

Putting More Science in Cost Risk Analyses

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Business Ventures - Statoil

- An integrated international Oil and Gas corporation, Statoil ASA operates in 40+ countries around the world with its operation base in Norway.
- Statoil's business spectrum covers entire value chain ranging from upstream exploration through pipelines to petrol stations.
- Statoil's business ventures include dealing with the most challenging geographic locations (Shtokman), finding renewable solutions (wind farm) and utilizing the most complex technological innovations (ESP).

> NEW ENERGY



> FIELD DEVELOPMENT



> TECHNOLOGY MANAGEMENT



High Risk Business in Oil & Gas

- Uncertainties in upstream subterranean are unpredictable; traditional mathematical modelling methods can not suffice new challenges for exploration, reservoir and economic valuations.
- Risks and stakes in building oil and gas infrastructures and processing facilities are extremely high; conventional management wisdom in managing project costs and schedules can no longer cope with new demands for controlling overruns.
- Legal liability exerts ever increasing pressures on Environmental & Safety risk assessment that is complicated and often probabilistic.

New Challenges in new Era

- New valuation and appraisal methods in Oil and Gas industry often engage probabilistic thinking and stochastic simulation techniques.
- Requirements for risk analysis expertise and competences are all time high in energy industry to suffice the increased demands.
- Major infrastructure building projects in Oil and Gas industry have continued overrunning cost budgets and time baselines.

Understanding Monte Carlo Simulation Method

Monte Carlo	# (USA)	# (UAE)	# (Canada)	Total	%
100%	4	1	1	6	7%
75 - 50%	4	2	11	17	19%
50-25%	5	6	13	24	27%
<25%	0	11	30	41	47%
TOTAL	13	20	55	88	

“Delinquency” of Cost Risk Analysis

- Intuitively responding to risks;
- Statically analysing math models;
- All line-item ranging exercises;
- Not challenging “most likely”;
- Randomly select key variables;
- Zero and Nil risk correlations;
- Ignoring systemic risk impacts;
- Lacking empirical validation;
- Minimal business knowledge.

Estimate Items	Most Likely (US\$)	P10 Value	P90 Value	Triangular (EV)
Install Pipes on Racks				
Pipefitter wage rate	50			
labour Productivity	1			
Field Piping Manhours	1 500	95 %	140 %	1 729
Total Pipe Installation Cost	75 000			86 437
Scaffolding Labour				
Wage Rate	50			
Labour Productivity	1			
Total DFL Manhours	1 500			
Scaffold Labour Hour %	17 %	95 %	150 %	20,3%
Total Indirect Cost	12 750			15 255
Field Indirect Costs				
Temp Facilities	15 000			
Small tools	20 000	90 %	125 %	21 293
Janitorial Services	8 000			
Total Indirect Cost	43 000			44 293
Engineering				
Eng. Staff Wage Rate	85	80 %	130 %	89
Eng. Productivity	1			
Estimate Manhours	600			
Total Eng. Cost	51 000			53 191
Total Estimated Cost				
	181 750			199 176
Contingency at EV				
			9,6%	17 426

Incredibility of Risk Analysis

Key issues that many organizations face now:

- Senior Management has not yet trusted and believed in the results of Risk Analyses, so decision-makings do not depend on analytical reports;

And / or

- Quantitative Risk Analyses results are yet to be more scientifically convincing and persuasive, so lacks of credibility ruined the analysts.

Such issues may have their roots in:

- Risk analysing techniques are yet to be further developed and matured;
- Lack interests in developing in-house risk competences and expertise;
- Risk analysis is an add-on exercise, not an embedded business process;
- No time, money & resources to collect empirical data for Benchmarking.

Adding Science into Risk Analyses

A simple cost risk analysis example is used to illustrate the effects of the following “supplements” on the contingency of a project cost estimate.

- **Choose righteous Probability Distribution**
- **Include Qualitative Risk Register**
- **Mind Correlation and Dependency**
- **Verify Risk Results with Empirical Data**

References are made to the “recommended practices” of AACEi for Cost Estimate Risk Analysis and Contingency Determination methods.

Many more areas of risk analyses can be further enhanced and matured but they are excluded from this discussion, including

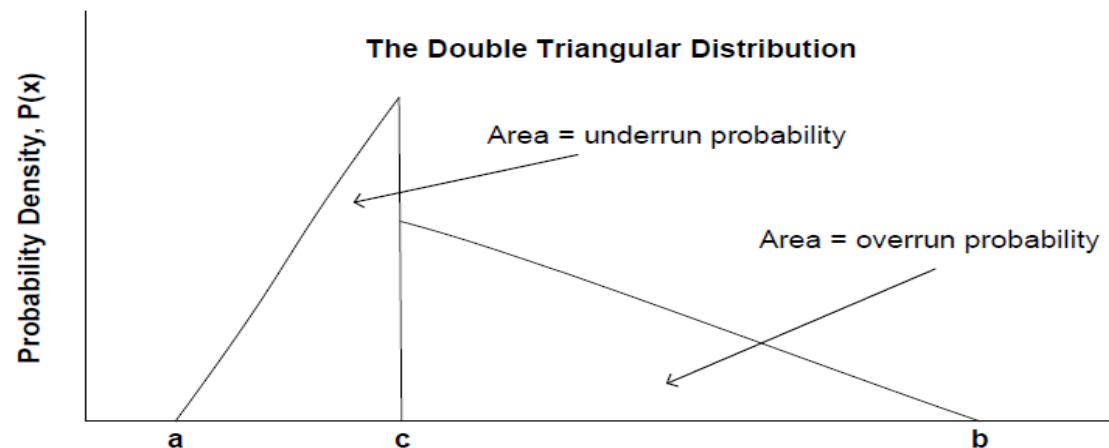
- **Integrated Risk Evaluation process of entire Business Value Chain**
- **Capital Projects Cost and Schedule Risk Quantification Integration**
- **Discrete Probabilistic Residual Risk Impacts on Project Economics**

Double-Triangular Distribution

AACE International Recommended Practice No. 41R-08 “RISK ANALYSIS AND CONTINGENCY DETERMINATION USING RANGE ESTIMATING” (TCM Framework 7.6 – Risk Management) states that:

“In most cases, the double triangular distribution is a better approximation since it can be made to conform to the implicit skew of the project team’s probability assessment. The double triangle allows the risk analyst to use the probabilities which the project team believes are reasonable rather than letting the triangular distribution dictate a probability...”.

It combines two triangular distributions truncating on one side to the most likely value – based on subjective over-run and under-run probabilities.

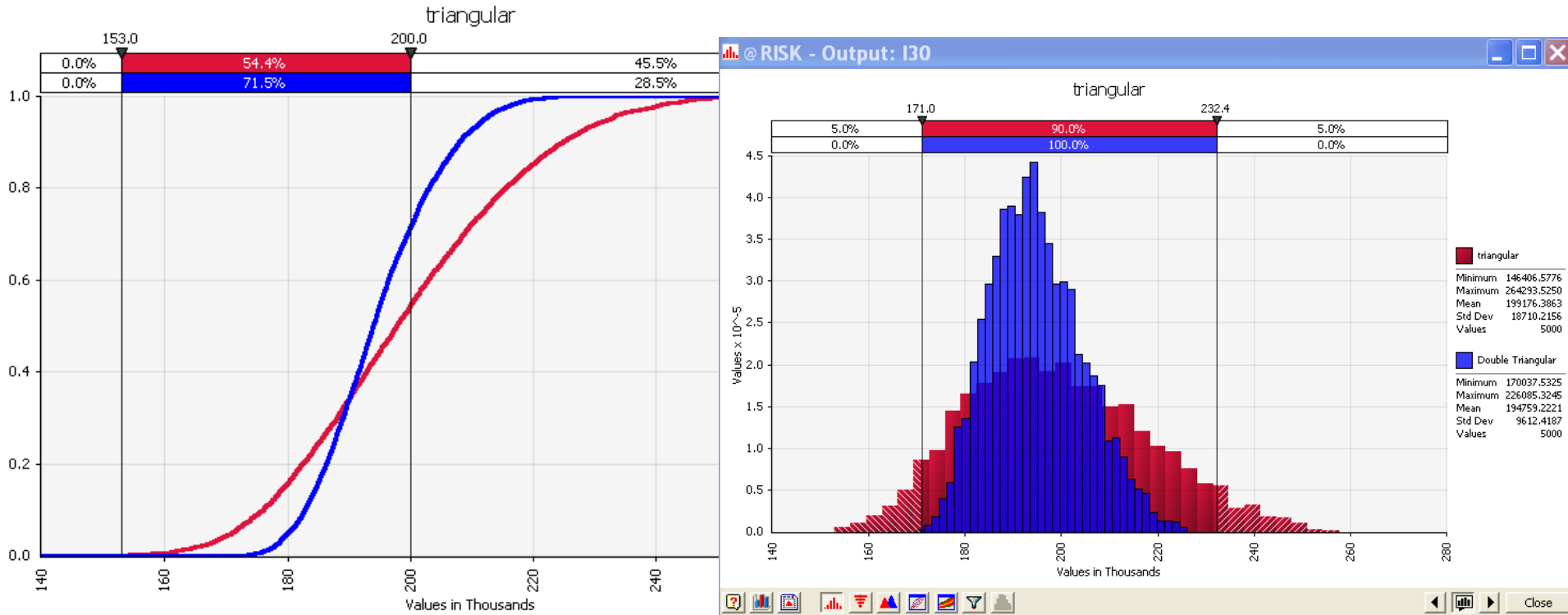


Results Comparison

Estimate Items	Most Likely (US\$)	P10 Value	P90 Value	Triangular (EV)	Under run Chance	Underrun Extreme	Over run Chance	Overrun Extreme	Double Triangular (EV)
		Triangular					Double Triangular		
Install Pipes on Racks									
Pipefitter wage rate	50								
labour Productivity	1				0.00800	95%	0.00233	140%	
Field Piping Manhours	1,500	95%	140%	1,729	30%	1,425	70%	2,100	1,677
Total Pipe Installation Cost	75,000			86,437					83,872
Scaffolding Labour					=RiskGeneral(L8,N8,{1500,1500},{0.0016,0.0018})				
Wage Rate	50								
Labour Productivity	1								
Total DFL Manhours	1,500				(2 x Underrun Probability) / (Most Likely - Underrun Extreme)				
Scaffold Labour Hour %	17%	95%	150%	20.3%					
Total Indirect Cost	12,750			15,255					15,255
Field Indirect Costs									
Temp Facilities	15,000				0.00040	90%	0.00024	125%	
Small tools	20,000	90%	125%	21,293	40%	18,000	60%	25,000	21,252
Janitorial Services	8,000								
Total Indirect Cost	43,000			44,293					44,252
Engineering					0.07059	80%	0.03137	130%	
Eng. Staff Wage Rate	85	80%	130%	89	60%	68	40%	111	86
Eng. Productivity	1								
Estimate Manhours	600								
Total Eng. Cost	51,000			53,191					51,381
Total Estimated Cost	181,750			199,176					194,761
Contingency at EV			9.6%	17,426				7.2%	13,011
P70 Value				208,673					199,484
Contingency at P70				14.8%					9.8%

“Buyers Beware” of D. Triangular

- End results are more aggressive (mean value \$194K vs. \$199k);
- It implies an optimistic risk profile (std. dev. 9612 vs. 18710);
- It demands less contingency amount (7.2% vs. 9.6% of base estimate);
- Probabilities under or over running base estimate are highly subjective;
- Use of the end results should be exercised with prudence and cautions.



Use of Risk Register

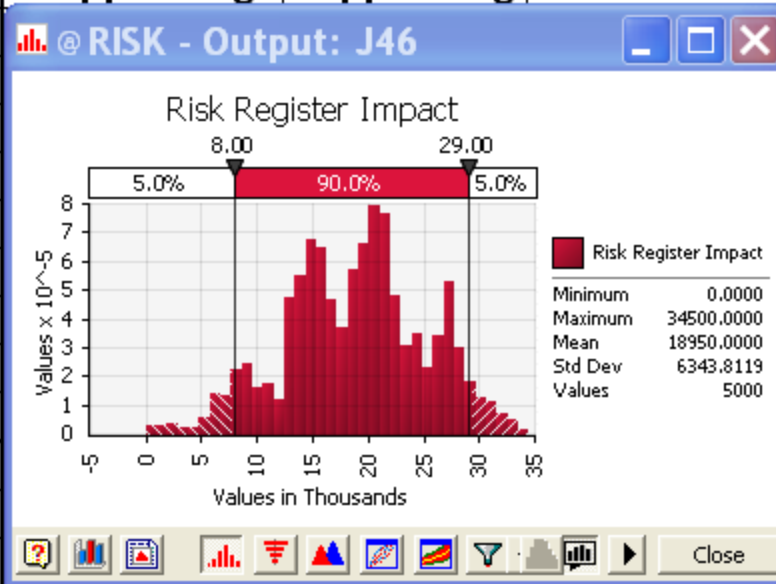
Risk Register Items	Probability of Happending	Impact Assessment	Mitigation Action Planning
1. Piping quantity may change	70%	5,000	Try to freeze SoW
2. Design may be revised	50%	1,500	Change Controls
3. Welding inspection may be new	30%	2,000	More field QC - Costs
4. Unskilled welders may be hired	60%	6,000	Selective Recruitment
5. Overall execution may be delayed	40%	7,000	Realistic Schedule
6. Labour market may be tight	80%	8,000	More attractive pay
7. Extreme cold weather may exist	20%	4,000	Reschedule / Hoarding
8. P.Manager may be changed.	50%	1,000	Ensure continuity

- Risk Register becomes an active managerial tool for PMs to control risks;
- Risk identification, ranking and action planning processes are matured;
- Costs / Time required for actions are NOT captured in base estimates;
- Probability weighted risk impacts are NOT quantified / included in costs;
- Risks in registers are NOT used to assess “variability ranges” of line items;
- Residual or rare-event driven risks with discrete nature are NOT captured;
- Accepted risks are NOT equipped with sufficient contingency planning;

Quantified Impacts of Risks

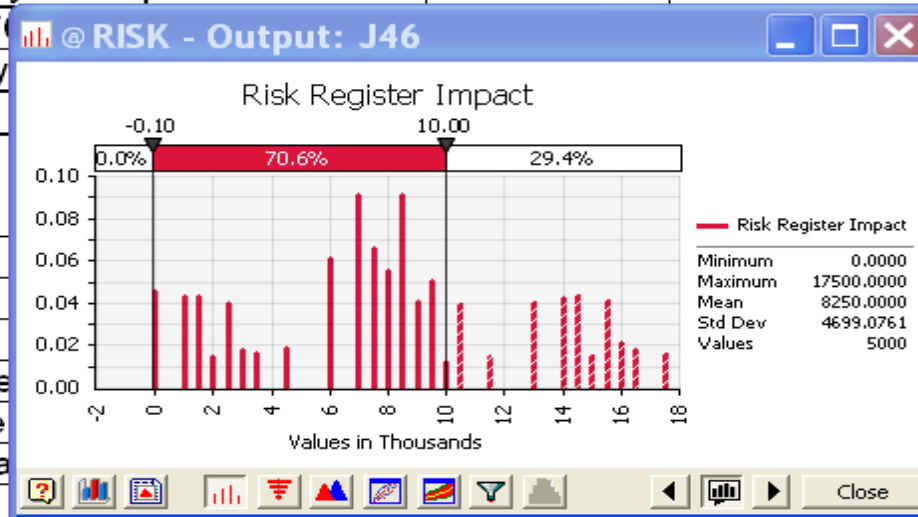
- Identify measurable risks that probability and impacts can be estimated;
- Identify risks that would have direct / indirect impacts on cost & time;
- Scrutinize and exclude risks that are already used for “range exercises”;
- Estimate the probability of risk happening and costs of risk impacts;
- Building risk model with Risk Discrete function to simulate contingency.

Risk Register Items	Probability of Happening	Not Happening	Impact Assessment	Simulated EV
1. Piping quantity may change				5,000
2. Design may be revised				0
3. Welding inspection may be new				0
4. Unskilled welders may be hired				6,000
5. Overall execution may be delayed				0
6. Labour market may be tight				8,000
7. Extreme cold weather may exist				0
8. P.Manager may be changed.				0
Contingency at Mean (EV) Value				19,000
P70 Value				22,000
Total Project Contingency at P70.				12.1%



Adequacy of Contingency

Total Estimated Cost	181,750			199,176
Contingency at EV			9.6%	17,426
P70				208,673
Contingency				14.8%
Risk Register Items				Simulated EV
1. Piping quantity may change				0
2. Design may be revised				0
3. Welding inspection may be ne				0
4. Unskilled welders may be hire				6,000
5. Overall execution may be dela				0
6. Labour market may be tight				0
7. Extreme cold weather may exist	20%	80%		0
8. P.Manager may be changed.	50%	50%	1,000	0
Contingency at Mean (EV) Value			3.3%	6,000
P70 Value				10,000
Total Project Contingency at P70.				5.5%



The proper contingency including risk register impacts may be:
 EV base (17,426) + EV Risk Register (6,000) = Total EV (23,426) @12.9%
 Or P70 base (26,923) + P70 Risks (10,000) = Total P70 (36,923) @20.3%

Risk Factors' Correlation

- Co-movements of key risk factors, which are often referred to as variables, could have significant domino effects or repercussions on the project outcomes invariably.

- **Dr. Stephen A. Book** acknowledged (2006 - NASA PM conference):

That the numerical values for correlations in cost risk analysis are difficult to establish, but the estimates of them must be made, because “total cost sigma is underestimated when all correlations assumed to be zero, or uncorrelated at all”.

- It is very important the risk analysts understand, or solicit the knowledge of from the experts, the underlining relationships among risk variables, as well as the negative or positive correlations between those variables.

- Degrees of correlation are measured using “Coefficients” in the matrix.

Correlation Coefficient

The “variable” of field piping hours is positively correlated to scaffold labour hours with high coefficient of 0.75 - i.e. the increases of piping hours will demand scaffold man-hours to increase in linear proportion.



Estimate Items	Most Likely (US\$)	P90 Value	Triangular (EV)		
		Triangular			
Install Pipes on Racks					
Pipefitter wage rate	50				
labour Productivity	1				
Field Piping Manhours	1,500	140%	1,729		
Total Pipe Installation Cost	75,000		86,437		
Scaffolding Labour					
Wage Rate	50				
Labour Productivity	1				
Total DFL Manhours	1,500				
Scaffold Labour Hour %	17%	150%	20.3%		
Total Indirect Cost	12 750		15 255		
Field	@RISK Correlations	Field Piping Manhours / Triangular in \$I\$8	Scaffold Labour Hour % / Triangular in \$I\$15	Small tools / Triangular in \$I\$20	Eng. Staff Wage Rate / Triangular in \$I\$25
	Field Piping Manhours / Triangular in \$I\$8	1			
	Scaffold Labour Hour % / Triangular in \$I\$15	0.75	1		
	Small tools / Triangular in \$I\$20	0.5	0.2	1	
	Eng. Staff Wage Rate / Triangular in \$I\$25	0	0	0	1
Total Estimated Cost		181,750		199,176	

The Impacts of Correlation

Original Estimate (US\$)	No Correlation Matrix inserted		Zero Correlations Coefficients		Follow Correlation Matrix Table	
	EV	P70	EV	P70	EV	P70
181,750						
Values (US\$)	199,176	207,743	199,176	207,274	199,176	208,485
Contingency %	9.6%	14.3%	9.6%	14.0%	9.6%	14.7%

- As it is affirmed before, the final contingency amounts are impacted by the Correlation and Correlation Coefficients in the risk model.
- The use of Expected Value (EV) as decision-making criteria may need to be revisited as EVs don't change in all three scenarios.
- Dr. Book made it clear that “we are Not free to assign correlation values arbitrarily”. Assuming zero rather than positive correlation values is too optimistic, because summing uncorrelated random variables exerts cancellation effect on total-cost standard deviation (“sigma value”).

Empirical Benchmarking

It would be beneficial to risk analysts if historical benchmarks of the similar projects are available. Both cost estimates and risk analyses would be easier if such benchmarks can be used for comparison.

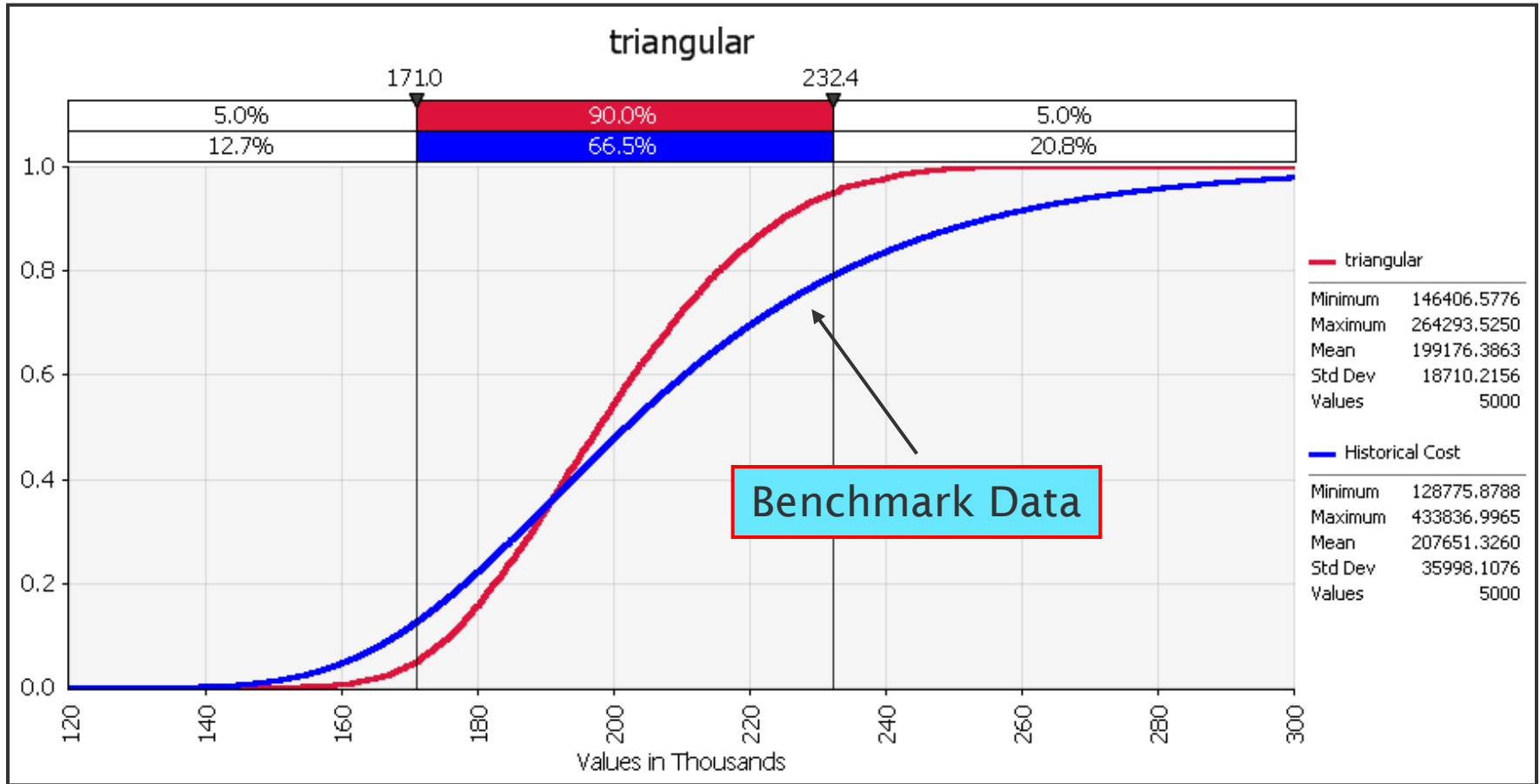
The sad facts are that companies are poor in collecting and keeping historical project cost data.

Historical data can be used as input to best “fit” a distribution that indicates the probability ranges of possible outcomes.

The benchmarks made out of reliable empirical data can at least verify if the risk analysis results are realistic and convincing, a crucial validation.

Company	A. Cost (US\$)
AAB	158,000
CCD	250,000
EEF	190,000
HHI	235,000
KKM	160,250
QQP	185,000
RRS	220,000
XXY	242,500

Validation of Risk Analysis



The risk result indicates that final project cost would be in between \$171K And \$232K with 90% confidence, but history confirmed only 66% confidence.

Interpreting the Risk results

The base case cost estimate may have less exposures to risks; so it can do better than the “history”;

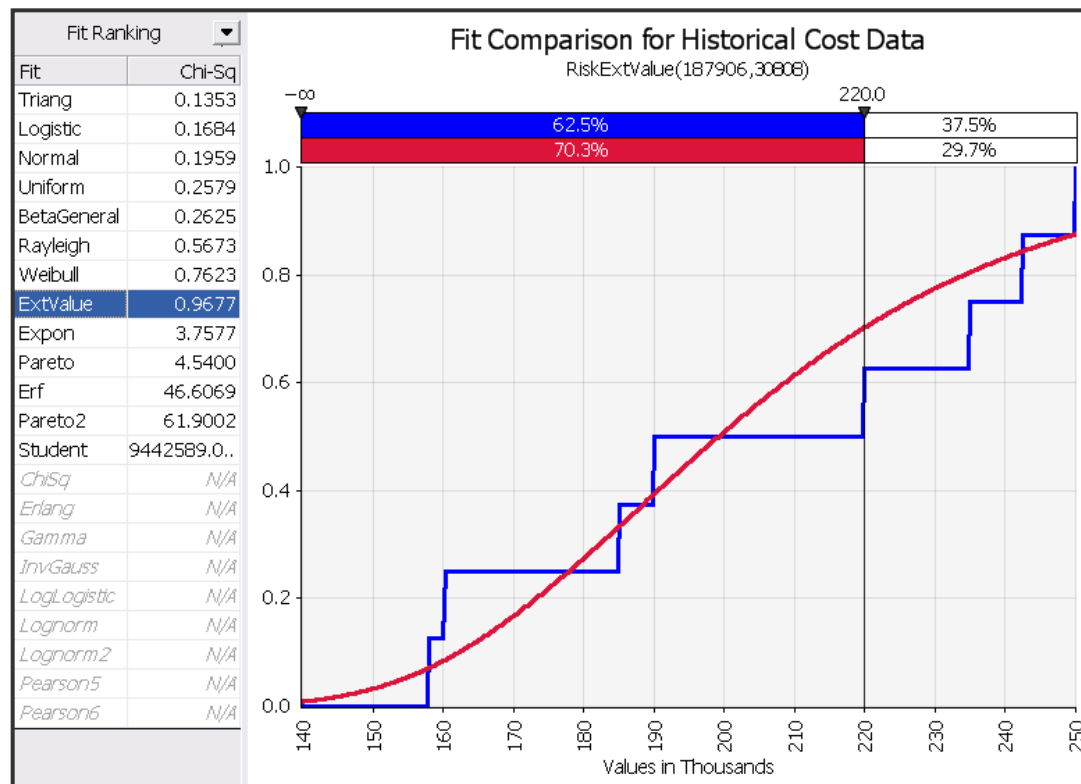
The risk analysis result may not reflect the reality, so risk ranges, risk register and correlations need to be revisited for validation;

Empiricism indicated

80% confident cost overruns if cost “budget” was \$182K;

50% confident cost overruns if cost “budget” was \$199K;

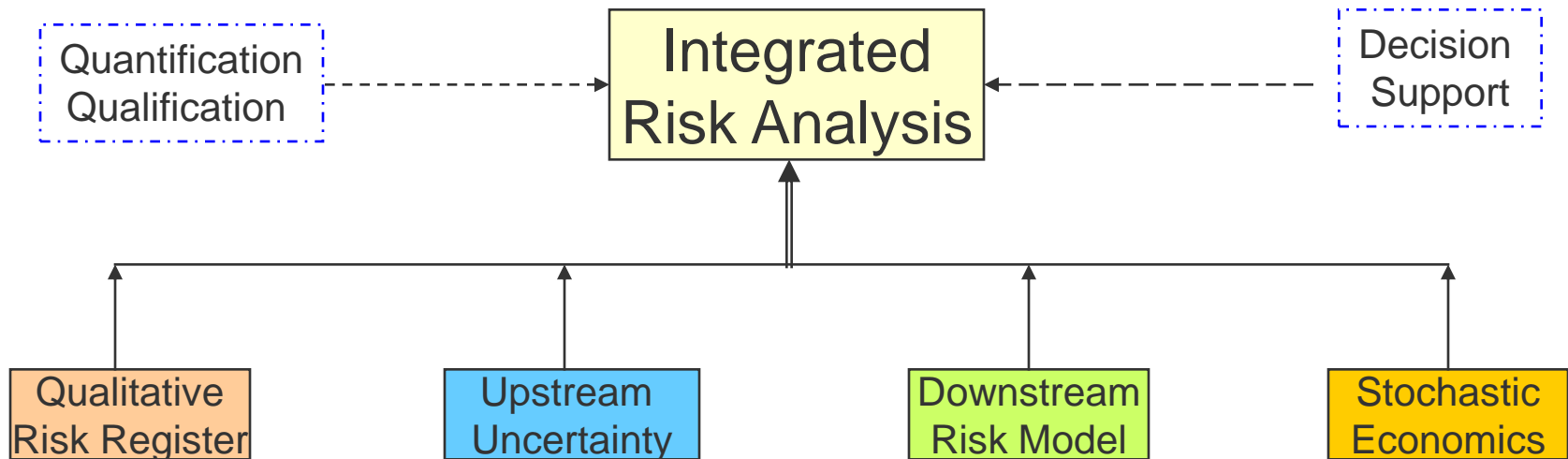
70% confident cost under-runs if cost “budget” was \$220K;



Trotting Unknown Waters

Risk analysis is a practice that can be very confusing, even for the experts. There is insufficient academic research and very little matured pragmatic empiricism in this field. Putting more science into risk analyses is just a rudimentary step, there are many unknown areas that await our explorations, and experiments.

The Integration of entire value chain risk assessment in Oil and Gas industry poses another major challenge to our risk experts...



Finally

Having realized the crucial importance of right competence in conducting uncertainty and risk management, Statoil has paid tremendous attention to developing business processes, building up @RISK user skills, and job training. It has risk expertise in the following areas conducting various quantitative risk modelling:

- Drilling and Well Completion / Reservoir Engineering
- Total Risk Analysis for Health, Safety and Environmental
- Capital investment project cost and schedule risk quantification
- Risk Analyses / Valuation for Economics, Trading and Credit

Education and on-job training to cultivate right in-house competence and necessary expertise proved to be fruitful and beneficial to the practices of Risk analysis in Statoil.

Thank you

Putting More Science into Risk Analysis

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