CALIFORNIA
High-Speed Rail Authority

REPORT

Update to Peer Review Group of work in progress on O&M Cost Risk and Monte Carlo Analysis

San Francisco
July 9th, 2013

FINAL

Disclaimer

All results presented in this report are based on preliminary model runs with final inputs and assumptions still being developed. All numbers should be considered draft and subject to change as the model is finalized.

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There are two risk analysis approaches to determine the risk exposure attached to the O&M cost forecasts

Risk Analysis Methodologies

Bottom-up

- Identifies individual risks/ uncertainties and then quantifies and correlates these individual risks (where appropriate) before running Monte Carlo simulations to determine potential cost outcomes and associated confidence levels.
- A specific dollar value for risk exposure is determined by the difference between the basis estimate or 'planned cost' and the desired confidence level on resulting distribution or S-curve, e.g. 80%

- Bottom-up analysis is based on identifying and assessing individual risks and using Monte Carlo analysis to determine their potential cumulative impact or cost

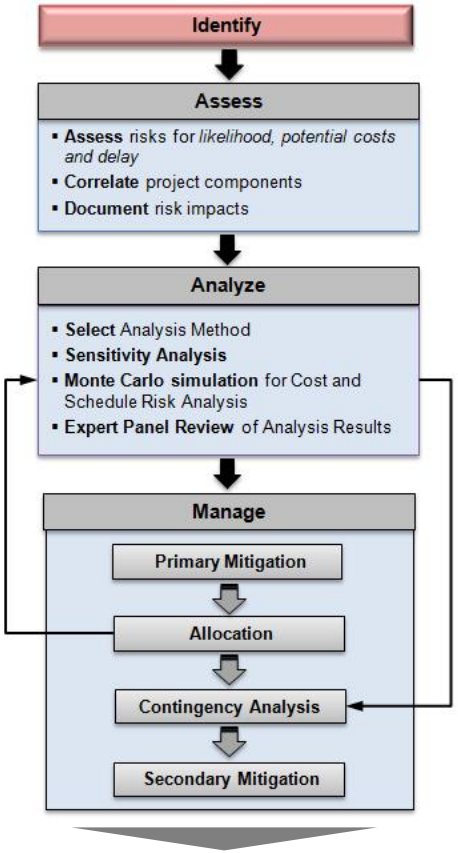
Top down or Reference Class

- Determines the overall risk exposure for a given project based on actual performance of a reference class of comparable projects.
- For Reference Class approach, the specific dollar value for risk exposure is determined as for Bottoms-up – the only difference is that the 80th percentile value is selected from a curve determined by outcomes of reference class projects as opposed to various combinations of individual risks and impacts

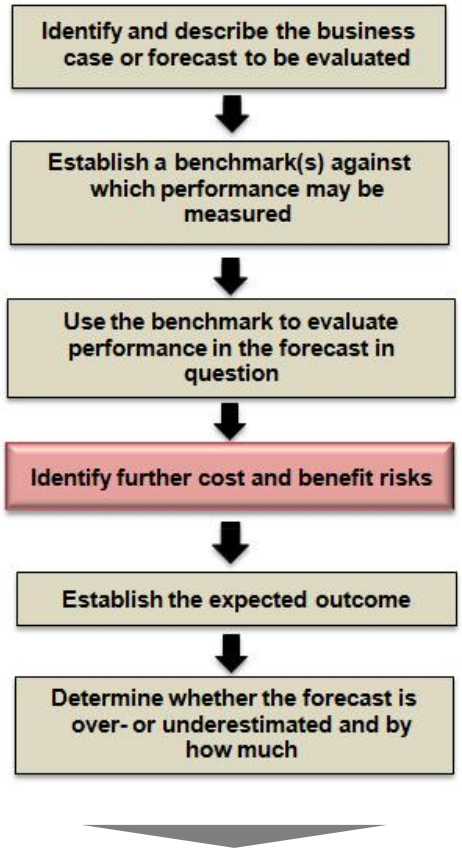
- Top down bases its Monte Carlo analysis on the outcomes of past, similar projects, using these outcomes to define its risk exposure curve

Each approach offers an alternative perspective of the risk exposure attached to a given project

Bottom-up Process



Top-down Process



The bottom-up process is what is traditionally thought of when analyzing project risks and takes an 'insiders' view of the project to determine risk exposure, identifying, assessing, analyzing and managing individual risks particular to the project

The Top-down approach takes the outsider's view – How have similar projects turned out in the past

Pros and Cons in each approach need to be well understood from the analysis perspective

Strengths and Weaknesses of Each Approach

Bottom-up

Strengths:

- Actual project is examined to determine risks particular to the assumptions, context and objectives of CHSRP
- Risks identified and assessed individually can be managed individually through primary mitigations, allocation, contingency or some combination thereof
- Risk management efforts can be better tailored to the Program's specific needs and resources

Weaknesses:

- Limited by the comprehensiveness of the risk identification and accuracy of the individual quantification and correlation
- Especially at preliminary or intermediate stages, more likely to underestimate risk exposure

- The Bottom-up approach identifies and assesses risks particular to the project and is thus better setup to manage them, but it can suffer from optimism bias and/or inadequate due diligence

Top down or Reference Class

Strengths:

- Actual project outcomes are used to define the risk exposure curve
  - Not dependent on quality /comprehensiveness of risk identification or assessment efforts
  - Objectivity, removes optimism bias

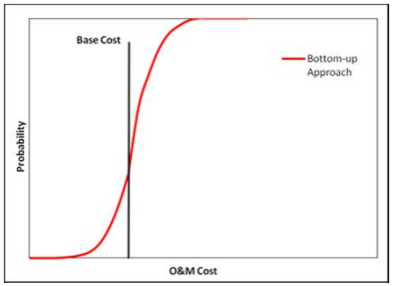
Weaknesses:

- Quality is dependent on number and applicability of reference projects
- Broadly applied, does not provide information about specific risks that can be used for management efforts

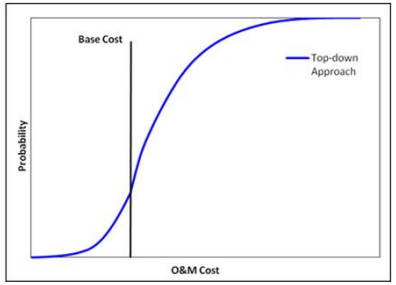
- The Top down approach is generally more objective but may not provide much particular management guidance or may be limited by the number or similarity of the reference projects

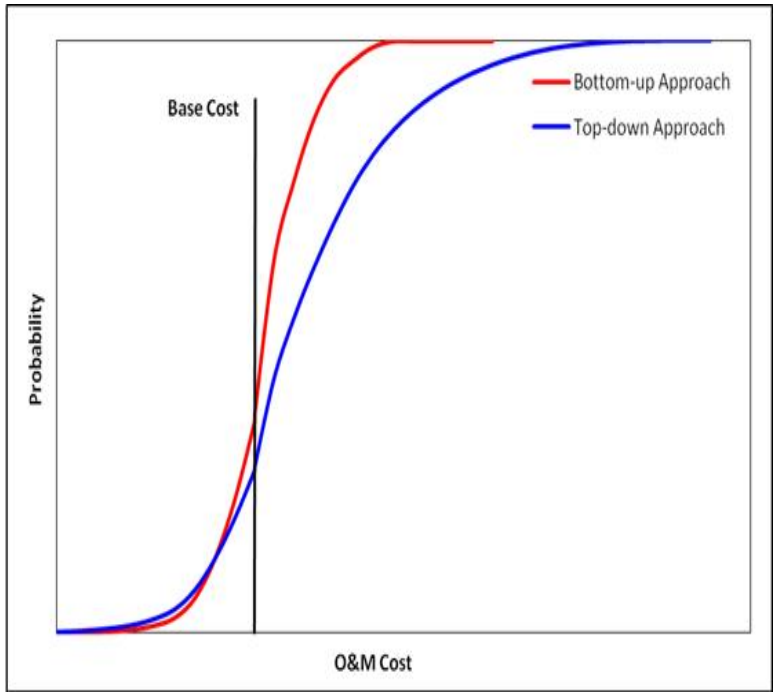
Given pros and cons of each methodology, we are using a combined approach to the risk analysis

Monte Carlo analysis based on bottom up risk assessment



Monte Carlo analysis simulation of distribution parameterized using reference project outcomes





Risk exposure is defined by a surface – the area between the bracketing risk exposure curves – as opposed to a single curve

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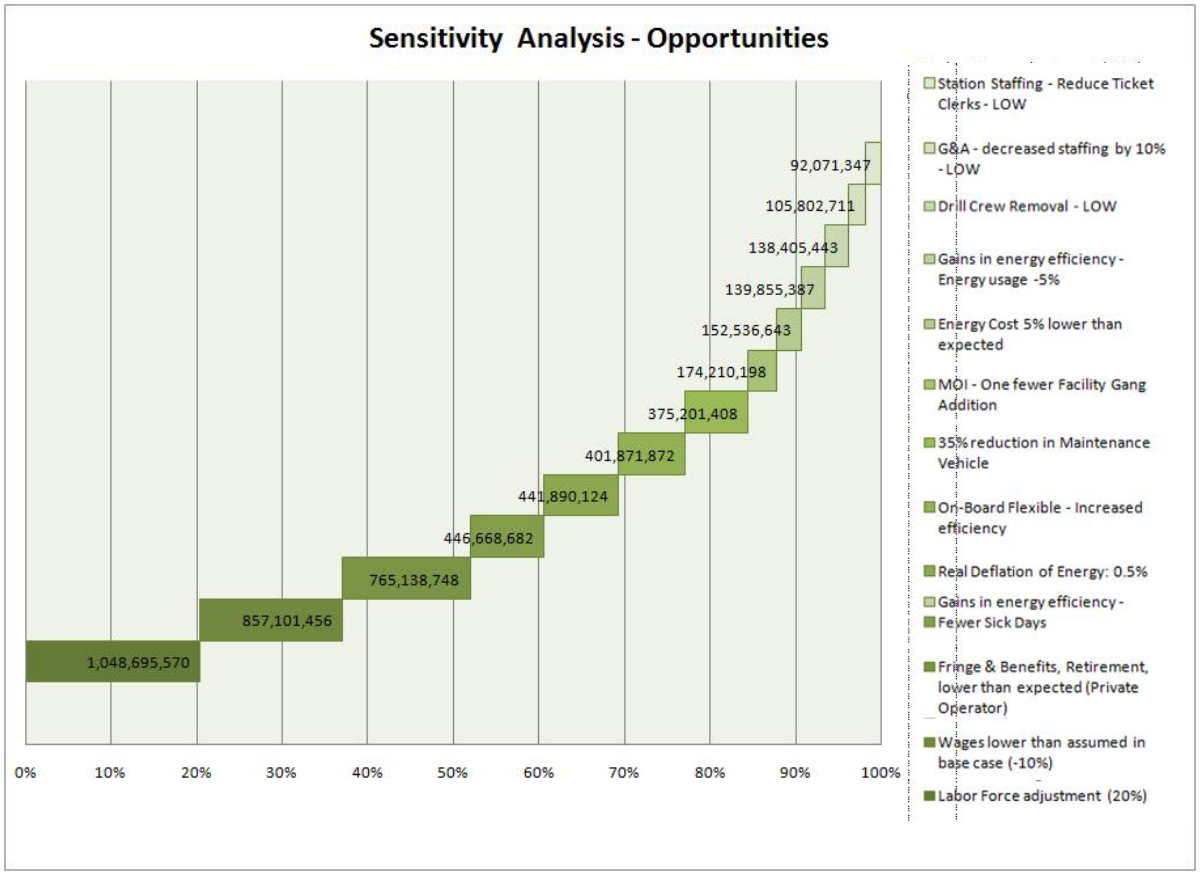
We first ran a sensitivity analysis to understand the potential opportunities (potential cumulative savings)



Comments

- Potential cumulative (2022 – 2060) O&M cost savings relative to Base (in 2012 $)
- The categories of potential cost savings demonstrated here are spread across all of the major cost categories in the O&M cost estimate.
- The largest potential cost savings are from 'Labor Force adjustment' (potential cumulative savings of $1.048 B) and 'Wages lower than assumed' ($857 M)
- Reduced Fringe & Benefits, retirement and fewer sick days cumulate potential benefits over $1B on the analysis period

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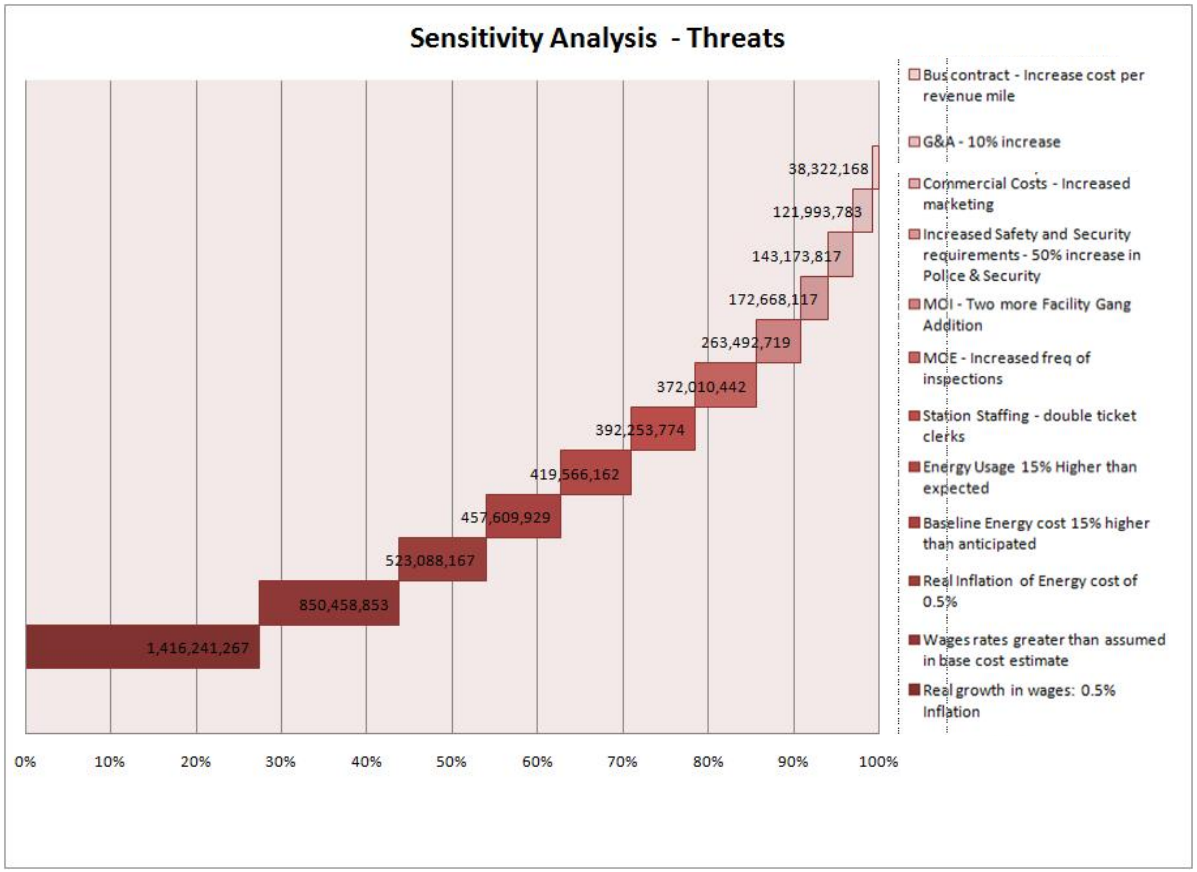
We then ran a sensitivity analysis to understand the potential threats (potential cumulative cost increases)



Comments

- Potential cumulative (2022 – 2060) O&M cost increases relative to Base (in 2012 $)
- Like the savings, the potential cost increases also span all major cost categories in the O&M cost estimate
- Taken together, these threats represent a scenario where *all* of the cost increase risks occur at the same time (a highly unlikely scenario).
- The largest potential cost increases are from Real growth in wages (cumulative cost increase of $1.416B) and Wage rates greater than assumed in base ($850 million).

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We developed very conservative assumptions taking the worst case cost overrun and minimizing the potential cost savings

Risk/Issue	Impact range ($M) Cumulative 2022 - 2060		
	Min Opportunities	Most Likely	Max Threats
Real growth in wages: 0.5% Inflation	$0.00	$0.00	$1,420.00
Wages rates greater than assumed in base cost estimate	-$425.00	$0.00	$850.00
Fringe & Benefit costs lower than expected (Private Operator) based on Private Operator with differently structured pension contributions, defined contribution v. defined benefit and less generous health care and long term disability payment schemes	-$765.00	$0.00	$0.00
Real inflation of energy: 0.5%	$0.00	$0.00	$525.00
Baseline energy costs too low: Energy cost up to 15% higher	-$155.00	$0.00	$460.00
System energy requirements higher than estimated: up to 15% higher	-$140.00	$0.00	$420.00
Additional station staffing: double number of ticket clerks	-$90.00	$0.00	$390.00
(MOE) Increased frequency of inspections	$0.00	$0.00	$370.00
Additional MOI staff required: Two more Facility Gangs	-$175.00	$0.00	$265.00
Higher commercial costs: Increased Marketing	$0.00	$0.00	$145.00
Increased G&A staffing: up to 10% increase	-$105.00	$0.00	$125.00
Cost per revenue mile higher than expected for Bus contract	$0.00	$0.00	$40.00
Increased Safety and Security personnel	$0.00	$0.00	$143.00
Private operator Labor force efficiencies: Productivity, Elimination of roles and minimize absenteeism	-$1,200.00	-$100.00	$0.00
Rationalization of Maintenance vehicle acquisition and use	-$187.50	$0.00	$0.00

Note: Preliminary list and not assumed to be comprehensive

Comments

- Individual distributions were specified to incorporate both positive and negative outcomes (opportunities and threats), where appropriate
- A number of fundamental cost drivers (based on the preceding sensitivity analysis) were treated as risks including wages and energy costs. However, this is a preliminary list and is not assumed to be a comprehensive
- When calculating the maximum values (threats) the values were drawn from the preceding sensitivity analysis
- On the Minimum, in most cases the value was smaller (potential savings were less), conservatively assuming that the full cost savings would not, generally, be fully realized in most situations
- There's not a one-to-one mapping of sensitivity analysis results to risk specification. Sensitivity items meet a reasonably possible threshold where as risks, implicitly or explicitly, are assessed for actual probability

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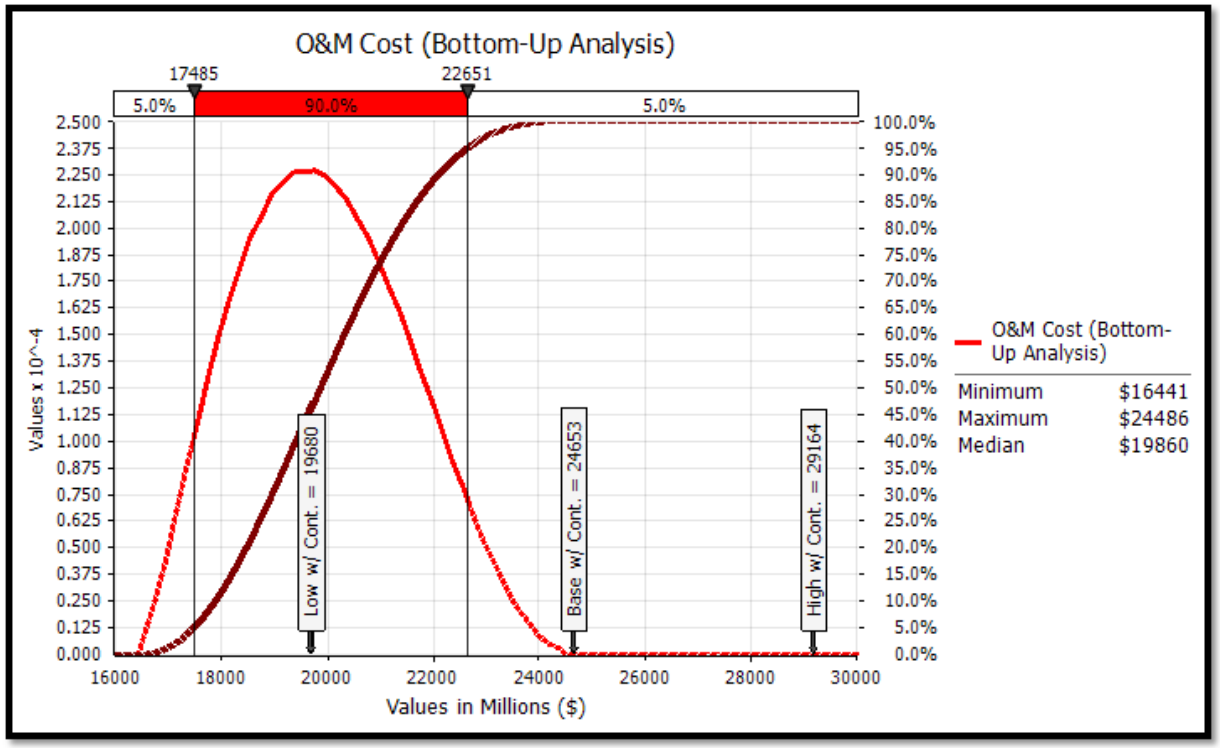
The provided contingency (alloc. & unalloc.) covers 100% of the worst case risk adjusted outcome (Bottom-up Analysis)



- Cumulative risk adjusted estimate (2022 to 2060), based on the Bottom-up Monte Carlo simulation, ranged from $16.4 B to $24.5 B
- The Base cost with allocated and unallocated contingency, at $24.6 B, just exceeded the worst case ($24.5 B) risk adjusted outcome, indicating that the provided contingency is sufficient to cover 100% of the Bottom-up assessed risk exposure

Comments

- The bottom-up analysis parameterized a risk curve defined, at the top-end (worst-case) by all cost increases happening at the same time and at their maximum impact
- This is a highly conservative assumption: the probability of this happening when the risks are treated statistically independently or semi-independently (correlation < 1) is near 0
- Even with the above, the Base cost estimate with allocated and unallocated contingency was associated with a 100% confidence (w/o contingency it was 44.4%)
- Put another way, the specified contingency (allocated + unallocated) was sufficient to cover even the worst-of-the-worst cases in the bottom-up analysis: *all* the identified downside risks occurring at their maximum cost impact

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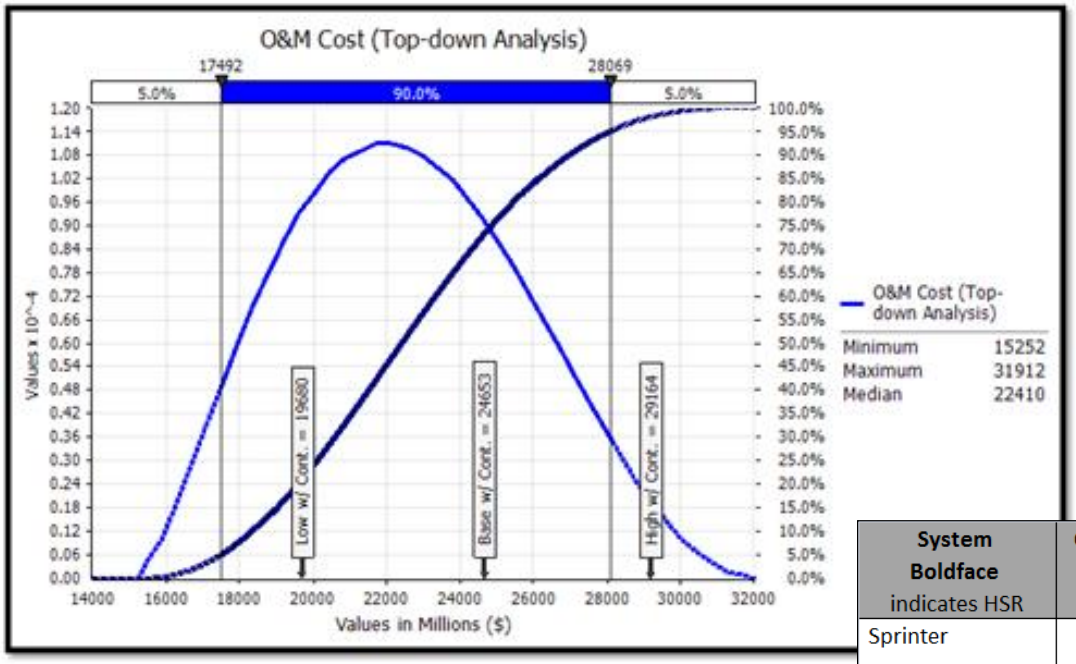
The Base cost with contingency ($24.6B) was greater than 73.1% of the risk adjusted outcomes (Top-down Analysis)



System Boldface indicates HSR	O&M Cost Variance from Plan
Sprinter	-1%
FrontRunner	1%
LGV Rhone-Alpes	4%
LGV Nord	6%
Music City Star	27%
RER E	34%
Median	5%
Mean	12%

- The Top down analysis provides a more conservative (greater) assessment of the risk exposure than the Bottom up, with a Cumulative risk adjusted estimate (2022 to 2060) ranging from $15.3 B to $31.9 B
- The Base cost with allocated and unallocated contingency ($24.6 B) was greater than 73.1% of the risk adjusted outcomes from the Monte Carlo simulation; i.e., the provided contingency is sufficient to cover the Top down assessed risk exposure approximately 3 out of 4 times

Comments

- Recognizing the preliminary to intermediate stage of O&M cost modeling, the reference class curve has been parameterized conservatively:
  - The Minimum assumes best possible outcome was the Low Cost scenario without allocated or unallocated contingency
  - Most Likely: Base (w/o any contingency) + the average cost overrun of 12% – 6 to 8% greater than our HSR reference cases
  - Maximum was set as High + 34% – worst case O&M cost overrun from reference set combined with the High cost scenario (also without contingency)
- The Base cost estimate with allocated and unallocated contingency was associated with a 73.1% confidence level

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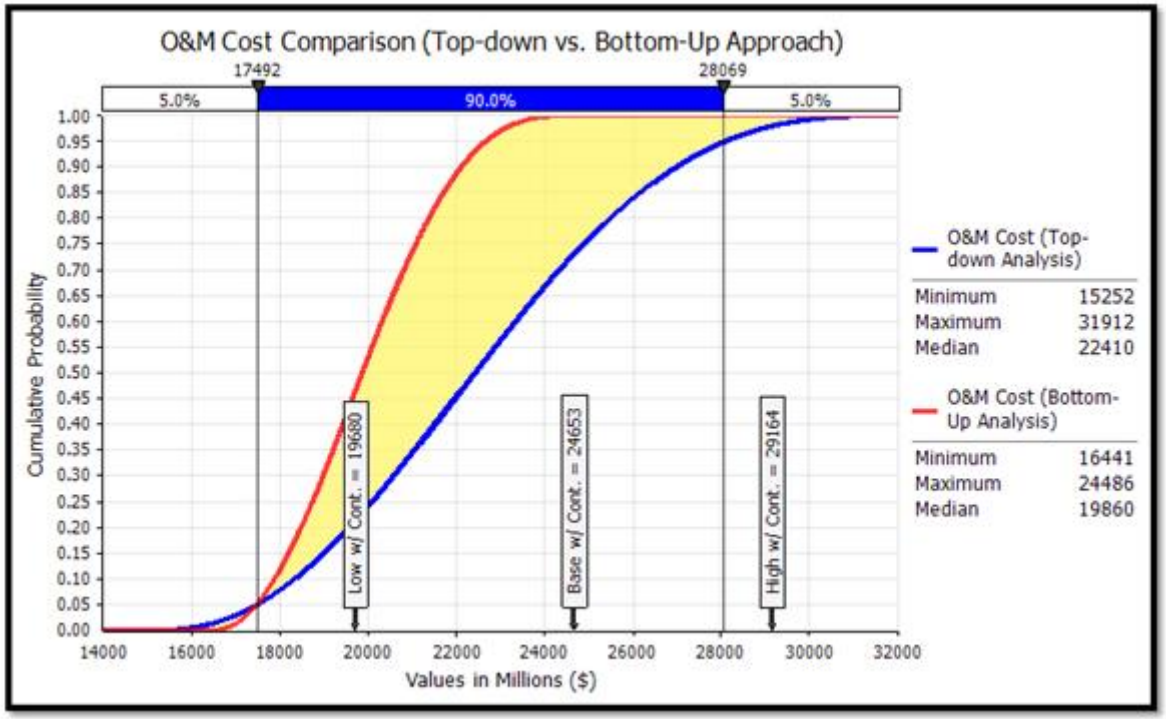
The risk exposure suggested by the Top-down Analysis is greater than that suggested by the Bottom-up Analysis



- As expected at this stage of the risk analysis, the risk exposure suggested by the Top-down, Reference Class analysis is greater than that suggested by the Bottom-up Analysis (graphically, top down is further to the right in the figure below)
- The area between the two bracketing distributions describes the risk surface, relating various cost outcomes to their confidence level

Comments

- Risk exposure suggested by the Top down analysis is greater than that suggested by the bottom-up analysis – graphically, this is indicated by the Top down curve being further to the right than the Bottom-up curve for most of its length
- This is especially true given the compounded conservatism of the upper-bound parameterization of the reference class distribution which applies the worst-case outcome (34% O&M cost overrun) to the high scenario cost
- As opposed to a single methodological approach which would define a single risk exposure curve (1D), this combined approach defines a *risk surface* (2D) - the area between the Red Bottom up and Blue Reference class curves

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Under either methodology, the Base cost estimate with contingency achieves a high confidence level

Cost Scenarios	Estimate $ Billions	Associated Confidence Level from Monte Carlo Simulation results	
		Bottom-Up	Reference Class
Low	$15.109	0.0%	0.0%
Low with allocated and unallocated contingency	$19.680	45.9%	21.0%
Base	$19.613	44.4%	20.4%
Base with allocated and unallocated contingency	**$24.653**	**100.0%**	**73.1%**
High	$24.107	99.9%	67.9%
High with allocated and unallocated contingency	$29.164	100.0%	98.0%

- Under either methodology, the Base cost estimate with allocated and unallocated contingency achieves a high confidence level: 73.1% under the Reference Class Monte Carlo analysis and 100% under the Bottom-up
- The median (half-way point between the 100% of the Bottom-up analysis and the 73.1% of the Reference Class) confidence level for Base with all contingency is 86.6%

Comments

- Under Bottom-up approach, the Base + allocated & unallocated contingency is associated with a 100% confidence level: the provided contingency is sufficient to cover all identified risks up to and including the worst (highest cost) of the 20,000 outcomes from the MC simulation.
- Under Reference Class analysis, the Base + allocated & unallocated contingency is associated with a 73.1% cl, i.e., the total contingency provided in the Base scenario was greater than or equal to the risk exposure in 73.1% of the Reference Class MC runs.
- Remembering that we have defined a risk *surface*, not just a single risk exposure curve, the median cl for the Base with allocated and unallocated contingency is 86.6%

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The Base case with allocated and unallocated contingency provides a median buffer of $1.24 B

Cost Scenarios	Estimate $ Billions	80th Percentile Value		Dollar Value difference ($ B) between Cost Scenario and 80% Confidence value	
		Bottom-Up	Reference Class	Bottom-Up	Reference Class
Low with allocated and unallocated contingency	$19.680	$21.361	$25.465	($1.68)	($5.79)
Base with allocated and unallocated contingency	$24.653			$3.292	($0.81)
High with allocated and unallocated contingency	$29.164			$7.803	$3.70

- Under the Bottom-up risk analysis, there is a cumulative (2022 to 2060) surplus of $3.292 B when comparing the Base with allocated and unallocated contingency ($24.65 B) to what would be necessary to reach the 80% confidence level under the Bottom-up risk analysis ($21.36 B)
- Under the Reference Class analysis there is an $810 M shortfall – it would 'cost' $810 M in additional contingency to reach 80% confidence.The median value is a cumulative surplus of $1.24 B (the half-way point between a surplus of $3.292B and a deficit of $810M)

Comments

- Positive values indicate that provided contingency is in excess of the 80th percentile risk exposure, i.e. there is a buffer between what has been provided and our 80% cl.
- ($$$) values indicate that the cost estimate with contingency does not reach 80% cl, i.e. contingency would need to be increased by this amount to reach the 80% cl under the given risk exposure curve (Bottom-up or Reference class).
- Under Bottom-up analysis, there is a buffer of $3.292 B between what is provided in contingency and the 80th percentile risk exposure. Under the Reference Class exposure curve, there is a deficit, ($810 M).
- The Base case with allocated and unallocated contingency provides a median buffer of $1.24 B

Summary

- The adopted methodology combines a Bottom-up approach to risk identification and analysis with a Top-down (Reference class) analysis to define bracketing risk exposure curves and resulting risk surface.
- Under this combined approach, the O&M Cost model was assessed from two different perspectives:
  - The insider's perspective – employing a Bottom-up approach to identify individual risks to the O&M Cost estimate
  - The outsider's perspective – using a set of similar project's actual O&M cost outcomes to assess the potential for O&M cost overruns
- The O&M Cost estimate methodology, results and recommended contingency were tested against the most extreme combinations of risks and worst cases from our reference set of projects:
  - The Bottom-up exposure curve was parameterized (at its maximum) based on *all* cost increases happening on the same run *and* at their maximum impact, *all striking the Program together and afflicting the Program every year from 2022 to 2060.*
  - The Top-down approach took the worst O&M Cost overrun from our reference set (34%) – *almost 30 percentage points higher than the average O&M cost overrun on HSR projects (5%)* – and applied this to the High (not most likely) cost scenario for O&M Cost.
- Under either line of attack, the O&M Base Cost Estimate proved remarkably robust:
  - Under Top-down analysis, the allocated and unallocated contingency were sufficient to achieve a 73.1% confidence level
  - Under Bottom-up analysis, the allocated and unallocated contingency were sufficient to achieve a 100% confidence level
- Based on this analysis, the median confidence level of the Base cost estimate with allocated and unallocated contingency is 86.6%. In dollar terms, this translates to a cumulative buffer of $1.24 B against the 80% confidence level over the period 2022 to 2060.

Next steps

Top-Down risk analysis

Continue investigation/collection of reference projects and refine parameterization of reference class distribution

Bottom-up risk analysis:

- Risks and potential impacts of changes to conception of operations (ConOps), service plan and system characteristics
- Potential impact of delays in construction or testing and commissioning that delay start of operations
- Potential legislative or regulatory requirements that affect ConOps or Service Plan
- Funding limitations that prevent or delay full build-out of all planned stations (in conjunction with affects on ridership and revenue)
- 'Root' testing of models that serve as input to O&M cost model

Baseline cost estimates

Where identifications or quantifications are made with respect to a specific scenario (Low/Base/High) these will also be adjusted as necessary as the O&M cost estimate is further developed

External review

- At PRG chair's request, independent review being conducted by David Hughes
- Ongoing work with UIC