Research Note

Risk-Based Estimate Self-Modeling

March 2010

Washington State Department of Transportation

The Problem

Cost estimating and risk analysis (Risk-Based Estimate) usually require employing the Monte Carlo Method to develop the range and shape for the project cost estimate. The Monte Carlo Method (MCM) mostly requires dedicated software and specialized users to model and compute large amounts of data. Risk-Based Estimate Self-Modeling (RBES) eliminates these requirements by allowing a regular MS Excel user to develop an integrated cost and schedule estimate with limited knowledge of risk analysis. In this way, large or small projects can benefit from the value added by employing the Risk-Based Estimate process.

Figure 1. Risk-Based Estimate Process

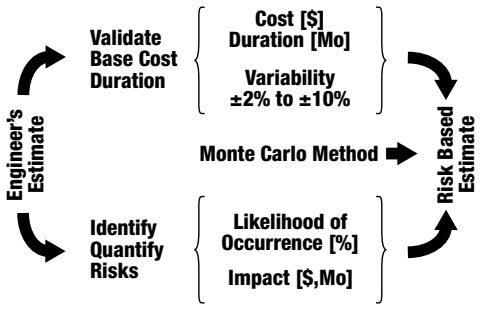
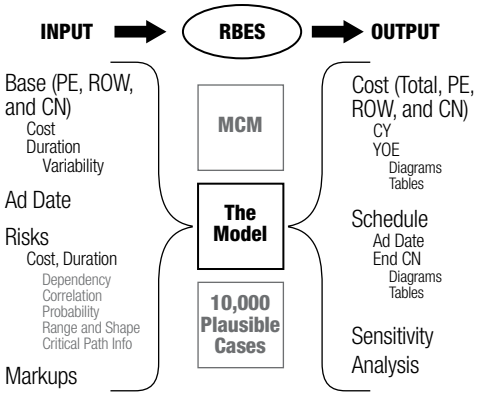


Figure 2. RBES Process Flow Diagram



Risk-Based Estimate Overview

Project cost estimating is an important component of project management throughout the life of a project. A good project cost estimate may determine whether the project will go forward or not or whether the project is a success or a failure. Among the several estimating procedures available, the Risk-Based Estimate (RBE) process described by Figure 1 emerges as a leading edge estimating process. The Association for Advanced Cost Estimating (AACE) recommends using risk analysis when determining the cost estimate and project's contingency.

The RBE is simply a Quantitative Risk Analysis (QRA) of the integrated project cost and schedule estimate. It seeks to make predictions about the uncertainty in a project's estimates relative to the impact project risks may have on cost and schedule. To do this, the QRA utilizes mathematical models. There are different kinds of software on the market that can perform the rigorous calculations and provide quantitative data. Most of these use Monte Carlo Simulation (MCS) as the basis for modeling RBE. Many are "plug-in" type programs that work with MS Excel.

The Washington State Department of Transportation developed an MS Excel-based risk modeling program. The program does not require any additional software to run and was developed specifically for use on public design and construction projects. In its current form, it is called Risk-Based Estimate Self-Modeling (RBES).

Overview of RBES

The RBES program is an open code tool designed to facilitate the integration of the cost and schedule estimates of projects by performing QRA. The model is capable of capturing, analyzing, and displaying the simulation results of "pre-mitigated" and "post-mitigated" scenarios on the same graph. The pre-mitigated scenario represents the range and shape of the project cost estimate before any action is taken to manage risks. The post-mitigated scenario represents the project cost estimate distribution after the risk management plan is developed. The post-mitigated scenario considers the so-called "residual risks" that remain after the risk response strategy is implemented. Having the information on pre- and post-mitigated scenarios on the same graph gives the viewer a powerful image that could greatly improve the understanding of the project's challenges. And it provides decision makers with new, richer data on which to base their decisions.

The RBES program presents its results in the form of diagrams of cost distribution (range and shape) and tables for different stages of project development—Preliminary Engineering (PE), Right of Way (ROW), Construction (CN), and Total Project Cost—in current year dollars (CY $) and year of expenditure dollars (YOE $). In addition, the ranges of the "Advertisement Date" and the "End of Construction Date" are calculated and displayed in the form of graphs and tables. Figure 2 presents the schematic form of how RBES implements RBE.

Cost and Schedule Data Input

The model can run two different scenarios: (1) The pre-mitigated scenario, where the cost and schedule represent the existing conditions, and (2) the post-mitigated scenario, where the cost and schedule is adjusted to reflect the consequences of the project risk mitigation plan. An attractive application of these two scenarios is materialized in an integrated RBE and Value Engineering (VE) study.

- Each of the scenarios is served by two spreadsheets.
- Each spreadsheet can record 12 risks.
- Each risk may have both components (cost and duration).

Base Cost and Schedule Data

The base cost and schedule values are typed in the upper section of the data entry sheet (see Figure 3). The filled-in data should be free of errors because the cells' definitions are self-explanatory and a pop-up window provides additional guidance if needed. The model can accommodate different cost escalation rates for PE, ROW, and CN phases.

By default, the model uses WSDOT escalation tables, but this can be easily overwritten by typing annual escalation rates in designated cells. This feature allows greater flexibility to users outside WSDOT.

Risk Data

Risk information is entered in the defined areas. Figure 4 presents all the requirements related to risk identification and quantitative risk analysis (data is entered in cells with arrows to drop-down menus). Figure 5 presents qualitative display of risk impact (Very Low to Very High), and Figure 6 presents the risk management and control portion of the risk management plan. The model can take 24 risks and has the capability of extending this number to 36, 48, and so on, by adding new spreadsheets.

User Options

The model has the following multifunctional capabilities:

- It can be used by regular MS Excel users with little training on risk analysis; this is the default setup.
- It can be used by power users who know the meaning of risks' dependency and risks' correlation.

Figure 3. Base Cost and Schedule Estimate: Data Entry

Project Title	Highway to Heaven			Value	Variability	Risk Markups		WSDOT Escalation tables built-in.			
Estimate Date	10/10/08		Target AD date	10/10/09	10%	Mob	10.0%	A/B/A Duration		2Mo	
Project PIN #	xxxx		Estimated CN Duration	12.0Mo	15%	Tax	9.0%	Non-WSDOT rates		YOE	
Last Review Date	12/12/08		Estimated PE Cost	20.00 $M	5%	CE	8.0%	PE	3%		
Project Manager	JD		Estimated ROW Cost	31.00 $M	20%	PE	9.5%	ROW	5%		
			Estimated CN Cost	210.00 $M	10%	C.O.C	4.0%	CN	2%		
Escalation Points			Base CN Cost Market Conditions			Distribution Type		Base ROW Cost Market Conditions			
Define escalation point of the activity cost. For example 50% means that the escalation point for that activity is the mid-point activity. 50% is the default value. If it is decided that the escalation point is at three quarters of respective activity			Better than planned	10%	30%	PE Duration	U	Better than planned	10%	50%	
			Worse than planned	10%	30%	CN Duration	U	Worse than planned	10%	50%	
			Probability	Impact		PE Cost	P		Probability	Impact	
Preconstruction activities (ROW and PE)	0.5					ROW Cost	T				
Construction	0.5					CN Cost	T				

N=normal distribution; U=uniform disgtribution; P=PERT or Beta) distribution; T=triangular distribution

Figure 4. Risk Data Entry Sheet

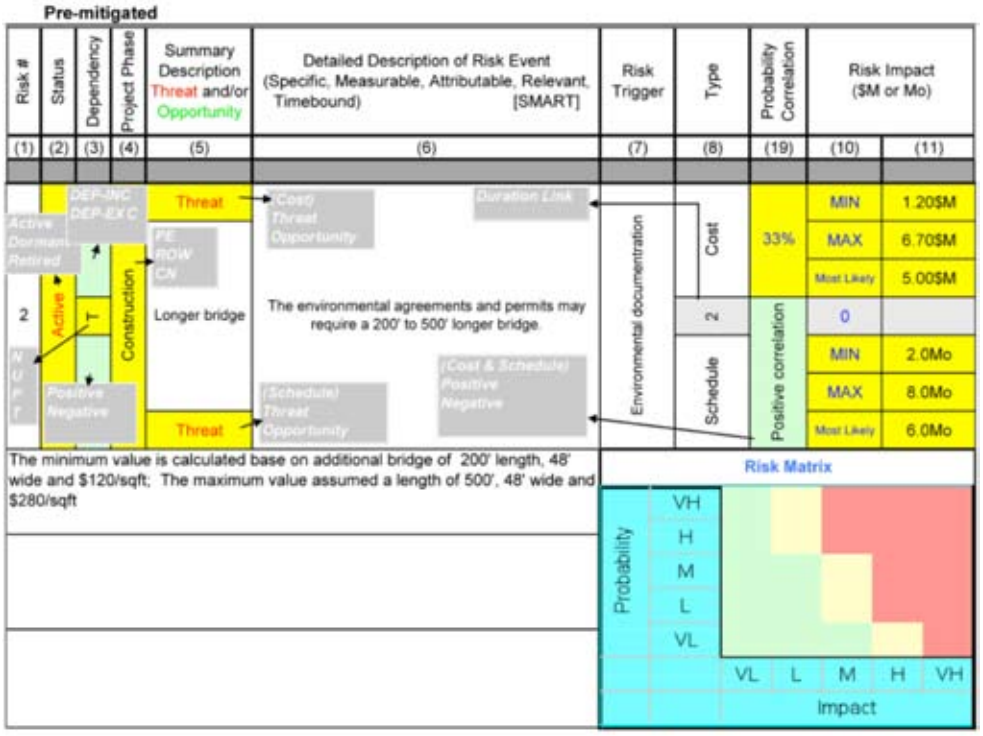


Figure 5. Graphical Display of Risk (Cost and Schedule) Impact

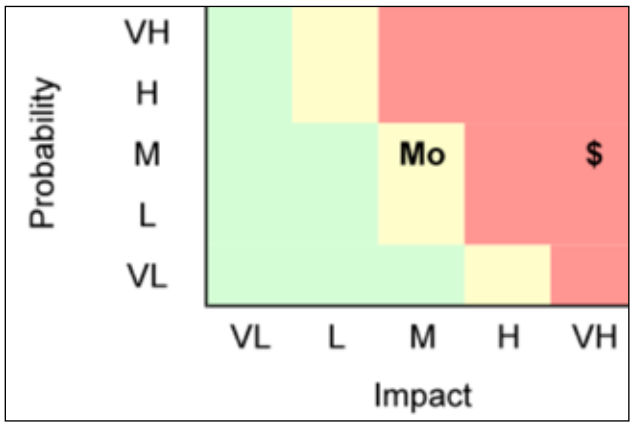


Figure 6. Risk Management Section

Risk Response Plan		Monitoring and Control			Critical Issue
Strategy	ACTION TO BE TAKEN Response Actions including advantages and disadvantages include date	Risk Owner	Risk Review Dates	Date, Status and Review Comments (Do not delete prior comments, therefore providing a history)	Is Risk on Critical Path?
(16)	(17)	(18)	(19)	(20)	(21)
Mitigation	Finalize design to identify all wetlands that are impacted. Early coordination with the outside agencies to determine mitigation ratio.	Design Leader/ Enviro. mgr	2006-Dec-2 2007-Jan-2	As of Nov. 15, 2005 there are only two potential areas where there could be additional wetland impacts. As of Dec. 2, 2005 agency has initially determined that mitigation ratio would be 4:1.	YES

Additionally, the pop-up windows give direction on what the user is supposed to enter in a specific cell. The User's Guide is designed to complement the spreadsheet information and is located in the workbook

The graphical display of the most likely impact is presented in Figure 5. The RBES allows data from both risks' components (cost and duration) to be calculated and displayed. The Risk matrix is a 5 x 5 array, which segments the range of probability and impact into five areas: Very Low, Low, Medium, High, and Very High.

The Risk matrix displays the cost impact with a "$" sign and the duration impact with "Mo."

Cost and Schedule Results

Results are presented in the form of graphs (histogram and cumulative distribution function) and tables. There are ten spreadsheets that present the results of:

- Schedule
  - Ad Date
  - End Construction Date
- Cost: Current year dollars (4) and year of expenditure dollars (4)
  - Preliminary Engineering
  - Right of Way
  - Construction
  - Total Estimate

A typical histogram for cost looks like the example in Figure 7.

A typical cumulative distribution diagram looks like Figure 8.

A typical output in the form of a table looks like Figure 9. These tables give the reader numbers related to the base cost and the distribution of possible cost outcomes at different levels of confidence in underrun.

Figure 7. Total Project Cost: Pre- and Post-Mitigated

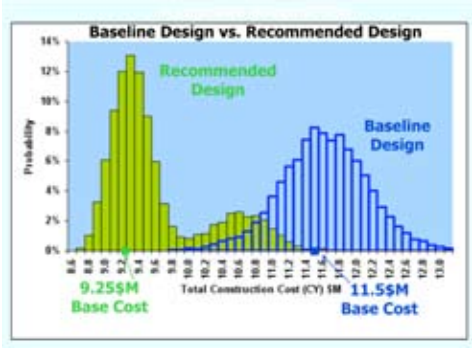


Figure 8. Cumulative Distribution Diagram

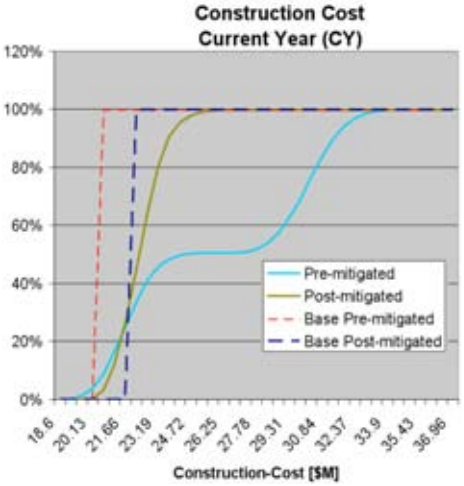


Figure 9. Base Cost and the Distribution of Possible Outcomes at Different Levels of Confidence in Underrun

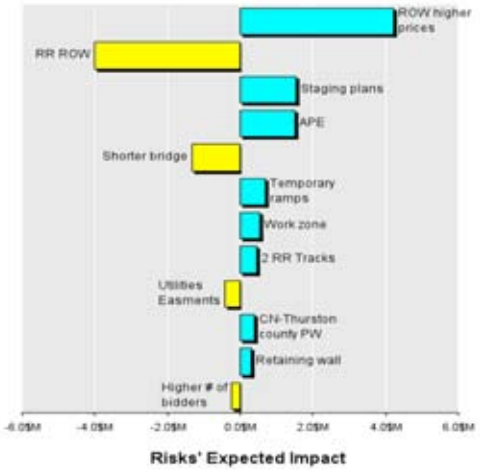
Total Base Estimate (CY)	
Pre-mitigated	Post-mitigated
75.00 $M	58.00 $M

Statistics	Pre-mitigated	Post-mitigated
Min	59.00 $M	39.09 $M
Max	109.64 $M	77.07 $M
Median	82.72 $M	58.17 $M
10%	74.30 $M	45.11 $M
20%	76.80 $M	47.97 $M
30%	79.85 $M	55.88 $M
40%	81.47 $M	57.17 $M
50%	82.72 $M	58.17 $M
60%	84.10 $M	59.27 $M
70%	86.49 $M	61.49 $M
80%	88.95 $M	68.94 $M
90%	91.15 $M	71.37 $M

Candidates for Mitigation

A typical "Candidates for Mitigation" (tornado) diagram is presented in Figure 10. The tornado diagram gives viewers an immediate image of how risks are ranking based on their expected impact.

Figure 10. Candidates for Cost Risk Management (pre-mitigated)



Each bar of the tornado diagram represents the product of the risk's mean value and its probability of occurrence. The threats direct to the right since they increase the project cost or project duration and opportunities direct to the left since they reduce the project cost or project duration.

The tornado diagram gives useful information about the risk's average magnitude but it may mislead the reader on risks with high impact and low or very low probability of occurrence.

The low probability and high impact risks are more dangerous than the high probability of occurrence risks as they may be easily missed and when they occur, the impact may be dramatic.

A different way of displaying the risk response priority is illustrated by the project's Risks Map presented in Figure 11.

The Risks Map brings together the significant project risks in the cost and schedule components.

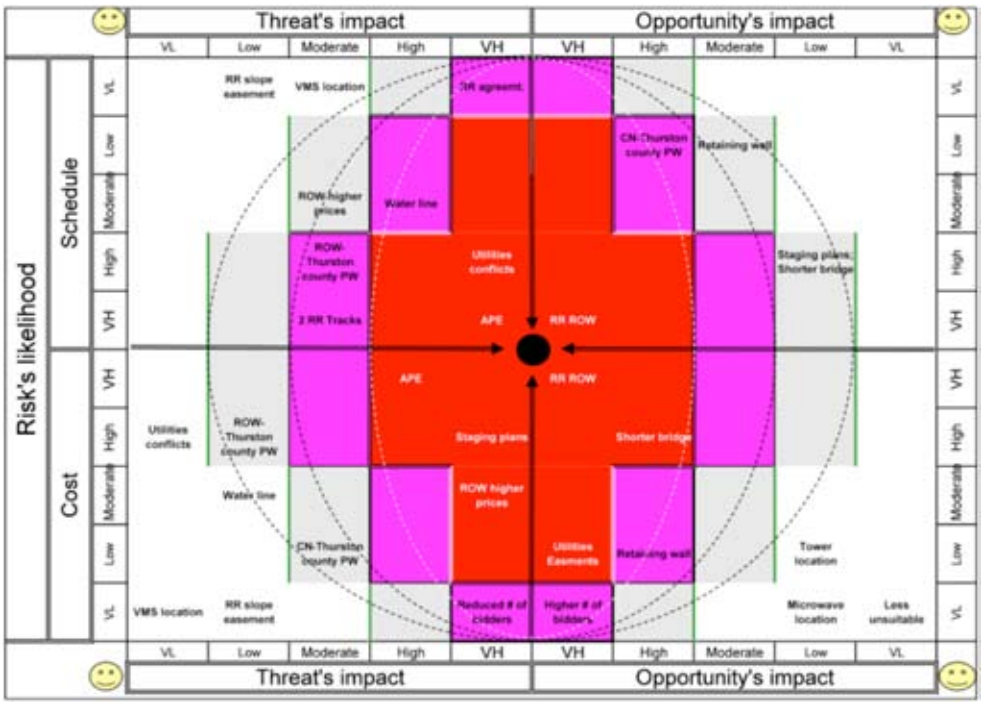
The low probability and high impact risks are represented to alert the project manager to future events. The project Risks Map has four quadrants to differentiate threats and opportunities and cost and schedule.

We recommend applying the risk response strategies first to risks located in proximity of the map's center (VH, VH). In addition to the color code (shading in black and white), the broken line ellipses complement the order of importance of risks included in each perimeter. The inside ellipse indicates the most critical area. Criticality reduces outwardly.

The color code and ellipses emphasize a secondary recommendation: the risk impact is more critical than the risk probability of occurrence. The secondary recommendation makes the broken lines curve to be ellipses and not circle.

In making a decision to respond to a risk or to let it go, the risk's impact is more important than the risk's probability of occurrence—thus the ellipses short axis are horizontal. In this way, risks with high impact value and low probability of occurrence are recognized and receive the attention needed.

Figure 11. Risks Map



Summary of Implementation

- WSDOT has already used the RBES for projects of various sizes (from 1$M to 100$M).
- WSDOT is considering making RBES mandatory on all WSDOT projects between 10$M and 25$M. The RBES helps project teams better define the estimate and better project risk management.
- Caltrans has used RBES for larger projects as a complement to some of its Value Engineering (VE) studies.
- MoDOT has used RBES for more than 11 large projects and plans to use it for many other projects as a complement to its Value Engineering (VE) studies.

Report Title and Location

Risk-Based Estimate Self-Modeling: The RBES application can be downloaded at: www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/Information.htm

Researchers:

Ovidiu Cretu, Ph.D., PE,
Estimating Unit Engineer, WSDOT

Technical Monitor:
Terry Berends, PE, AVS,
Assistant State Design Engineer, WSDOT

Technical Advisory Committee:
Terry Berends, PE, AVS, Assistant State Design Engineer, WSDOT
Kenneth Smith, PE, CVS,
Senior Project Manager, HDR Inc.
Robert B. Stewart, CVS-Life, PMP,
Executive Vice President, VMS Inc.

Contact Information:

Ovidiu Cretu, Ph.D., PE,
Estimating Unit Engineer, WSDOT
360-705-7599
CretuO@wsdot.wa.gov