete	$0	$0	$750
Box	Environmental	Archeological finds and curation	10%	Discrete	$0	$0	$1,000
Box	Environmental	Hazardous materials	15%	Discrete	$0	$0	$750
Box	Organizational	Labor issues (such as strikes)	10%	Discrete	$0	$0	$200
Box	Organizational	Sequencing of work among contractors/Delays due to Hazmat and others	15%	Discrete	$0	$0	$200
Box	Construction	Delay in execution of Construction Agreement	50%	Triangular	$0	$0	$500
Box	Environmental	Force majeure (extreme weather event)	50%	Triangular	$0	$0	$50
Box	Management	QA/QC	5%	Discrete	$0	$0	$200
Box	Construction	Interferences with Other Lower Manhattan Projects	10%	Pert	$0	$0	$100
Finishes	Management	Scope Reductions - finishes, cladding, column coverings, etc.	30%	Triangular	-$3,000	$0	$0
Finishes	Organizational	Communications Equipment - obtain some equipment from TA	30%	Triangular	-$1,000	$0	$0
Finishes	Organizational	Fare Array Equipment - obtain from TA	75%	Triangular	-$600	$0	$0
Finishes	Organizational	Sequencing of work among contractors	20%	Triangular	$0	$0	$250
Finishes	Organizational	Design errors and omissions	10%	Discrete	$0	$0	$200
Finishes	Organizational	Contractor non-performance	5%	Discrete	$0	$0	$100
Finishes	Organizational	Coordination with R/W	10%	Pert	$0	$0	$50
Finishes	Construction	Utility relocations	10%	Pert	$0	$0	$10

Project Cost Distribution



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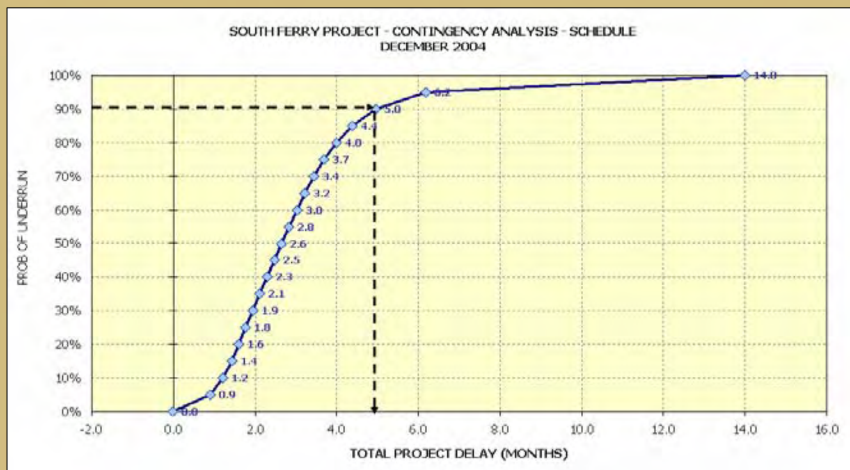
Schedule Delay Distribution



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Identification of Key Risks

<u>Top Five Cost Risks and Mitigation Strategies</u>:

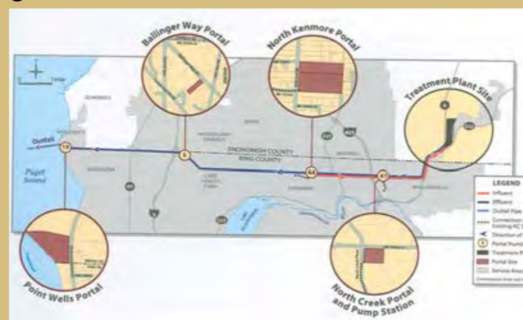
- Escalation (Budget Risk): MTACC based its cost estimate on an escalation of 3% APR. Recent history of construction in New York suggests a higher escalation rate. Escalation included in bid pricing for the structural box contract will be reviewed to refine the estimated escalation rate.
- Indirect Costs (Budget Risk): Magnitude of the indirect costs and their potential variability.
- Quantities: Mining, Underpinning, Rock Excavation (Budget Risk): MTACC did not provide quantity estimates in the D/B bid documents. MTACC has received contractor input regarding quantities and may provide estimated quantities to the proposers to support the BAFO process.
- Labor productivities: Mining, Underpinning, Rock Excavation (Budget Risk): Contractor bids for the D/B structural box will establish productivity rates for these elements of the project.
- Quantities: Station Work/Escalators/ Elevators/Pump Room (Budget Risk): Future design work will define these program elements and associated costs with more certainty.

<u>Top Five Schedule Risks and Mitigation Strategies</u>:

- Sequencing of work among contractors: MTACC is defining contractor work schedules to reduce conflicts between contractors.
- Acquisition of permits: MTACC attends monthly interagency coordination meetings to resolve permitting and other issues.
- QA/QC: MTACC will provide a construction QA/QC plan.
- Interferences with other Lower Manhattan projects: MTACC is coordinating with other agencies to develop a plan to manage access to construction sites and minimize the impact of short and long term street closures.
- Structural damage to project/adjacent properties: The D/B structural box contract includes requirements for monitoring to detect potential damage and limits construction techniques.

HDR Projects Using Cost-Risk Analysis

- King County, Washington - Brightwater Influent/Effluent Tunnel Program



- Pittsburgh, Pennsylvania - North Shore Connector Program Management for Port Authority of Allegheny County

Summary: Reasons to Use a Cost-Risk Analysis

- Develop consensus around uncertainties and enhance confidence in estimates.
- Identify key risk factors and facilitate mitigation strategies.
- Better information for budgeting, scheduling, deal structuring, pricing and/or risk management.
- Increased likelihood of delivering project on budget and schedule.