

Put More Science into Quantitative Risk Analyses

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Abstract:

Intuitively responding to risks or crisis can not be qualified as proper risk management; statically analysing difficult mathematical problems for solutions can barely be called risk analysis. Recent financial system breakdown was rooted in decisions driven by egos and prides rather than scientific risk quantifications and controls. Companies thirsty and hungry for profits simply forget to exercise prudence and necessary discretion when it comes to accepting and taking risks. Cost overruns and schedule delays in capital investment world become common place and gradually accepted phenomenon. Fewer know and understand how Monte Carlo simulation works, and sadly those who knew are often brushed aside for the reasons of “lacking credibility”. We, risk practitioners, are responsible for putting more science into risk analyses to foster and bolster the credibility, convincing-ability and the bona fide of risk quantification.

Key Words: Monte Carlo, Risk Quantification, Credibility, Modelling, Integration

The Applications of Risk Analyses

Economists have recently nicknamed next “te(e)n” years as ”debtcade” due to the unexpected but already anticipated naughty financial behaviour (Economics Dec 2009). The crisis had been forecasted by those quant specialists but was unfortunately ignored by those ego-driven management generals. For recent years, the application of risk quantification using @RISK has been pervasive in many industries, and its use proliferated. Even though quantitative risk analyses have the merits to quantify risk probability and forecast consequences, their results and “recommendations” have not been widely accepted in the industry as the scientific means of measuring risks. It therefore implies that either the risk analyses lack science and credibility or managerial generals lack understanding and knowledge. Perhaps, it is both!

In oil and gas industry, oil price drives profitability in many ways but the CAPEX often is one of the sensitive drivers to the NPV, the profit margins of projects with higher-than-budget costs can be eroded quickly. Whilst the futuristic oil prices may be hard to predict due to its low

manageability, it is absolutely possible to scientifically forecast the sizes of risks that companies are willing to take, and such risks may include the probabilistic volumes of newly discovered reserves, probability of meeting a project development schedule, chances of project cost overruns, for all of which the overall objective is to measure the likelihood of eroding entire project economics in terms of profitability (NPV). To achieve these goals, @RISK has lent a helping hand to risk analysts for easier operation of complicated mathematical modelling.

The use of @RISK and its applications is widespread in Statoil, an integrated international Oil and Gas corporation, who operates in 40+ countries with its operational base in Norway. Because of the high risks in running oil and gas businesses, quantitative risk analyses have become part of required business process in Statoil who has over 1,000+ @RISK user licenses¹. The spectrum of @RISK application ranges in many diversified ways that are used to measure risk intensities; check and attenuate risk criticality; apply risk actions to reduce risk severity and final impacts to business or project objectives. Acknowledging the following circumstances, risk analyses in Statoil are often performed.

- Uncertainties in upstream subterranean are unpredictable; traditional mathematical modelling methods can not suffice new challenges.
- 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.
- New valuation and appraisal methods in Oil and Gas industry often engage probabilistic thinking and risk based stochastic simulation for the business spectrum of entire value chain ranging from upstream exploration through pipelines to downstream refineries.
- Statoil's business ventures deal with the most challenging geographic locations; find new renewable solutions and utilize the most complex technological innovations.

Current Cost Risk Analyses

Many risk practitioners call themselves quantitative risk analysts trying to predict “future” risk impacts through running Monte Carlo simulation which becomes a posh word in management arena. However, fewer truly understand the complicated, often misleadingly skewed, twist of the process and the correct interpretation of the final results. Those who can skilfully run @RISK software often claim that they have mastered risk analysis skills and quickly jump to becoming

¹ This estimated number was based on the Palisade revealed unofficial figure in 2007, not Statoil internal data.

risk consultants. Risk analysis entails more than just running a few iterations of simulations, it requires, as a minimum, an overall understanding of the business’ objectives, the trained pair of eyes to catch invisible risk implications, and a robust risk analysing process.

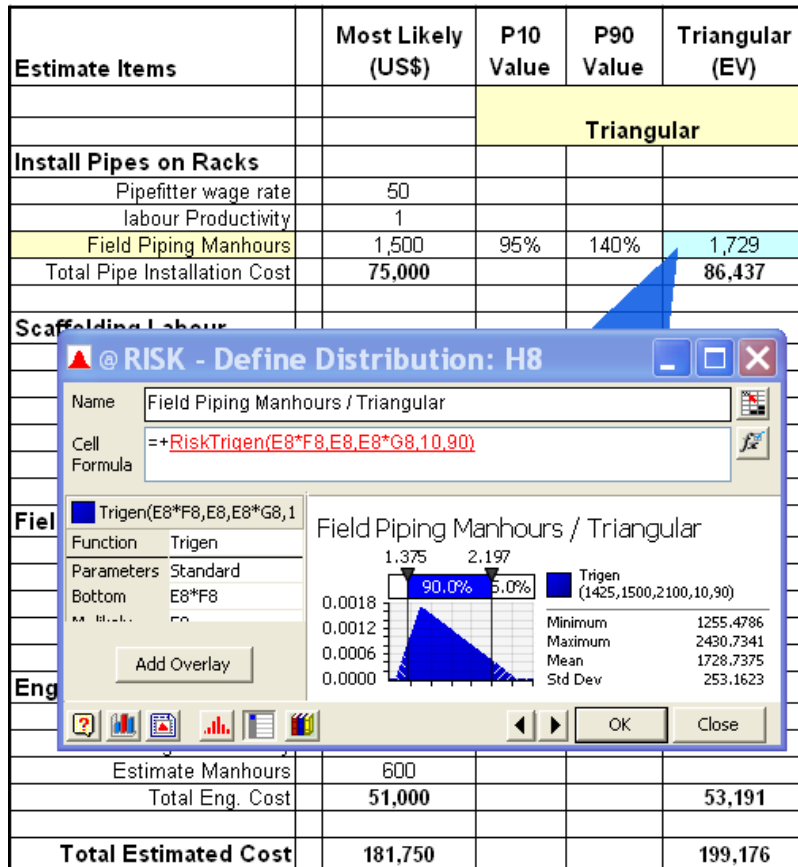


Figure 1-1: Line-item Risk ranging Approach for Contingency (based on @RISK)

Debates about the best methodology and the toolkit for quantitative risk analyses have never stopped in the industry, however one fact remains that the contingency estimates, as the result of risk analyses, are on average getting further from the actual contingency required, according to IPA’s recent study. The traditional line-item ranging method using simulation technique has dominated cost risk analyses for past few decades without a major breakthrough. The majority of new entrants to risk analysis profession unfortunately are often taught the line-item ranging approach only. Probabilistic ranging on line items only, on either cost account or single estimate element, significantly undermines the end results and often provides inadequate contingency to cover the real project risk pictures.

The line-item ranging method is widely used because of its simplicity with focuses on visible variables for their continuous probability distribution. In real life, it is the discrete risks that

often causes unpredictable surprises. Harvard Business Review (October 2009) identified six mistakes that executives make in risk management; the first one is that “we think we can manage risks by predicting extreme events”. It may not be impossible to predict the probabilities or frequencies of discrete risk occurrences, however, we can prepare for the consequences using contingency plan. The contingency fund should therefore count for both continuous and discreet risk events; however in reality, systemic project risks, with discrete nature, are often ignored but the empirical experiences have attested that they will impact the integrity of overall project budget if they are not properly captured. If a risk analyst can not elevate him to a higher ground to see the entire forest but single trees, the analysis will be only partial and probably biased. The other common problem of line-item ranging approach goes to against the Pareto’s Law that risk analysts analyse everything – putting probability distribution on almost all estimate elements. They forget the effects of the large number theory, and fail to identify critical variables. After all, it is critical that risk analyses are well balanced between science and arts.

Putting More Sciences in Risk Analyses

This task is easy said than done as many oil companies currently have not sufficiently matured their risk analyses techniques in terms of estimating cost, schedule, weight and productions. Fewer firms are interested in collecting empirical data, developing in-house competences and changing their paradigms, so ranging line-item method continues to be prominent in the industry. For risk results to be more convincing and persuasive, company’s risk culture must be enhanced from strategic point of view whilst the risk analysis techniques need to be improved from tactic perspective. Theoretical trials and pragmatic frontiers have to be compensated for each other to reach the climax of best in class quantitative risk analysis with scientific basis but easy-to-use processes. The author’s self interested manipulation of a “mock” cost estimate contingency model using @RISK simulation functions indicated that the risk analysis results are quite different if different techniques are employed; it has been proven that risk analysis is a very subtle and sensitive exercise, and is also quite “fragile” to its inputs, analyzing approach and overall comprehension of the problem in reality. To illustrate the different yields using differing features of risk analysis technique, the line-item method is used as the base-case for comparison.

1-1 Choose righteous Probability Distribution

There are many ways to perform cost risk analysis and “calculate” the required contingency which itself is sensitive. If it is too high a number, a bidding contractor may lose his bid but he

may inversely suffer profit loss if the contingency is unreasonably low. For offshore platform weight risk analysis, the safety concerns may be raised if design margins or confidence levels are not correctly chosen.

The Recommended Practice No. 41R-08² of AACEi (RISK ANALYSIS AND CONTINGENCY DETERMINATION USING RANGE ESTIMATING) put forth two PDFs (probability density functions) for cost risk analyses. Often taught at schools and historically proven useful, the triangular distribution with P10 and P90 truncation has been used extensively for ranging risk variability in risk analysis world. It is also a well known fact that the conventional “trigen” distribution inevitably includes some “extras”, so the results of triangular PDF are relatively conservative.

It is really difficult in practical life to reckon which distribution can best and truly represent the reality; after all, they should reasonably represent the approximation and best resemblance of real cases. A very little used and less common distribution goes to double triangular probability distribution, which is recommended in the AACEi RP 41R-08 that states that “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 which, more often than not, is invalid”.

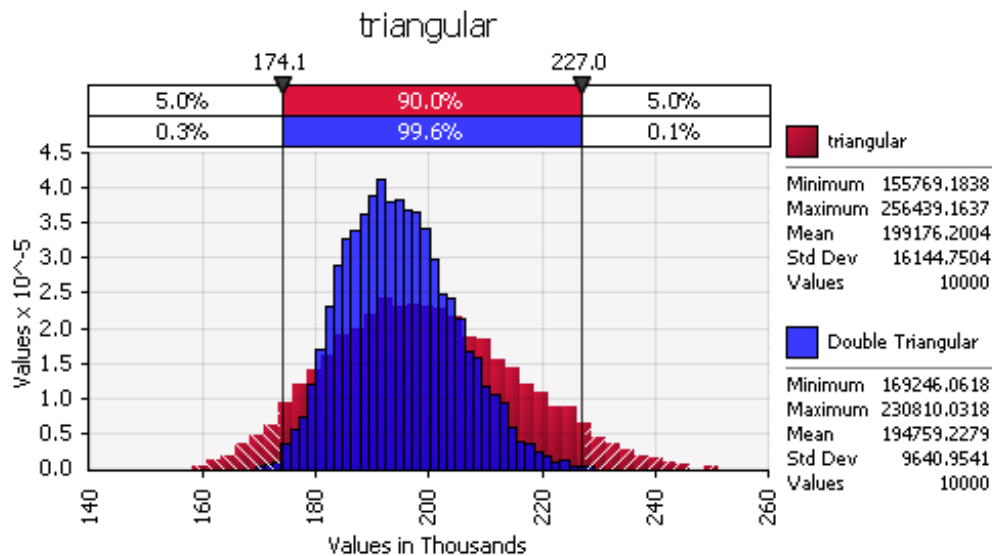


Figure 1-2: Comparison of Single and Double Triangular Distribution

² The Author of this RP is Dr. K. Humphreys and it differs from RP 44R-08.

However, prudent cautions must be taken when applying for double triangular distribution in risk analysis. As it is shown in Figure 1-2 which compares the results of single and double triangular PDFs, the kurtosis of the latter is higher but its standard deviation is narrower, i.e. the results of double triangular distribution may be realistic but it is also more aggressive and less conservative, i.e. it requires less contingency amount at 9.6% versus 14.3% @P70 for a single triangular distribution in Figure 1-1. For projects in the stage of acquiring financing and funding, owners may prefer to have the results of the latter whilst for the execution phase, owners may want to have tighter controls of project budget hence choosing the former result.

It must be realised that risk analysis as a double-edged sword can play tricks in business decisions, so managers must be informed and risk analysis report be qualified with conditions. In the end, its use must be prudent and consistent with business objectives.

1-2 Include qualitative Risk Register

As the AACEi RP 44R-48 rightfully pointed out, the qualitative risk evaluation process has traditionally divorced from the quantitative risk analysis approach. Typically, risk identification process is not set up to aid cost or schedule contingency simulation, notwithstanding they are occasionally used as inputs to cost risk analyses. Most risk management processes unfortunately do not mandate risk registers to be included in project contingency calculation, rather they are merely used to inform management of risks for awareness and planning mitigating actions. Worse yet, the costs of carrying out risk response actions are often dropped out of project budget and at the end project team always struggles to grab “money” from contingency to manage identified risks, for the risk register is not used to contribute to contingency in the first place.

As a good risk analyst, he / she should not forget the impacts of identified risks which are of project life cycle and for entire value chain. In the contingency calculation, identified risks with their discrete probability distribution should be counted for using RiskDiscrete function. Ideally the costs and time required to manage risks to an acceptable tolerance level should have been captured and included in the base cost estimates and schedule baseline, the residual risks and rare-event driven risks shall contribute to quantified project contingency. Detailed risk response action planning including TEAM³ (Transferring, Eliminating, Accepting and Mitigating) should be left as project management tasks; however it is paramount that risk analysts ensure that adequate money and time are included in contingency. This is a daunting job indeed as it

³ TEAM approach is the method that the author has tried, used and documented as his best work practice.

requires a set of reliable and proven heuristic data (empiricism) – a list of systemic risks that may impact the project outcomes as a whole (parametric method).

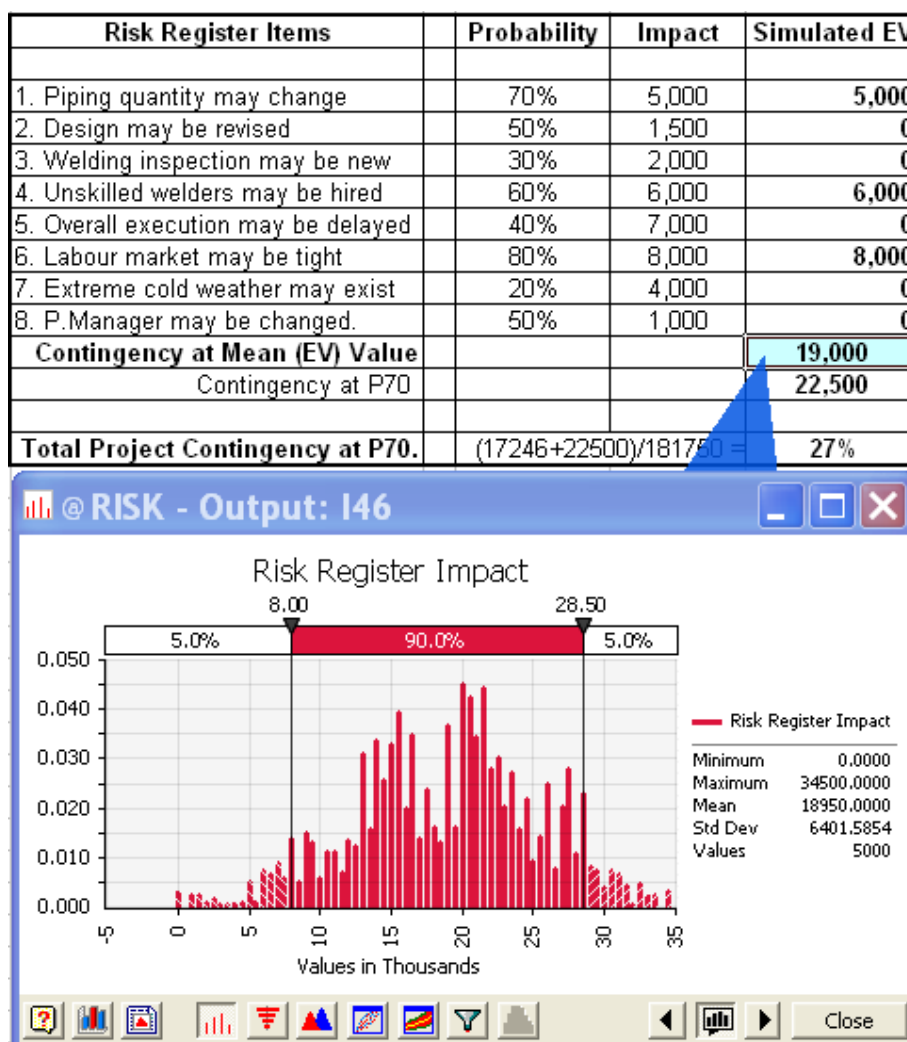


Figure 1-3: The impacts of Discrete Risks and Continuous Triangular Distribution

To avoid double dipping is important; it can be seen from Figure 1-3. The impacts of discrete risk register alone have yielded 12.4% contingency with P70 confidence, and adding the 14.3% contingency from Figure 1-1 (ranging line-items) will get 26.7% contingency that may “kill” the project economics, due to unacceptable high CAPEX. It is obvious that the variability ranges of critical variables in Figure 1-1 are actually the consequential impacts of identified risk items listed in Figure 1-3, therefore the risk analysts should have clear minds to carefully scrutinise all risks and include Either continuous Or discrete risks. Those systemic risks that are mutually exclusive and deemed to have monetary impacts on projects outcomes shall be included as contributors to quantified contingency.

Individual risks' occurrences are not rational but random; their probabilities of happening can only subjectively estimated, which many scholars have argued unscientific. Because reliable empirical data is often poorly recorded or not available, it seems that risk analysts invent wheels all the time. By definition risks are very individualized and prejudiced to some degree, the use of expected value method⁴ (EV) with relatively large number of risks in the register hopefully can dilute the negative influences of subjectivity. The key message here is to remind risk analysts that line-item ranging approach should be supplemented with risk register, otherwise pure ranging line-items can be dangerous and misleading, as the interplays of project risks are totally excluded from the model.

1-3 Mind Correlation and Dependency

Correlations or interdependencies have special places in the world of risk analysis, either cost or financial derivatives. Co-movements of key risk factors, which are often referred to as variables, could invariably have significant domino effects or repercussion on the project outcomes. Again, it is tricky and grey area that assigned correlation coefficients among identified key risks are not necessarily scientifically based, unless historical data can prove otherwise. Because correlation requires the risk analysts to thoroughly understand the business, not just the risk model, and the effects of intermingled relationships of model inputs, interdependencies often get omitted in quantitative risk modelling, which results in underestimated project contingency necessitated to complete the project successfully. Stephen A. Book (2006) in his NASA PM conference clearly acknowledged that the numerical values for correlations in cost risk analysis are difficult to establish, but insisted on that the estimates of them must be made, because "total cost sigma is underestimated when all correlations assumed to be zero, or uncorrelated at all".

Software @RISK offers correlation matrix that risk variables to a risk model can be correlated with estimated coefficients. In the example of Figure 1-4, interdependencies exist between changes of field piping man-hours and corresponding variations in scaffold labour hours with roughly 0.75 coefficient which is heuristics based; there is no relationship between increases or decreases of engineering staff wage rates and field work uncertainties. It is very important the risk analysts understand, or solicit from the experts the knowledge of, underlining relationships among risk variables, as well as the negative or positive correlations.

⁴ The method is detailed in AACEi Recommended Practice, 44R-08, Risk Management.

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 \$1\$8	Scaffold Labour Hour % / Triangular in \$1\$15	Small tools / Triangular in \$1\$20	Eng. Staff Wage Rate / Triangular in \$1\$25
		1			
		0.75	1		
Eng		Small tools / Triangular in \$1\$20	0.5	0.2	1
		Eng. Staff Wage Rate / Triangular in \$1\$25	0	0	1
Total Estimated Cost		181,750		199,176	

Figure 1-4: Risk Variables' Correlation Table and Coefficients

Many companies naturally choose EV (expected value) or mean values as the business decision points. In the Figure 1-5, it is well evidenced that the mean values of \$199,176.00 don't change in various correlation scenarios⁵ whilst P70 values vary quite bit under the influences of different correlations. In reference to Stephen Book's statement earlier, a fully correlated risk model yields higher contingency than zero or uncorrelated models, and this difference is significant to project managers in real life. It is therefore essential that the risk analysts pay attention to the details of model set-up, relationships of inputs and the sensitivity of risk results, accordingly he or she should apply the analysis techniques as scientifically as practically possible.

Original Estimate (US\$)	No Correlation Matrix inserted		Zero Correlations Coefficients		Follow Correlation Matrix Table	
	EV	P70	EV	P70	EV	P70
181,750						
P70 (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%

Figure 1-5: The Impacts of Correlations on Project Contingency

⁵ The author can not offer theoretical / academic explanations why those EV values don't change.

1-4 Verify Risk Results with Empirical Data

Historical cost data is an important indicator for any new capital cost estimate but the difficulty of collecting and analysing such empirical information is notoriously known in the industry as this has been further ascertained in AACEi RP 42R-08 (Risk Analysis and Contingency Determination using Parametric Estimating) where it says that dealing with lack of company specific historical data is unfortunate. AACEi therefore advocates the parametric modelling approach for contingency determination and encourages validation against risk analysts' own benchmarking data.

Completed Projects	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

Figure 1-6: The Table of Empirical Cost Data for Completed Projects

Should companies be prudent in compiling historical data, both cost estimates and risk analyses would be easier. The table in Figure 1-6 has listed 8 projects and their inflation adjusted hypothetical final costs, in which productivity factors are also adjusted for geographic locations. The spread of this set of empirical data indicated the mean of \$207.6K, which is higher than the mean of \$199K in our risk analysis base case (shown in Figure 1-7). The data in above table is plotted using Data-fit function in @RISK, and the CDF curve of "historical data" in blue colour is overlaid on top of the triangular CDF curve of the base case in red, as shown in Figure 1-7.

Whilst the CDF curves indicated that the estimate of \$153K would have zero chance to achieve under-runs in both scenarios, the base case CDF at \$209K implies a bit over-confidence (P70.7) in comparison with the confidence level (P56.7) of historical data for the same number. Because capital cost risk distributions are skewed to the right in most cases due to higher potential of over-runs, only mean (EV) result does not necessarily tell the whole picture of project risk profile. From the curves in Figure 1-7, we may conclude the following:

1. The base case project may have a stronger management team with better cost and schedule estimates, more robust cost control technique / competence, hence it may have less exposures to identified risks;
2. The risk analysis result in base case needs re-validation using historical benchmarks; and each variable's PDF to be re-visited for the reality of distribution ranges; and inclusion of systemic risks to be confirmed as impacts to the contingency outcome.

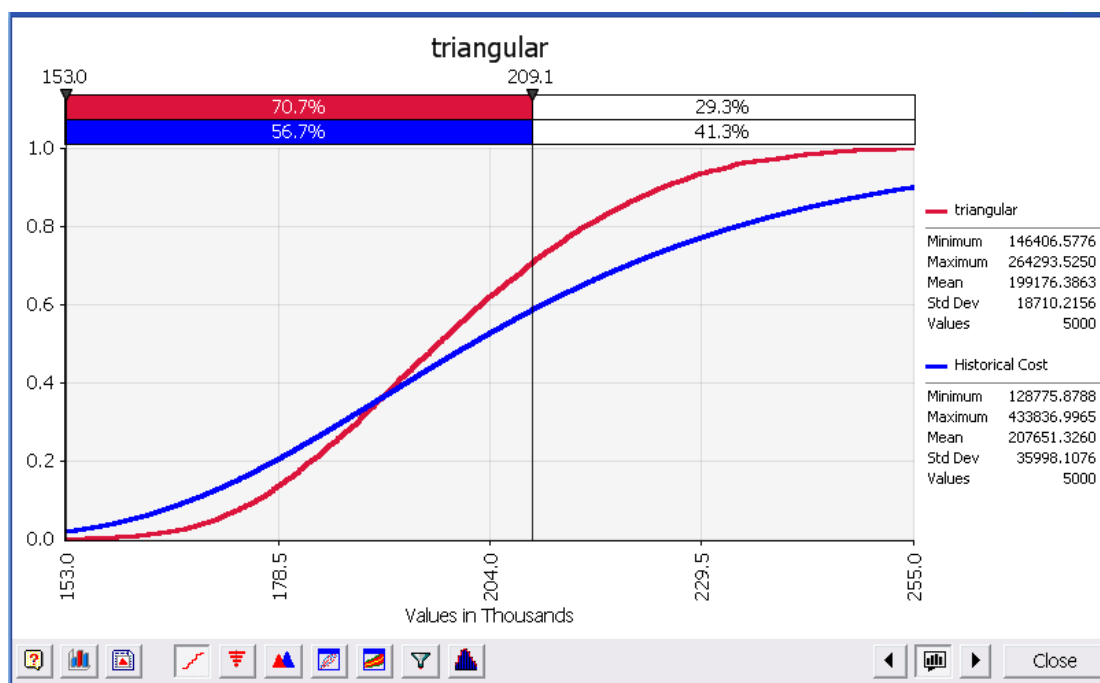


Figure 1-7: The CDF comparison of the simulated Result and Empirical Data

It is true though that “the history can not tell the future”, benchmarks with empirical data can at least provide indications of reality and convincing-ability of both cost estimates and risk analysis. Luckily, data-fit-for-distribution in @RISK provides a tool for risk analysts to conduct risk analysis more diligently, and confidently.

Summary

Risk analysts with their competences in various industries can collectively contribute to improve the credibility of risk analysis results, through the means and ways of putting more scientific processes, methods and modeling techniques into quantitative risk evaluations. They also can, collectively through seminars, conferences and in-house trainings, set good examples and provide recommendations for the best practices for new entrants. They can form and / or

contribute to various associations by establishing standardized quantitative risk analysis practices and procedures.

Education is important in any company to help improve scientific risk analysis techniques. Statoil ASA has many dedicated discipline advisors, who are the subject-matter experts and specialists in their respective areas, and they provide guidance, answer technique queries and liaison with practitioners in projects. For instance, the company representative for @RISK in Statoil ASA represents over 1,000 users, so centralised technical expertise for risk analysis is made available immediately. More over, there are many discipline advisors in the area of uncertainty management, to cover:

1. Drilling and well / Reservoir Engineering risk analyses
2. Total Risk Analysis for Health, Safety and Environmental
3. Capital investment project cost and schedule risk quantification
4. Quantitative Risk Analysis for Finance, Economics, Trading and Credit

However, the integration of the above risk areas, wholly or partially, has been a challenging task to many risk practitioners in oil and gas industry for past decades, partially due to lacking mature and reliable systematic tools to embrace multidisciplinary inputs, and lacking interests and investments from companies to develop the integration technique. It is dauntingly complex for any oil company to think through, and integrate entire value chain from initial oil exploration, through facilities building, to final economic valuation. Thanks to the foresight vision for the future, Statoil has started its path for the integration of stochastic simulation modelling in such endeavours.

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