Headquarters U.S. Air Force

Integrity - Service - Excellence

AFCAA COST RISK AND UNCERTAINTY ANALYSIS METRICS MANUAL

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08 June 2010

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Overview

- Introduction
- CRUAMM Table of Contents
- Orders of Dispersion
- Data Structure
- Curve-Fitting Model description*
- Example Results
- Path forward

* Alf Smith will be presenting a related paper titled "*Build your Own Distribution Finder* "

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Introduction

- **Cost Risk and Uncertainty remain high visibility and high priority items of interest to AFCAA and the Cost Community in general**
- **AFCAA Cost Risk and Uncertainty Handbook (CRUH) released July 2007, was a significant addition to the body of knowledge**
- **The AFCAA Cost Risk and Uncertainty Analysis Metrics Manual (CRUAMM) will augment the CRUH by providing guidelines and empirical metrics for developing cost uncertainty analyses**
- **The objective of this presentation is to describe the upcoming metrics manual and discuss the effort's methodologies.**

Augmenting the CRUH Content

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CRUH did not address 17 KEY ELEMENTS that a standard cost risk and uncertainty guide should address:

1. List of commodity independent cost drivers that should be adjusted for uncertainty.
2. List of commodity specific cost drivers that should be adjusted for uncertainty.
3. List of O&S cost drivers from the OSD CAIG O&S Guide that should be adjusted for uncertainty.
4. List of technical parameters that should be adjusted for uncertainty.
5. List of schedule parameters that should be adjusted for uncertainty.
6. Empirically based uncertainty bounds and distributions for commodity independent cost drivers.
7. Empirically based uncertainty bounds and distributions for commodity specific cost drivers.
8. Empirically based uncertainty bounds and distributions for O&S cost drivers.
9. Empirically based uncertainty bounds and distributions for schedule parameters.
10. Empirically based uncertainty bounds and distributions for technical parameters.
11. Empirically based Operations & Support (O&S) Cost Uncertainty Analysis Guide.
12. Empirically Based Schedule Uncertainty Analysis Guide.
13. Guide on how to define uncertainty bounds and distributions based on small dataset.
14. Guide on how to define uncertainty bounds and distribution based on large dataset.
15. Guide on how to accept or reject outliers from a small or large dataset.
16. Guide on how to write a cost uncertainty report.
17. Guide on how to brief cost uncertainty results to decision makers.

Existing AFCAA Guidance on Bounds (Subjective)

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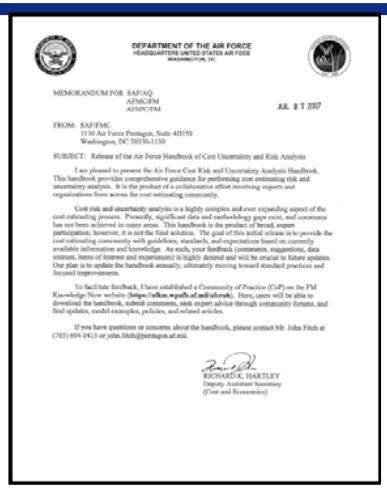


DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, DC

MEMORANDUM FOR SAF/AQ
AFMC/FM
AFSPC/FM

JUL 2 7 2007

FROM: SAF/FMC
1130 Air Force Pentagon, Suite 4D959
Washington, DC 20330-1130

SUBJECT: Release of the Air Force Handbook of Cost Uncertainty and Risk Analysis

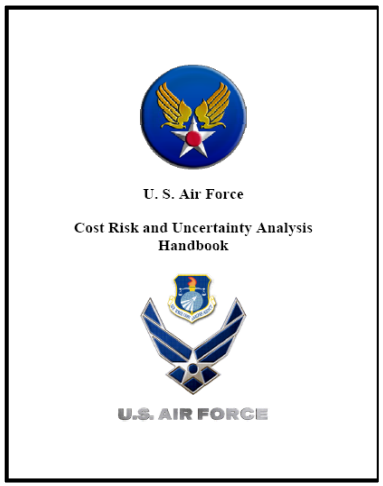
I am pleased to present the Air Force Cost Risk and Uncertainty Analysis Handbook. This handbook provides comprehensive guidance for performing cost estimating risk and uncertainty analysis. It is the product of a collaborative effort involving experts and organizations from across the cost estimating community.

Cost risk and uncertainty analysis is a highly complex and ever expanding aspect of the cost estimating process. Presently, significant data and methodology gaps exist, and consensus has not been achieved in many areas. This handbook is the product of broad, expert participation; however, it is not the final solution. The goal of this initial release is to provide the cost estimating community with guidelines, standards, and expectations based on currently available information and knowledge. As such, your feedback (comments, suggestions, data sources, items of interest and experiences) is highly desired and will be crucial to future updates. Our plan is to update the handbook annually, ultimately moving toward standard practices and focused improvements.

To facilitate feedback, I have established a Community of Practice (CoP) on the PM Knowledge Now website (https://afkm.wpafb.af.mil/afcoek). Here, users will be able to download the handbook, submit comments, seek expert advice through community forums, and find updates, needed examples, policies, and related articles.

If you have questions or concerns about the handbook, please contact Mr. John Fitch at (703) 604-0413 or john.fitch@pentagon.af.mil.

RICHARD K. HARTLEY
Deputy Assistant Secretary
(Cost and Economics)



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Cost Risk and Uncertainty Analysis Handbook

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Distribution	Point Estimate Interpretation	Point Estimate and Probability	Mean	15%	85%
Lognormal Low	Median	1.0 (50%)	1.011	0.856	1.168
Lognormal Med	Median	1.0 (50%)	1.032	0.772	1.296
Lognormal High	Median	1.0 (50%)	1.063	0.696	1.437
Lognormal Ehigh**	Median	1.0 (50%)	1.107	0.627	1.594
Normal Low	Mean	1.0 (50%)	1.000	0.845	1.155
Normal Med	Mean	1.0 (50%)	1.000	0.741	1.259
Normal High	Mean	1.0 (50%)	1.002	0.640	1.363
Normal EHigh	Mean	1.0 (50%)	1.015	0.555	1.470
Weibull Low	Mode	1.0 (25%)	1.158	0.956	1.370
Weibull Med	Mode	1.0 (20%)	1.393	0.956	1.855
Weibull High	Mode	1.0 (15%)	2.104	1.000	3.277
Triangle Low Left	Mode	1.0 (75%)	0.878	0.695	1.041
Triangle Low	Mode	1.0 (50%)	1.000	0.834	1.166
Triangle Low Right	Mode	1.0 (25%)	1.122	0.959	1.305
Triangle Med Left	Mode	1.0 (75%)	0.796	0.492	1.069
Triangle Med	Mode	1.0 (50%)	1.000	0.723	1.277
Triangle Med Right	Mode	1.0 (25%)	1.204	0.931	1.508
Triangle High Left*	Mode	1.0 (75%)	0.745	0.347	1.103
Triangle High	Mode	1.0 (50%)	1.000	0.612	1.388
Triangle High Right	Mode	1.0 (25%)	1.286	0.903	1.711
Triangle EHigh Left*	Mode	1.0 (75%)	0.745	0.300	1.150
Triangle EHigh	Mode	1.0 (50%)	1.004	0.509	1.500
Triangle EHigh Right	Mode	1.0 (25%)	1.367	0.876	1.914

Distribution	Point Estimate Interpretation	Point Estimate and Probability	Mean	15%	85%
Uniform Low Left	Mode	1.0 (75%)	0.870	0.688	1.052
Uniform Low	Mode	1.0 (50%)	1.000	0.818	1.182
Uniform Low Right	Mode	1.0 (25%)	1.130	0.948	1.312
Uniform Med Left	Mode	1.0 (75%)	0.784	0.480	1.087
Uniform Med	Mode	1.0 (50%)	1.000	0.697	1.303
Uniform Med Right	Mode	1.0 (25%)	1.217	0.913	1.520
Uniform High Left	Mode	1.0 (75%)	0.697	0.273	1.121
Uniform High	Mode	1.0 (50%)	1.000	0.576	1.424
Uniform High Right	Mode	1.0 (25%)	1.303	0.879	1.728
Uniform EHigh Left	Mode	1.0 (75%)	0.695	0.2085	1.181
Uniform EHigh	Mode	1.0 (50%)	1.000	0.454	1.546
Uniform EHigh Righ	Mode	1.0 (25%)	1.390	0.844	1.935
Beta Low Left	Mode	1.0 (61%)	0.939	0.775	1.099
Beta Low	Mode	1.0 (50%)	1.000	0.838	1.162
Beta Low Right	Mode	1.0 (39%)	1.061	0.901	1.225
Beta Med Left	Mode	1.0 (63%)	0.883	0.605	1.152
Beta Med	Mode	1.0 (50%)	1.000	0.726	1.274
Beta Med Right	Mode	1.0 (37%)	1.117	0.848	1.396
Beta High Left	Mode	1.0 (66%)	0.808	0.412	1.186
Beta High	Mode	1.0 (50%)	1.000	0.605	1.395
Beta High Right	Mode	1.0 (33%)	1.202	0.816	1.606

** EHigh = Extreme High

* To match these paramaters, tools must be set to truncate the distribution at zero.

CRUAMM will provide empirically-based bounds to replace these suggested subjective bounds

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New Evolving AFCAA Guidance on Bounds (Empirically Based)

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Cost Risk and Uncertainty Analysis

Metrics Manual

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Level 1	Level 2	Level 3	Uncertainty Parameters	
Commodity			Input-Based	Output-Based
1.1	Launch Vehicle			
	1.1.1	Propulsion (Single Stage Only)		
	1.1.2	Stage I		
	1.1.3	Stage II...n (As Required)		
	1.1.4	Strap-On Units (As Required)		
	1.1.5	Shroud (Payload Fairing)		
	1.1.6	Guidance and Control		
	1.1.7	Integration, Assembly, Test and Checkout		
1.3	Space Vehicle			
	1.3.1	Spacecraft		
	1.3.2	Payload I...n (As Required)		
	1.3.3	Reentry Vehicle		
	1.3.4	Orbit Injector/Dispenser		
	1.3.5	Integration, Assembly, Test and Checkout		
1.4	Ground Command, Control, Communications and Mission Equipment			
2.0	Systems Engineering/Program Management			
3.0	System Test and Evaluation			
	3.1	Development Test and Evaluation		
	3.2	Operational Test and Evaluation		
	3.3	Mock-ups		
	3.4	Test and Evaluation Support		
4.0	Training			
5.0	Data			
6.0	Peculiar Support Equipment			
7.0	Common Support Equipment			
8.0	Operational/Site Activation			
9.0	Industrial Facilities			
10.0	Initial Spares and Repair Parts			

Recommended:
Lognormal (Mean = 313; Std Dev = 55)

Cost Risk and Uncertainty Analysis Data Report

Record (Air Vehicle

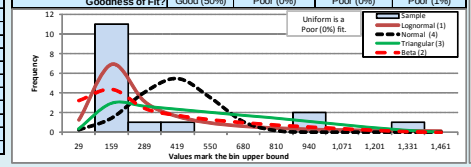
Commodity	Missiles	Dispersion	
WBS		Unit	
Element	Nonrecurring / Recurring	Measurement	Factor
Sub-Element		Phase	RDT&E
Category	Ratio	Filter and Fit	Filter= Air-Launched SDD, Air-to-ground Mission: 1, Fit = SSE
Data Element Comments			

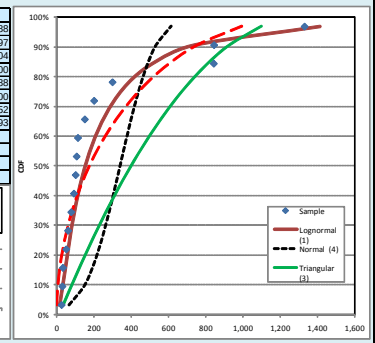
Recommended Risk Metric	Lognormal (Mean = 313.40, Std Dev = 550.52)
Risk Metric Comments	

Dataset Statistics and Fitted Distributions

Sample	
Can be used to define a CDF directly.	
Percentile	Value
0%	26.55
5%	29.89
10%	33.09
15%	**35.37**
20%	48.02
25%	58.13
30%	68.07
35%	81.49
40%	93.05
45%	101.03
50%	**106.42**
55%	111.17
60%	119.87
65%	149.12
70%	187.66
75%	252.07
80%	464.27
85%	**844.19**
90%	845.49
95%	1185.40
100%	1573.67

	Sample	Lognormal	Normal	Triangular	Beta
Mean	274.66	313.40	340.69	453.21	281.88
StdDev	383.74	550.52	146.45	310.40	292.97
CV	1.40	1.76	0.43	0.68	1.04
Min	28.64			0.00	0.00
Mode		37.95	340.69	28.64	281.88
Max	1,331.00			1,331.00	1,331.00
Data Count	16			Alpha	0.52
				Beta	1.93
Rank		1	4	3	2
Standard Error of Estimate		375.00	269.10	128.76	171.75
SEE / Mean		35.1%	87.4%	62.0%	57.5%
Goodness of Fit?		Good (50%)	Poor (0%)	Poor (0%)	Poor (1%)





CRUAMM will be a catalog of empirically-based distributions and bounds

Notional data

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CRUAMM Table of Contents

- **Document Content**
  - **Chapter 1- *Empirically Based Uncertainty Parameters for Commodity Independent Cost Drivers***
  - **Chapter 2 - *Empirically Based Uncertainty Parameters for Commodity Dependent Cost Drivers***
  - **Chapter 3 - *Empirically Based Uncertainty Parameters for Operations & Support Cost Drivers***
  - **Chapter 4 - *Empirically Based Schedule Uncertainty Analysis Guide***
  - **Chapter 5 - *Quality Assurance Guide***
  - **Chapter 6 - *Guidelines for Presenting and Documenting Results***

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Commodities CRUAMM Will Address

- Space
- Aircraft
- Electronics
- Missiles
- Software
- Sensors
- Other

Introducing Orders of Dispersion

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- **First Order**
  - Amount of spread in a single parameter of a dataset
  - **Example**: Cost elements, cost drivers, rates, slopes
- **Second Order**
  - Amount of spread in a factor relationship
  - **Example**: Cost-to-cost driver ratios

CRUAMM

- **Third Order**
  - Amount of spread in the error term of a best fit equation
  - **Example**: Residuals from a regression-derived CER
- **Fourth Order**
  - Prediction interval from a statistically derived CER
  - **Example**: CER prediction interval for a given independent variable

Data Structure

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	First Order of Dispersion Data											
	RDTE Nonrecurring HDW	RDTE Recurring HDW	RDTE Application Software	RDTE SEPM	RDTE ST&E	PROC Recurring Hardware	PROC SEPM	PROC UC100	SW Size	RDTE Duration	System Weight	System Speed
Obs 1	109.00	100.00	39.00	46.00	59.00	9,935.00	818.00	69.00	285.00	58.00	290.00	1.71
Obs 2	52.00	49.00	42					0	2,432.00	38.00	210.00	0.67
Obs 3	170.00	139.00	11					0	483.00	56.00	179.00	2.51
Obs 4	547.00	342.00	24					0	1,301.00	60.00	433.00	3.63
Obs 5	273.00	195.00	24					0	1,236.00	54.00	247.00	3.57
Obs 6	208.00	177.00	23					0	1,305.00	70.00	391.00	3.85
Obs 7	39.00	42.00	31							37.00	570.00	0.35
Obs 8	144.00	142.00	24							56.00	407.00	1.81
Obs 9	456.00	308.00	37							65.00	641.00	3.49
Obs 10	57.00	53.00	8							48.00	196.00	0.81
Obs 11	97.00	103.00	3							59.00	342.00	1.68
Obs 12	43.00	42.00	45							31.00	233.00	0.76
Obs 13	180.00	165.00	9							64.00	146.00	2.21
Obs 14	486.00	321.00	28							69.00	381.00	3.38
Obs 15	251.00	181.00	24							59.00	254.00	3.96
Obs 16	243.00	173.00	22							72.00	340.00	4.54
Obs 17	38.00	46.00	25							41.00	661.00	0.33
Obs 18	167.00	130.00	26							48.00	341.00	1.95
Obs 19	483.00	271.00	43							68.00	737.00	3.32
Obs 20	64.00	56.00	7							57.00	164.00	0.92
Obs 21	97.00	100.00	2							67.00	328.00	1.75
Obs 22	34.00	45.00	44							35.00	216.00	0.81
Obs 23	158.00	163.00	10							69.00	160.00	1.97
Obs 24	466.00	353.00	25							61.00	350.00	3.65
Obs 25	225.00	179.00	28							50.00	287.00	4.12

	Second Order of Dispersion Data				
	RDTE Nonrecurring/ Recurring	RDTE SEPM/ Recurring	RDTE ST&E/ Recurring	Proc SEPM/ Recurring	UC100/ Weight
Obs 1	1.09000	0.46000	0.59000	0.08234	0.23793
Obs 2	1.06122	0.40816			
Obs 3	1.22302	0.44604			
Obs 4	1.59942	0.53509			
Obs 5	1.40000	0.54359			
Obs 6	1.17514	0.44068			
Obs 7	0.92857	0.38095			
Obs 8	1.01408	0.40141			
Obs 9	1.48052	0.56494			
Obs 10	1.07547	0.41509			
Obs 11	0.94175	0.41748			
Obs 12	1.02381	0.52381			
Obs 13	1.09091	0.32121			
Obs 14	1.51402	0.45483			
Obs 15	1.38674	0.54696			
Obs 16	1.40462	0.51445			
Obs 17	0.82609	0.28261			
Obs 18	1.28462	0.50769			
Obs 19	1.78229	0.65314			
Obs 20	1.14286	0.37500			
Obs 21	0.97000	0.43000			
Obs 22	0.75556	0.42222			
Obs 23	0.96933	0.30061			
Obs 24	1.32011	0.43626			
Obs 25	1.25698	0.60894			

	Filter Types		
	Service	Platform	Warhead
Obs 1	Air Force	Air	HE
Obs 2	Navy	Air	Blast Frag
Obs 3	Army	Air	Blast Frag
Obs 4	Army	Ground	Bomblets
Obs 5	Air Force	Ground	Bomblets
Obs 6	Navy	Sea	Blast Frag
Obs 7	Army	Ground	Blast Frag
Obs 8	Army	Ground	Blast Frag
Obs 9	Air Force	Air	Blast Frag
Obs 10	Navy	Sea	Blast Frag
Obs 11	Army	Ground	HE
Obs 12	Army	Ground	HE
Obs 13	Air Force	Air	HE
Obs 14	Navy	Air	Blast Frag
Obs 15	Army	Air	Blast Frag
Obs 16	Army	Ground	Bomblets
Obs 17	Air Force	Ground	Bomblets
Obs 18	Navy	Sea	Blast Frag
Obs 19	Army	Ground	Blast Frag
Obs 20	Army	Ground	Blast Frag
Obs 21	Air Force	Air	Blast Frag
Obs 22	Navy	Sea	Blast Frag
Obs 23	Army	Ground	HE
Obs 24	Army	Ground	HE
Obs 25	Air Force	Air	HE

Notional data

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Proposed Descriptive Statistics

Element	RDTE SEPM	RDTE Duration	RDTE SEPM / Recurring
Units	FY2008K$	Months	
Count	25	25	25
Minimum	13.000	31.000	0.2826
5%	15.250	34.000	0.2961
15%	20.250	38.750	0.3765
30%	22.000	50.000	0.4151
50%	57.000	58.000	0.4407
70%	99.000	64.000	0.5145
85%	152.000	68.500	0.5461
95%	178.500	70.500	0.6200
Maximum	183.000	72.000	0.6531
Range	170.000	41.000	0.3705
Inner Quartile Range	84.750	17.500	0.1202
Mean	74.680	55.680	0.4556
Std Dev	55.034	11.912	0.0919
CV	0.737	0.214	0.202

Notional data

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Key Elements of the Curve Fitting Process

- Goal: Fit Lognormal, Normal, Triangular and Beta to the sample data
- Store the data on a single spread sheet (Data)
  - First and Second order data
  - Filters to properly stratify data
  - Descriptive Statistics
- Analysis Sheets
  - Select filtered data for analysis
  - Inspect selected data for possible outliers, exclude as appropriate
  - Choose plotting options, bound constraints, fit method, basis for goodness of fit measure and histogram bin number
  - Perform the fit to populate the CRUAMM form
- Handbook
  - Main Body: Curve fit results suitable for public release
  - Appendix: Results and data points, restricted release

Core Steps on the Analysis Sheet

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- **Sort sample data in ascending order**
- **Assign a cumulative percentile using the NIST[1] formula (different than Excel) but apply a "correction for continuity" [2]**

  (0.5*ObsFreq+NumObsBelow)/ObsCount
- **Use the sample descriptive statistics to provide a starting point for fit parameters**
- **Assess the difference between the sample and fit using either:**
  - **Sum Squared Error**
  - **Sum Squared Percent Error**
    - **n = number of data points**
    - **y = a sample data point**
    - **$\hat{y}$ = a fitted point**

$$SSE = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2$$

$$SSPE = \sum_{i=1}^{n} \left(\frac{y_i - \hat{y}_i}{\hat{y}_i} \right)^2$$

1. NIST= National Institute of Standards and Technology

2. From "Reliability and Information Functions for Percentile Ranks" Kim May and W. Alan Nicewander, Journal of Educational Measurement, Vol. 31, No. 4 (Winter, 1994), pp. 313-325

Core Steps on the Analysis Sheet

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- Use *Excel Solver to find the fit parameters that minimize SSE or SSPE
  - Set optional constraints such as: Low>0, High>HighestSamplePoint
  - Select SSE or SSPE as error to be minimized
    - SSE is highly influenced by very large sample points (as compared to mean)
    - SSPE is highly influenced by fitted points close to zero (divide by zero)
- Rank the fits using Standard Error of the Estimate (SEE) or Standard Percent Error (SPE)
  - Where k = number of parameters in the fit
    - Normal, lognormal k = 2
    - Triangular k = 3
    - Beta k = 4

$$SEE = \sqrt{\frac{SSE}{n-k}} \qquad SPE = \sqrt{\frac{SSPE}{n-k}}$$

  - This is a preferred method to rank the fits (rather than SSE or SSPE directly) because it accounts for the degrees of freedom
- Use a Goodness-of-Fit test (Chi^2) to determine significance of the fit
  - Minimum SSE or SSPE alone does not necessarily mean the fit is meaningful

* Microsoft Excel Solver was developed by Frontline Systems, Inc. and distributed with MS Excel

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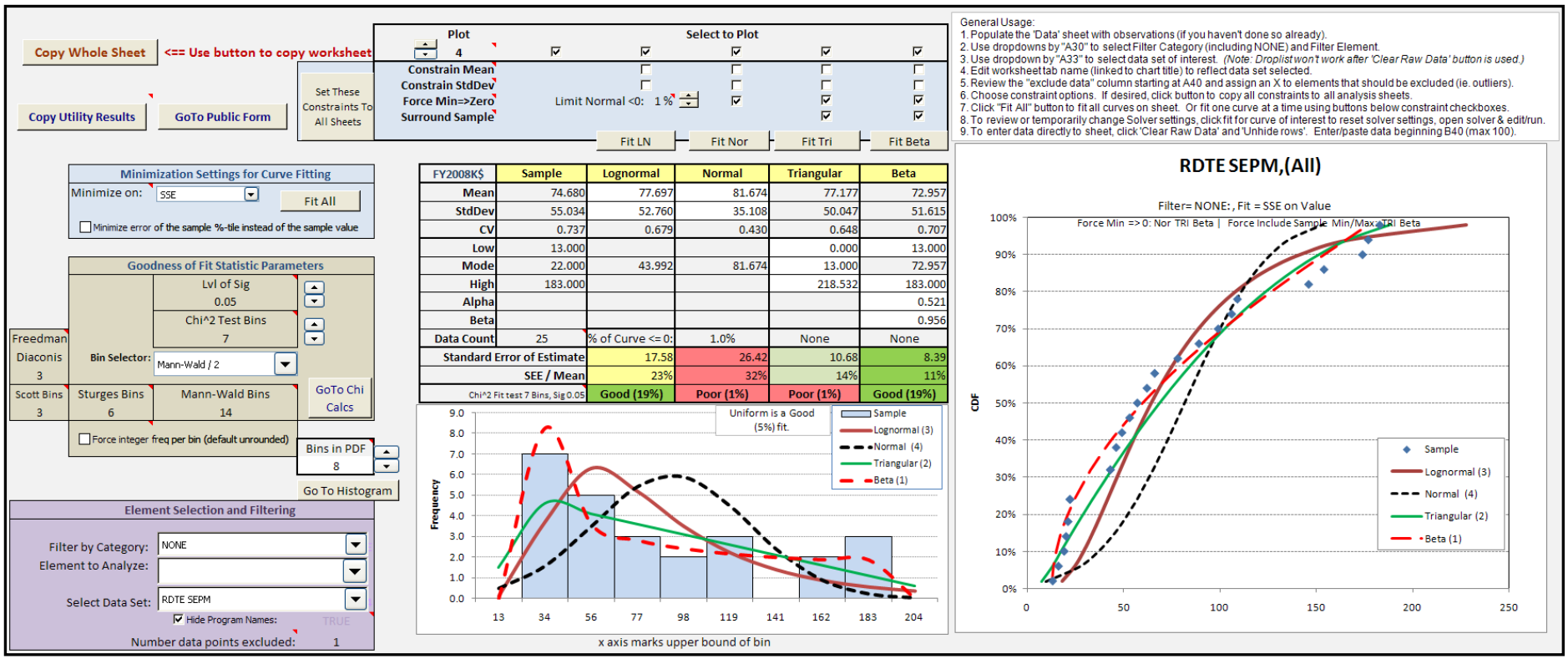
Curve Fitting Tool Analyst's View



Notional data

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Second Order Dispersion Example: SEPM / Recurring Hardware

Cost Risk and Uncertainty Analysis Data Report

Record 0

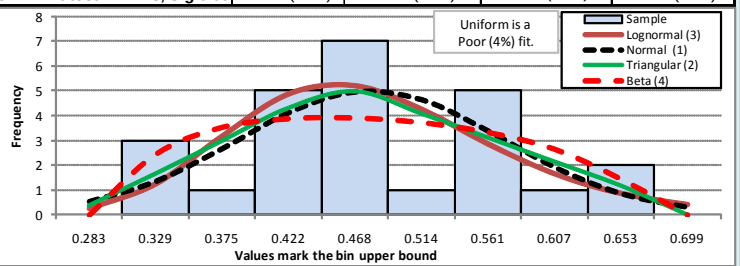
Commodity	Sample	**Dispersion**	Second
WBS	nn.04	**Unit**	
Element	RDTE SEPM/ Recurring	**Measurement**	Cost-to-cost
Sub-Element		**Phase**	RDTE
Category		**Filter and Fit**	Filter= NONE: , Fit = SSE on Value
Fit Constraints	Force Min => 0: Nor TRI Beta | Force Include Sample Min/Max: TRI Beta		

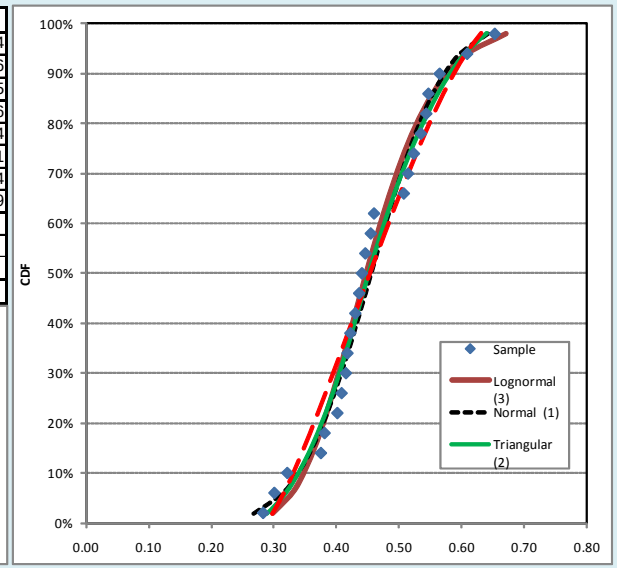
Recommended Risk Metric	Normal (Mean = 0.46, Std Dev = 0.09)
Risk Metric Comments	

Dataset Statistics and Fitted Distributions

Sample	
Can be used to define a CDF directly	
Percentile	**Value**
0%	0.2736
5%	0.2961
10%	0.3212
15%	**0.3765**
20%	0.3912
25%	0.4065
30%	0.4151
35%	0.4187
40%	0.4261
45%	0.4347
50%	**0.4407**
55%	0.4482
60%	0.4574
65%	0.4958
70%	0.5145
75%	0.5266
80%	0.5393
85%	**0.5461**
90%	0.5649
95%	0.6200
100%	0.6531

	Sample	Lognormal	Normal	Triangular	Beta
Mean	0.4556	0.4563	0.4556	0.4557	0.4554
StdDev	0.0919	0.0909	0.0914	0.0898	0.0936
CV	0.202	0.199	0.201	0.197	0.205
Min	0.2826			0.2480	0.2826
Mode		0.4304	0.4556	0.4329	0.4554
Max	0.6531			0.6861	0.6531
Data Count	25			**Alpha**	1.354
				Beta	1.549
Rank		3	1	2	4
Standard Error of Estimate		0.0147	0.0133	0.0136	0.0195
SEE / Mean		3.2%	2.9%	3.0%	4.3%
Chi^2 Fit test 14 Bins, Sig 0.05		Good (25%)	Good (41%)	Good (42%)	Good (33%)





Notional data

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First Order Dispersion Example: RDTE SEPM

Cost Risk and Uncertainty Analysis Data Report

Record 0

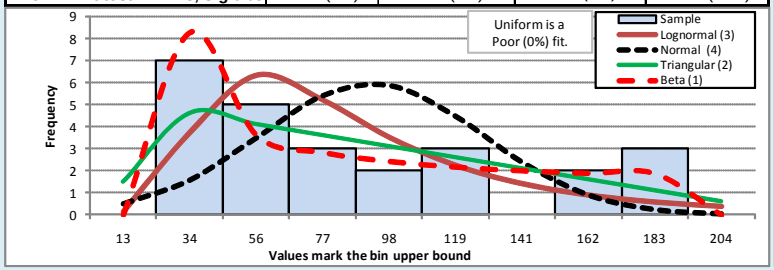
Commodity	Sample	Dispersion	First
WBS	nn.04	Unit	FY2008K$
Element	RDTE SEPM	Measurement	Cost
Sub-Element		Phase	RDTE
Category		Filter and Fit	Filter= NONE: , Fit = SSE on Value
Fit Constraints	Force Min => 0: Nor TRI Beta | Force Include Sample Min/Max: TRI Beta		

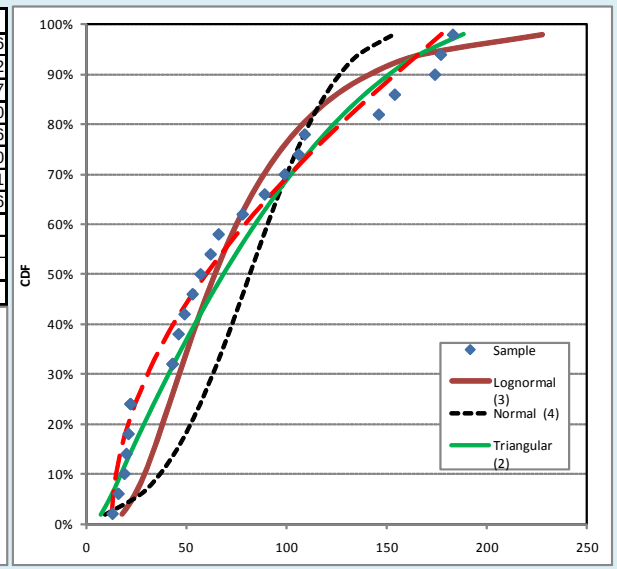
Recommended Risk Metric	Beta (Low = 13.00, High = 183.00, Alpha = 0.52, Beta = 0.96)
Risk Metric Comments	

Dataset Statistics and Fitted Distributions

Sample	
Can be used to define a CDF directly	
Percentile	Value
0%	11.50
5%	15.25
10%	19.00
15%	**20.25**
20%	21.33
25%	22.00
30%	22.00
35%	43.00
40%	47.50
45%	52.00
50%	**57.00**
55%	63.00
60%	72.00
65%	86.25
70%	99.00
75%	106.75
80%	127.50
85%	**152.00**
90%	174.00
95%	178.50
100%	183.00

FY2008K$	Sample	Lognormal	Normal	Triangular	Beta
Mean	74.68	77.70	81.67	77.18	72.96
StdDev	55.03	52.76	35.11	50.05	51.62
CV	0.737	0.679	0.430	0.648	0.707
Min	13.00			0.00	13.00
Mode	22.00	43.99	81.67	13.00	72.96
Max	183.00			218.53	183.00
Data Count	25			Alpha	0.521
				Beta	0.956
Rank		3	4	2	1
Standard Error of Estimate		17.58	26.42	10.68	8.39
SEE / Mean		22.6%	32.4%	13.8%	11.5%
Chi^2 Fit test 14 Bins, Sig 0.05		Poor (3%)	Poor (0%)	Poor (4%)	Good (10%)





Notional data

Cost Driver Example: SDD Duration

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Cost Risk and Uncertainty Analysis Data Report

Record 0

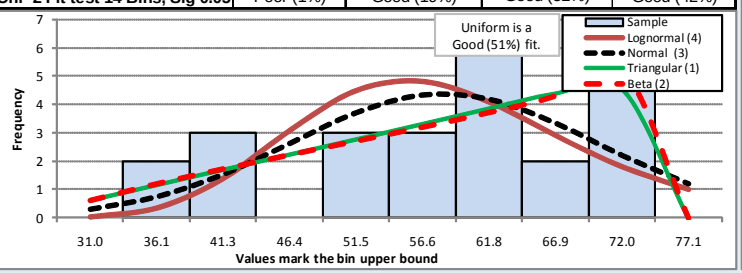
Commodity	Sample	**Dispersion**	First
WBS		**Unit**	Months
Element	RDTE Duration	**Measurement**	Duration
Sub-Element		**Phase**	RDTE
Category		**Filter and Fit**	Filter= NONE: , Fit = SSE on Value
Fit Constraints	Force Min => 0: Nor TRI Beta | Force Include Sample Min/Max: TRI Beta		

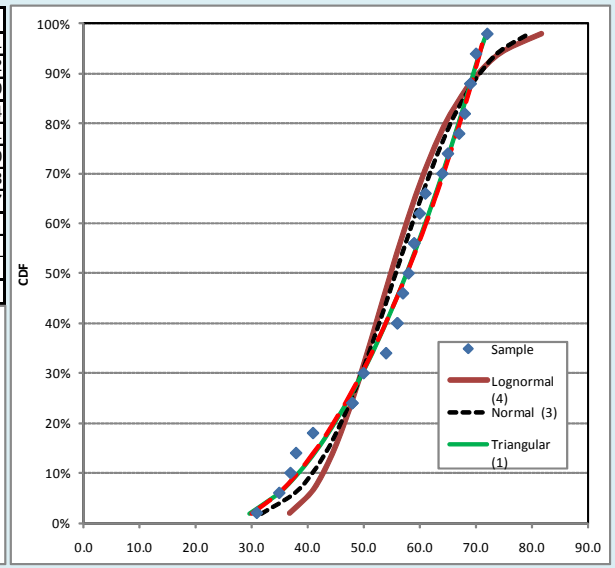
Recommended Risk Metric	Triangular (Low = 22.70, Mode = 70.49, High = 73.79)
Risk Metric Comments	

Dataset Statistics and Fitted Distributions

Sample	
Can be used to define a CDF directly	
Percentile	**Value**
0%	29.00
5%	34.00
10%	37.00
15%	**38.75**
20%	43.33
25%	48.00
30%	50.00
35%	54.33
40%	56.00
45%	56.00
50%	**58.00**
55%	58.83
60%	59.00
65%	60.75
70%	64.00
75%	65.50
80%	67.50
85%	**68.50**
90%	69.00
95%	70.50
100%	72.00

Months	Sample	Lognormal	Normal	Triangular	Beta
Mean	55.68	55.82	55.68	55.66	55.71
StdDev	11.91	10.94	11.63	11.67	11.72
CV	0.214	0.196	0.209	0.210	0.210
Min	31.00			22.70	24.54
Mode	48.00	52.75	55.68	70.49	55.71
Max	72.00			73.79	72.00
Data Count	25			**Alpha**	1.773
				Beta	0.927
Rank		4	3	1	2
Standard Error of Estimate		4.12	2.96	1.46	1.49
SEE / Mean		7.4%	5.3%	2.6%	2.7%
Chi^2 Fit test 14 Bins, Sig 0.05		Poor (1%)	Good (19%)	Good (52%)	Good (42%)





Notional data

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Descriptive Statistics and Curve Fit Results

Element	RDTE SEPM	RDTE Duration	RDTE SEPM / Recurring
Units	FY2008K$	Months	
Count	25	25	25
Minimum	13.000	31.000	0.2826
5%	15.250	34.000	0.2961
15%	20.250	38.750	0.3765
30%	22.000	50.000	0.4151
50%	57.000	58.000	0.4407
70%	99.000	64.000	0.5145
85%	152.000	68.500	0.5461
95%	178.500	70.500	0.6200
Maximum	183.000	72.000	0.6531
Range	170.000	41.000	0.3705
Inner Quartile Range	84.750	17.500	0.1202
Mean	74.680	55.680	0.4556
Std Dev	55.034	11.912	0.0919
CV	0.737	0.214	0.202

Element	RDTE SEPM	RDTE Duration	RDTE SEPM / Recurring
Units	FY2008K$	Months	
Filter and Fit	Filter= NONE: , Fit = SSE on Value	Filter= NONE: , Fit = SSE on Value	Filter= NONE: , Fit = SSE on Value
Fit Constraints	Force Min => 0: Nor TRI Beta | Force Include Sample Min/Max: TRI Beta	Force Min => 0: Nor TRI Beta | Force Include Sample Min/Max: TRI Beta	Force Min => 0: Nor TRI Beta | Force Include Sample Min/Max: TRI Beta
Recommendation	Beta (Low = 13.00, High = 183.00, Alpha = 0.52, Beta = 0.96)	Triangular (Low = 22.70, Mode = 70.49, High = 73.79)	Normal (Mean = 0.46, Std Dev = 0.09)
Lognormal Mean	77.697	55.818	0.4563
Lognormal StdDev	52.760	10.937	0.0909
CV	0.679	0.196	0.199
SEE	17.579	4.121	0.0147
Normal Mean	81.674	55.684	0.4556
Normal StdDev	35.108	11.629	0.0914
CV	0.430	0.209	0.201
SEE	26.424	2.959	**0.0133**
Triangular Absolute Low	0.000	22.704	0.2480
Triangular Mode	13.000	70.487	0.4329
Triangular Absolute High	218.532	73.787	0.6861
CV	0.648	0.210	0.197
SEE	10.684	**1.456**	0.0136
Beta Absolute Low	13.000	24.537	0.2826
Beta Mode	72.957	55.710	0.4554
Beta Absolute High	183.000	72.000	0.6531
Alpha	0.5208	1.7734	1.3543
Beta	0.9558	0.9267	1.5493
CV	0.707	0.210	0.205
SEE	**8.386**	1.489	0.0195

Notional data

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Path Forward

- **Expand Dataset**
  - **More Commodities**
  - **More Observations**
- **Reduce Data into General-purpose Uncertainty Metrics by WBS and Commodity**
  - **Data Stratification**
  - **Descriptive Statistics (data points, mean, median, mode, standard deviation, CV)**
  - **Fit data to uncertainty distributions**

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BACKUP

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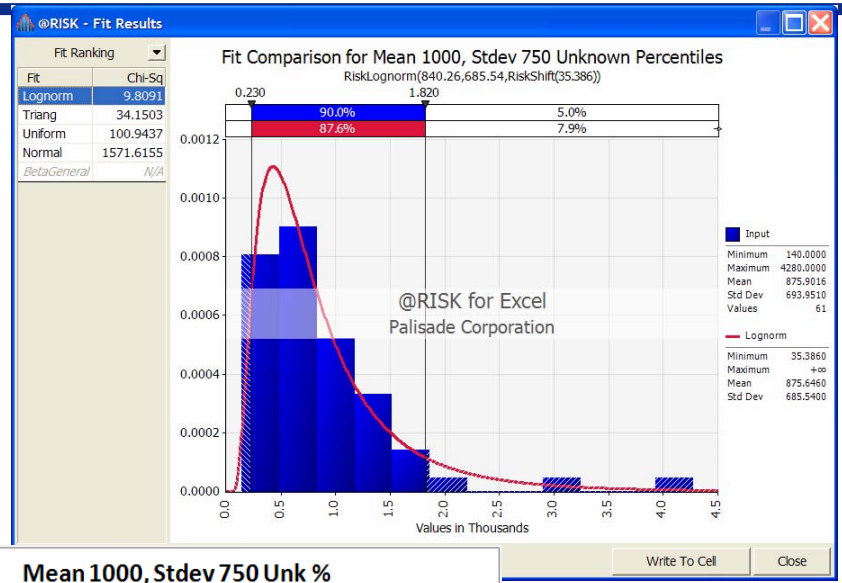
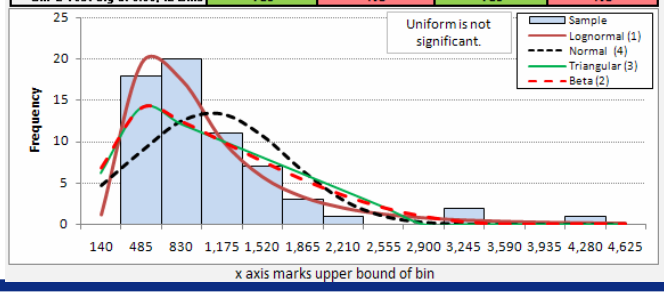
Fit Without Knowing Data Percentiles

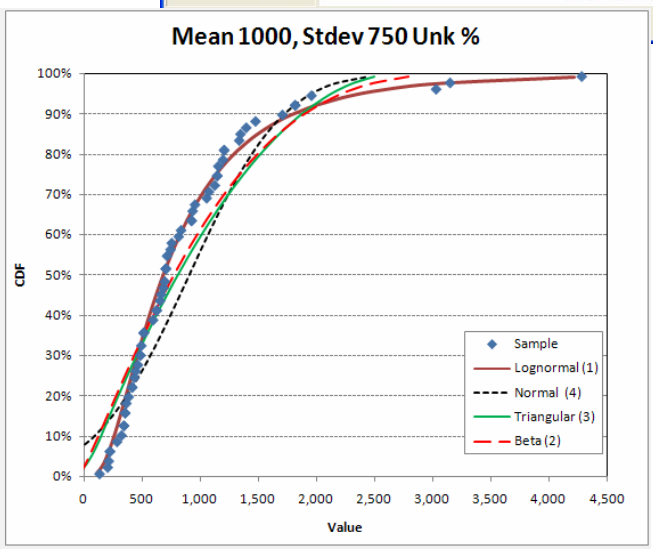
- **@Risk LN Chi 9.8 on 12 Bins**
  Mean 875.64; Stdev 685.54
  (note: bins displayed not necessarily bins for chi calc)

- **Utility LN Chi 12.4 on 12 Bins**
  Mean 906.67; Stdev 795.08
  (note: bins displayed does equal bins for chi calc)



FY08 $M	Sample	Lognormal	Normal	Triangular	Beta
Mean	906.67	904.40	906.61	913.77	1,165.81
StdDev	735.30	795.08	640.02	650.08	619.47
CV	0.811	0.879	0.706	0.711	0.531
Low	140.00			-143.84	-44.07
Mode	520.00			140.00	907.52
High	4,280.00			2,745.14	3,508.61
Alpha					1.17
Beta					3.21
Data Count	63				
Standard Error of Estimate		96.18	368.00	325.03	285.51
SEE / Mean		10.6%	40.6%	35.6%	24.5%
Chi^2 Test Sig at 0.05, 12 Bins		Yes	No	Yes	No





Chi critical value for 12 bins

0.05 sig level =

16.9 for Log Normal

16.9 for Normal

15.5 for Triangular

14.1 for beta

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CRUAMM Orders of Dispersion

- **Premise: The cost estimating process is one of narrowing uncertainty through the use of cost drivers, metrics, CERs, and models.**
- **Uncertainty is quantified by measuring dispersion in observed data sets.**
- **Define Four Orders of Dispersion.**
- **Illustrate each with an example.**

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Orders of Dispersion Summary

- **Observe successive narrowing of each distribution.**