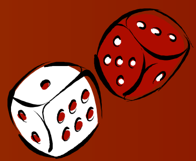
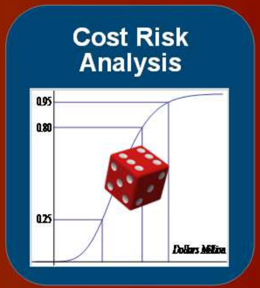
Enhanced Scenario-Based Method (eSBM) for Cost Risk Analysis



Presentation to the
ICEAA Washington Chapter



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BACKGROUND

In 2006, the Scenario-Based Method (SBM) was introduced as an alternative to advanced statistical methods for generating measures of cost risk

SBM was created to run in either of two modes

- SBM without the use of statistics – "*cost risk analysis without statistics*"
- SBM with the use of statistics, but without reliance on Monte Carlo Simulation

Since then, WSARA became law and the requirement for cost estimate confidence measures brought an emphasis on the statistical mode of SBM

BACKGROUND

Today, enhancements to SBM have been made

Integrating historical cost performance data into SBM's statistical equations

A context for applying SBM from a WSARA perspective

With WSARA now law, the original SBM (2006) is called the **enhanced SBM (eSBM) – an historical data-driven statistical version of the SBM (2006)**

This briefing is a companion talk to accompany ground-breaking historical data collection and analysis by the Naval Center for Cost Analysis (NCCA) that enables eSBM to be cost-efficiency driven (see Appendix for further information)

With NCCA's contribution, eSBM advances WSARA aims of realism in estimating future program costs, while offering decision-makers a traceable and defensible basis behind data-derived measures of risk and cost estimate confidence

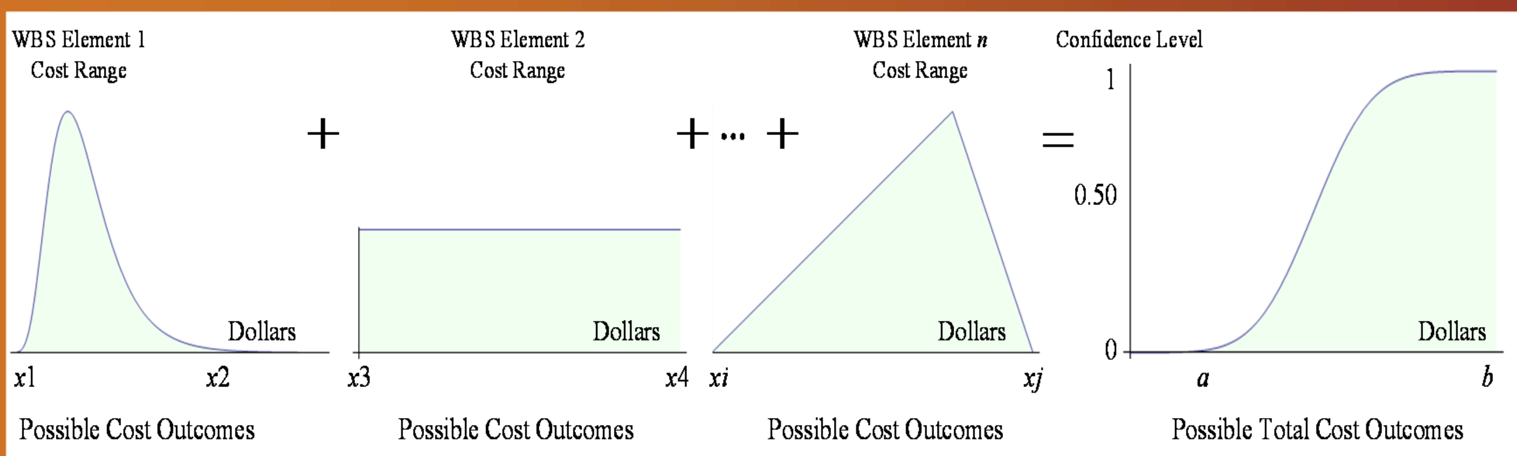
The collection and analysis of historical data for use in cost risk analysis was under the auspices of Ms. Wendy Kunc, (Deputy Assistant Secretary for Cost and Economics, Office of the Assistant Secretary of the Navy (Financial Management & Comptroller) and Executive Director of the Naval Center for Cost Analysis (NCCA). The analysts who led the analysis were Dr. Brian Flynn, Mr. Peter Braxton, and Mr. Richard Lee of Technomics, Inc. The reader is also directed to https://www.ncca.navy.mil/tools/tools.cfm for further information and access to the S-curve tool that contains the NCCA historical cost risk data.

eSBM

WSARA (2009): Public Law 111-23, Section 101 states the following:

The Director [CAPE] shall … issue guidance relating to the proper selection of confidence levels in cost estimates generally, and specifically, for the proper selection of confidence levels in cost estimates for major defense acquisition programs and major automated information system programs

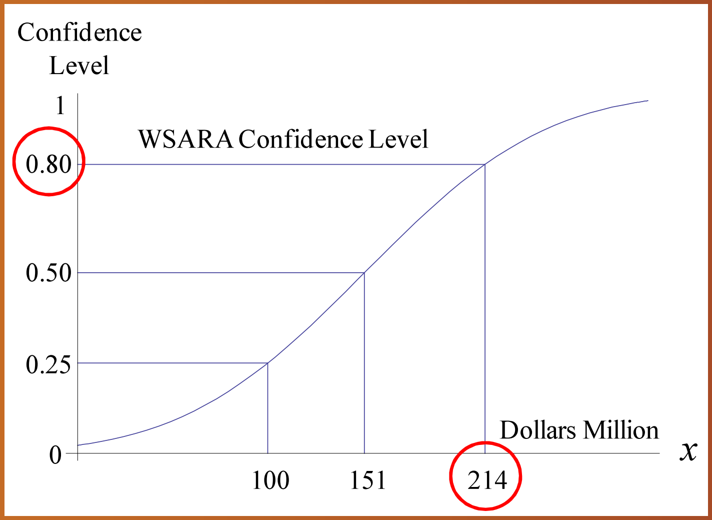
Probability theory is the ideal formalism for deriving measures of confidence; with it, a program’s cost can be treated as an uncertain quantity – one sensitive to many conditions and assumptions that change across its acquisition life cycle



eSBM

This figure illustrates a cumulative probability distribution of a program's total cost; cost estimate confidence is read from this distribution

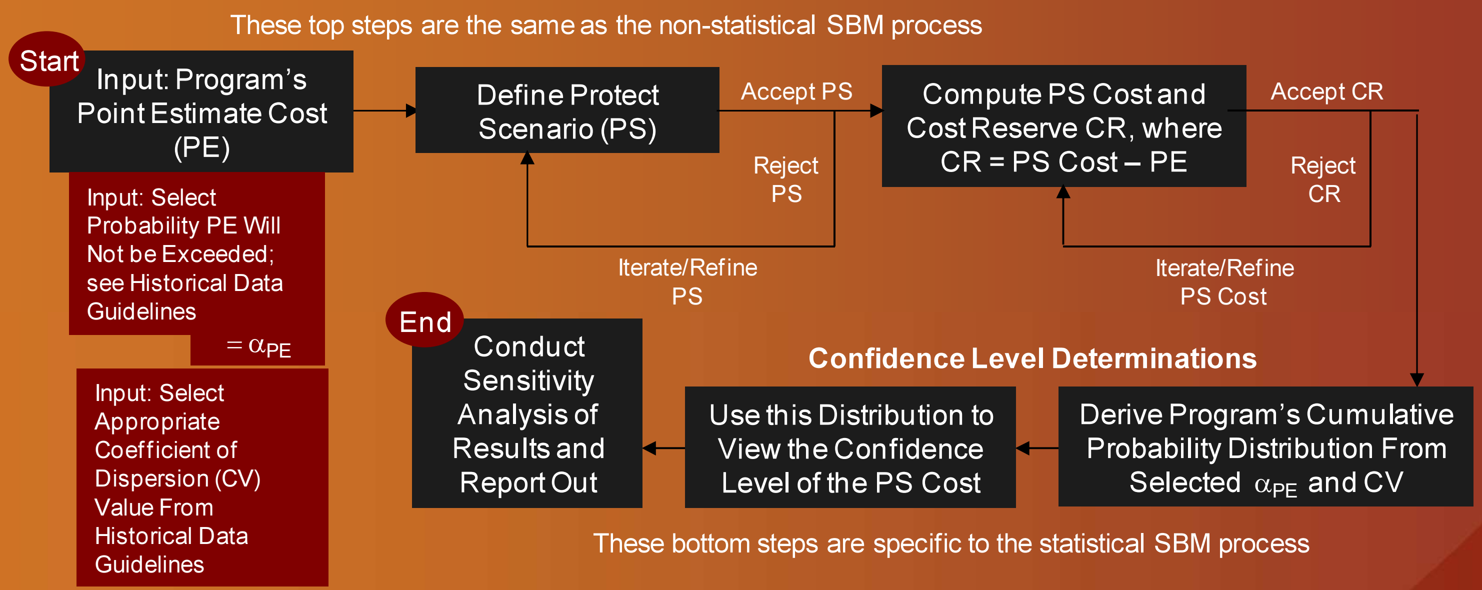
For example, there is a 25 percent chance the program will cost less than or equal to $100M, a 50 percent chance the program will cost less than or equal to $151M, and an 80 percent chance the program will cost less than or equal to $214M



Note: Public Law 111-23, 2009 "Weapon Systems Acquisition Reform Act of 2009", 22 May 2009, cites reporting the 80 percent confidence level; today that numerical level is being revised

eSBM

This figure illustrates the eSBM analytic work flow



Notation: In statistics, the coefficient of variation is often abbreviated as COV or CV; this statistic is also known as the coefficient of determination (COD)

eSBM

What is a scenario?

By definition, a scenario is a sequence of events; an account or synopsis of a possible course of action or outcome expected from possible events (Merriam-Webster)

SBM operates on specified scenarios that, if they occurred, would result in costs higher than the level planned or budgeted

These scenarios are not worst cases; they should reflect a set of **coherent** conditions a program manager or decision-maker would want to have budget to guard against, should any or all of these conditions or events occur

Think of a scenario as articulating **a risk-adjusted cost analysis requirements document (CARD)** – one that is tightly coupled to the program's systems engineering plan (SEP), the risks identified in that plan, as well as those identified in the program's acquisition strategy (and other documents)

These source documents form the basis for the integrity of scenarios developed by the program, its participants, and its stakeholders

eSBM Inputs

Running eSBM requires only 3 inputs that come from the analytic work flow

The eSBM needs only three inputs. These are the point estimate cost, the probability PE cost will not be exceeded, and the coefficient of variation. The probability PE cost x_{PE} will not be exceeded is the value α_{PE}, such that

$$P(Cost_{Pgm} \leq x_{PE}) = \alpha_{PE} \quad (1)$$

In Equation 1, $Cost_{Pgm}$ is the true but uncertain total cost of the program and x_{PE} is the program's point estimate cost. The probability α_{PE} is a judged value guided by experience that it typically falls in the interval $0.10 \leq \alpha_{PE} \leq 0.50$. This interval reflects the understanding that a program's point estimate usually faces higher, not lower, probabilities of being exceeded.

The coefficient of variation (CV) is the ratio of a probability distribution's standard deviation to its mean. This ratio is given by Equation 2. The CV is a way to examine the variability of any distribution at plus or minus one standard deviation around its mean.

$$CV = D = \frac{\sigma}{\mu} \quad (2)$$

With values assessed for α_{PE} and CV, the program's cumulative cost probability distribution can then be derived. This distribution is used to view the confidence level associated with the PS cost, as well as confidence levels associated with any other cost outcome along this distribution.

eSBM Equations Reduce to Simple Algebra

If a program's cost is assumed to follow a normal distribution* then …

If we're given the point estimate cost PE, α_{PE}, and CV, then the mean and standard deviation of $Cost_{Pgm}$ are given by the following:

$$\mu_{Cost_{Pgm}} = x_{PE} - z_{PE}\frac{Dx_{PE}}{1+Dz_{PE}} \tag{3}$$

$$\sigma_{Cost_{Pgm}} = \frac{Dx_{PE}}{1+Dz_{PE}} \tag{4}$$

where D is the coefficient of variation (CV), x_{PE} is the program's point estimate cost, and z_{PE} is the value such that $P(Z \le z_{PE}) = \alpha_{PE}$ where Z is the standard (or unit) normal random variable. Values for z_{PE} are available in look-up tables for the standard normal, provided in Appendix B [Garvey, 2000].

With the values computed from Equation 3 and Equation 4, the distribution function of $Cost_{Pgm}$ can be fully specified, along with the probability that $Cost_{Pgm}$ may take any particular outcome, such as the protect scenario cost. WSARA confidence levels can be determined.

* eSBM provides the equations if a program's cost is best represented by a lognormal distribution; for these procedures, refer to the eSBM technical paper in the references slide to this briefing

eSBM Numerical Example

If a program's cost is assumed to follow a normal distribution then …

Suppose the distribution function of $Cost_{Pgm}$ is normal. Suppose the program's point estimate cost is \$100M and this was assessed to fall at the 25th percentile. Suppose the type and life cycle phase of the program is such that 30 percent variability in cost around the mean has been historically seen. Suppose the program's protect scenario was defined and determined to cost \$145M.

a) Compute the mean and standard deviation of $Cost_{Pgm}$.
b) Plot the distribution function of $Cost_{Pgm}$.
c) Determine the confidence level of the protect scenario cost and its associated cost reserve.
d) Determine the program cost outcome associated with the WSARA confidence level.

3 Inputs

$x_{PE} = 100$
$\alpha_{PE} = 0.25$
$D = CV = 0.30$

Solution
a) From Equation 3 and Equation 4

$$\mu_{Cost_{Pgm}} = x_{PE} - z_{PE}\frac{Dx_{PE}}{1+Dz_{PE}} = 100 - z_{PE}\frac{(0.30)(100)}{1+(0.30)z_{PE}}$$

$$\sigma_{Cost_{Pgm}} = \frac{Dx_{PE}}{1+Dz_{PE}} = \frac{(0.30)(100)}{1+(0.30)z_{PE}}$$

We need z_{PE} to complete these computations. Since the distribution function of $Cost_{Pgm}$ is normal, it follows that $P(Cost_{Pgm} \le x_{PE}) = \alpha_{PE} = P(Z \le z_{PE})$, where Z is a standard normal random variable. Values for z_{PE} are available in statistical tables. In this case, $P(Z \le z_{PE} = -0.6745) = 0.25$; therefore, with $z_{PE} = -0.6745$ we have

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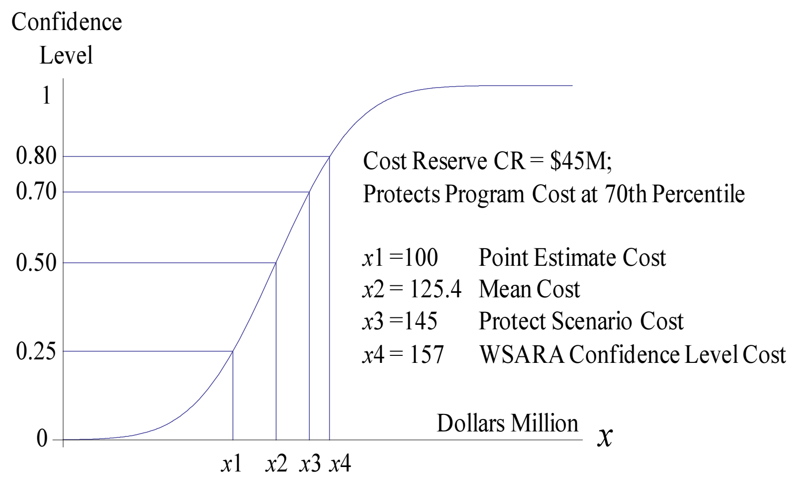
eSBM Numerical Example (concluded)

If a program's cost is assumed to follow a normal distribution then …

$$\mu_{Cost_{Pgm}} = x_{PE} - z_{PE}\frac{Dx_{PE}}{1 + Dz_{PE}} = 100 - z_{PE}\frac{(0.30)(100)}{1 + (0.30)z_{PE}} = 125.4\ (\$M)$$

$$\sigma_{Cost_{Pgm}} = \frac{Dx_{PE}}{1 + Dz_{PE}} = \frac{(0.30)(100)}{1 + (0.30)z_{PE}} = 37.6\ (\$M)$$

b) A plot of the probability distribution function of $Cost_{Pgm}$ is shown. This is a normal distribution with mean \$125.4M and standard deviation \$37.6M, as determined from a).



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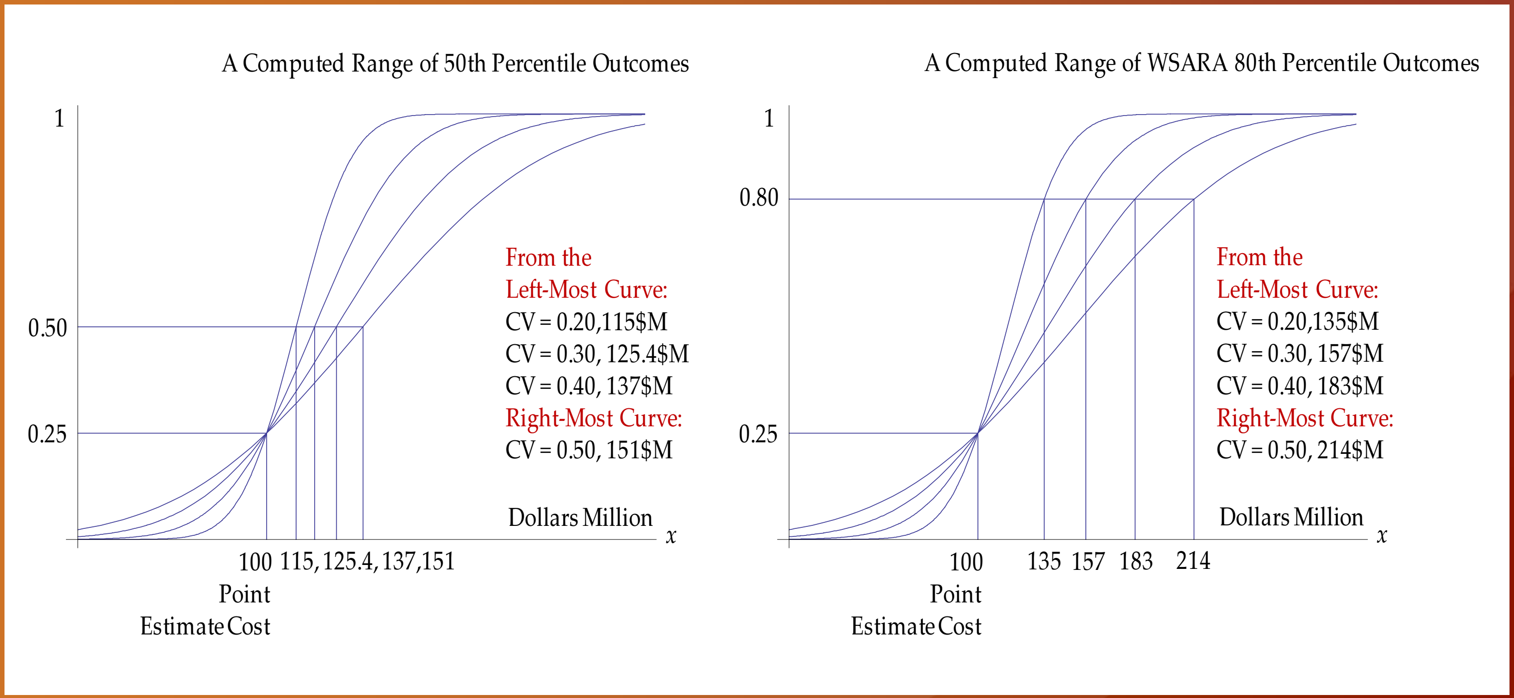
eSBM Sensitivity Analyses

Sensitivity analyses are easy in eSBM; shown below is a range of possible cost outcomes for the 50th and 80th percentiles

Selecting a particular outcome can be guided by the **historical** CV considered most representative of the program's uncertainty at its specific life cycle phase – guided by the scenario or scenarios developed at the start of the SBM process



eSBM and Historical Cost Risk Data

Cost Risk Analysis

A view into historical cost risk data from the NCCA Study

Cost Growth Factors & CVs for All DON MDAPs at MS B for 1969 & Later; n = 50				
	(Without Qty Adjustment)		(Quantity Adjusted)	
Statistics	Base-Year$	Then-Year$	Base-Year$	Then-Year$
Mean	1.48	1.84	1.23	1.36
Standard Deviation	0.94	1.60	0.44	0.69
CV	0.63	0.87	0.36	0.51

From: Garvey, P. R., Flynn, B. J., Braxton, P., Lee, R., "Enhanced Scenario-Based Method for Cost Risk Analysis: Theory, Application, and Implementation", Journal of Cost Analysis and Parametrics, Volume 5, Issue 2, pp. 98-142, December 2012.

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The Naval Center for Cost Analysis (NCCA) recently developed a large dataset of historical CVs from hundreds of major defense programs. From this, we now have ways to guide the choice α and CV from their analysis of program cost growth histories published in articles by Garvey (2012) and Braxton, Flynn, and Lee, (2012). For example, the NCCA data revealed a historical CV for a set of Milestone B Navy programs as

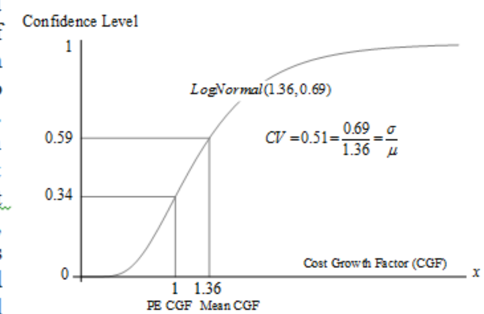
$$CV = 0.51 = \frac{0.69}{1.36} = \frac{\sigma}{\mu}$$

If this CV follows a lognormal distribution (with $\sigma = 0.69$ and $\mu = 1.36$) then it can be shown that the mean cost growth factor falls at the 59th percentile confidence level.

A program's point estimate cost PE is the baseline from which cost growth is applied. Thus, PE has a cost growth factor (CGF) equal to one. In the figure, this is shown by $x = 1$. For the historical programs with CV represented by the lognormal distribution, it can be shown that $x = 1$ falls at the 34th percentile confidence level. This means $\alpha = 0.34$ for these program histories and we can write

$$CV = 0.51 = \frac{0.69}{1.36} = \frac{\sigma}{\mu} \Rightarrow \alpha = 0.34$$

This discussion shows how an empirical α can be derived from program cost growth histories to guide the choice of its value in eSBM. The historical cost growth data developed by the NCCA enables deriving insights into point estimate confidence by major acquisition milestone. An analysis of Milestone B program histories indicate a probability of 0.34 that program point estimates will not be exceeded. In eSBM, this is the value α such that $P(Cost \le PE) = \alpha$. This is the first time an historical, data-driven, insight into point estimate confidence has been derived. It furthers the otherwise anecdotal experience that α often falls in the interval $0.10 \le \alpha \le 0.50$ for programs in these life cycle phases.



Summary

There is a growing realization within the defense cost analysis community that estimates of cumulative probability distributions of cost, or S-curves, too often understate true, underlying risk and uncertainty

In 2006, the Scenario-Based Method (SBM) was introduced as an alternative to advanced statistical methods for generating measures of cost risk

The intent was a return to "the basics" of what decision-makers need from a cost risk analysis and to find a more straightforward approach than experiences-to-date

Post 2006

Since 2006, enhancements to SBM have been made; these include integrating historical cost performance data into SBM's algorithms and providing a context for applying SBM from a WSARA perspective

Together, these improvements define the enhanced SBM (eSBM) – an historical data-driven application of SBM

Summary

Features of eSBM include the following:

- Provides an analytic argument for deriving the amount of cost reserve needed to guard against well-defined "scenarios";
- Brings the discussion of "scenarios" and their credibility to the decision-makers; this is a more meaningful topic to focus on, instead of statistical abstractions simulation approaches can sometimes create;
- Does not require the use of statistical methods to develop a valid measure of cost risk reserve; this is the top three steps of the eSBM work flow;
- Percentiles (confidence measures) are designed into the approach with a minimum set of statistical assumptions;
- Percentiles (as well as the mean, median (50th%), variance, etc) can be calculated algebraically and thus can be executed within a simple spreadsheet environment;
- Does not require analysts develop probability distribution functions for all the uncertain variables in a WBS, which can be time-consuming and hard to justify;
- Correlation is indirectly captured in the analysis by the magnitude of the coefficient of variation applied in the statistical eSBM;
- The approach fully supports traceability and focuses attention on key risk events in the written scenarios that have the potential to drive cost higher than expected

Summary

In conclusion, eSBM encourages and emphasizes a careful and deliberative approach to cost risk analysis

It does so by requiring the development of scenarios that represent the program's "risk story" rather than debating what percentile to select for a series of risk events that may never be articulated in a coherent form

Time is best spent building the case arguments for how a confluence of risk events that form a risk scenario might drive the program to a particular percentile; this is where the debate and the analysis should always center

eSBM promotes realism in estimating future program costs, while offering decision-makers a traceable and defensible basis behind data-derived historical measures of risk and cost estimate confidence

References

eSBM has been published or referenced in the following:

- Arena, M. V., et al. 2006. Impossible Certainty: Cost Risk Analysis for Air Force Systems, Project Air Force, published by The RAND Corporation.
- GAO 2009. Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs, GAO-09-3SP, March 2009.
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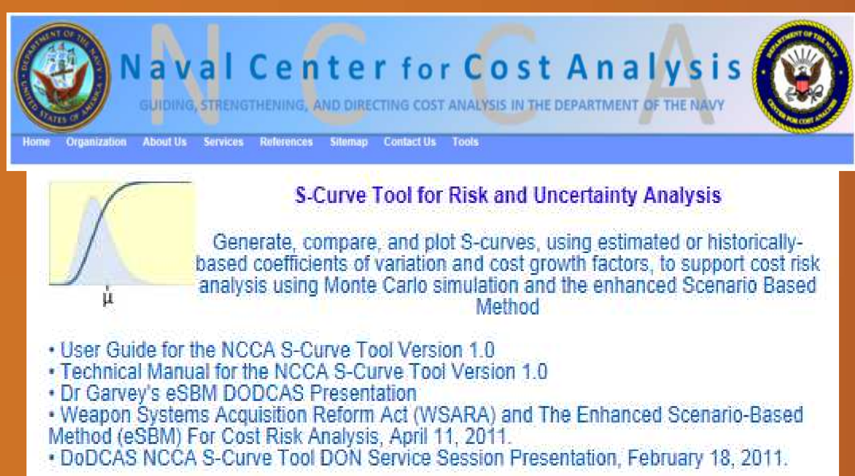

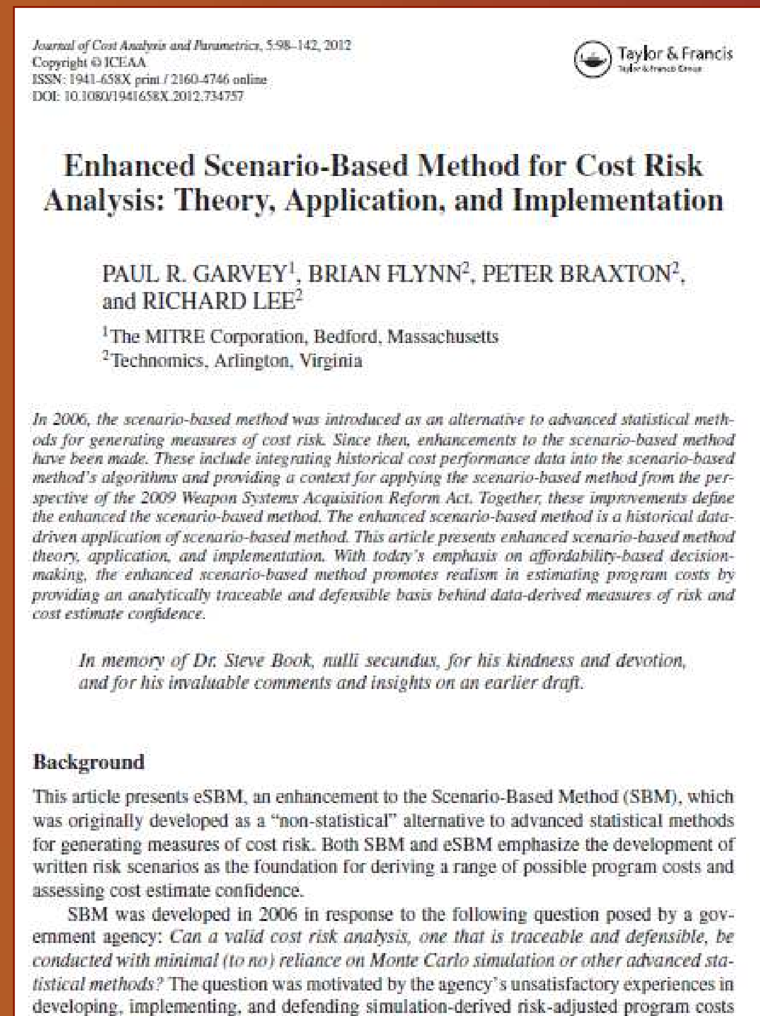

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Enhanced Scenario-Based Method for Cost Risk Analysis: Theory, Application, and Implementation

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In 2006, the scenario-based method was introduced as an alternative to advanced statistical methods for generating measures of cost risk. Since then, enhancements to the scenario-based method have been made. These include integrating historical cost performance data into the scenario-based method's algorithms and providing a context for applying the scenario-based method from the perspective of the 2009 Weapon Systems Acquisition Reform Act. Together, these improvements define the enhanced the scenario-based method. The enhanced scenario-based method is a historical data-driven application of scenario-based method. This article presents enhanced scenario-based method theory, application, and implementation. With today's emphasis on affordability-based decision-making, the enhanced scenario-based method promotes realism in estimating program costs by providing an analytically traceable and defensible basis behind data-derived measures of risk and cost estimate confidence.

In memory of Dr. Steve Book, nulli secundus, for his kindness and devotion, and for his invaluable comments and insights on an earlier draft.

Background

This article presents eSBM, an enhancement to the Scenario-Based Method (SBM), which was originally developed as a “non-statistical” alternative to advanced statistical methods for generating measures of cost risk. Both SBM and eSBM emphasize the development of written risk scenarios as the foundation for deriving a range of possible program costs and assessing cost estimate confidence.

SBM was developed in 2006 in response to the following question posed by a government agency: *Can a valid cost risk analysis, one that is traceable and defensible, be conducted with minimal (to no) reliance on Monte Carlo simulation or other advanced statistical methods?* The question was motivated by the agency's unsatisfactory experiences in developing, implementing, and defending simulation-derived risk-adjusted program costs

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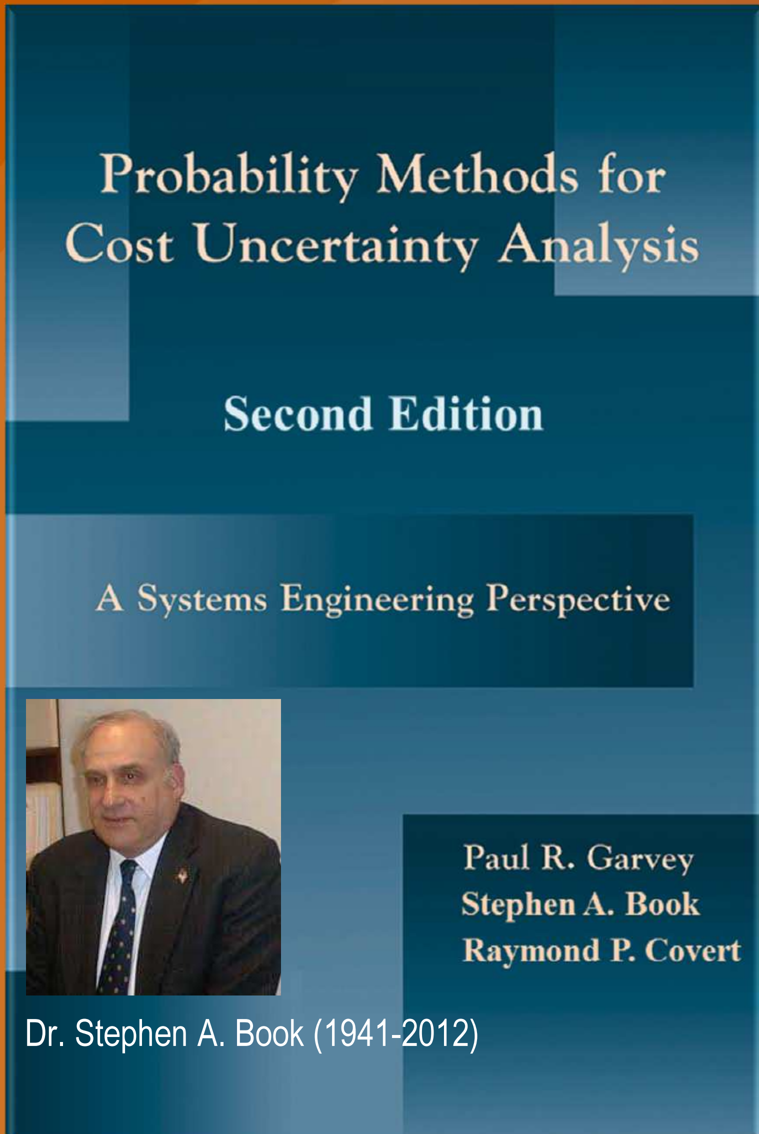

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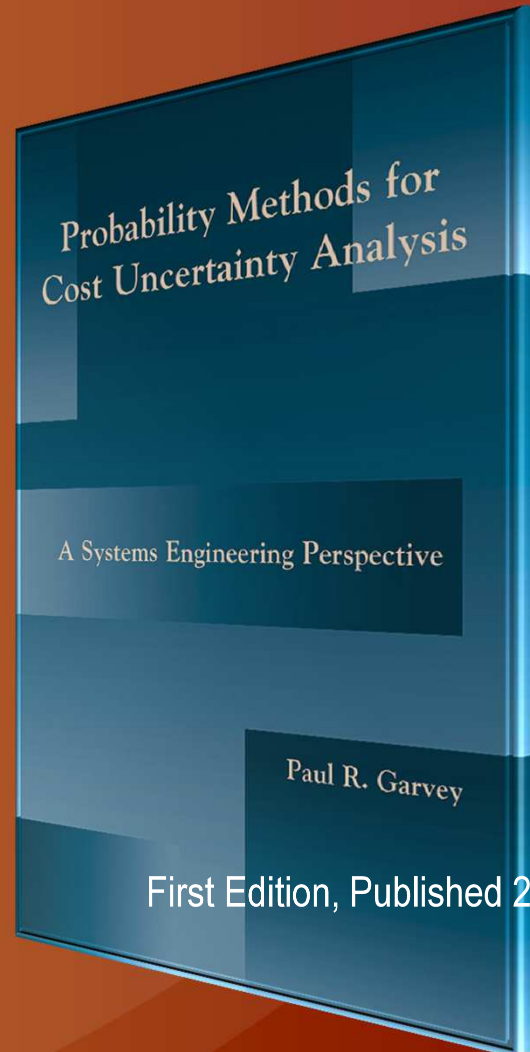

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