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Common Misconceptions in Subsurface and Surface Risk Analysis

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Abstract

This paper is intended to highlight some of the misconceptions that enter decision making whether as a consequence of human bias or as statistical inaccuracies and misuse of mathematically robust equations.

There are three basic questions in the oil and gas industry: 1) How big is it? i.e.: Resources, 2) How quickly can we get it out? i.e.: Rate, and 3) How much can we make from it? i.e.: Value. All three contain risk and uncertainty. Several methods are used by oil and gas professionals to manage these variables, ranging from the simple toss of a coin, to complex mathematical algorithms and statistics. If only it were so simple to use a formula for the decision and have the confidence to trust it. However, business decisions are often more than just complex logic and the worlds of subsurface geoscience and reservoir engineering add yet more variables and uncertainty.

The paper uses real world examples in the oil and gas industry and highlights the difference between Risk Management and simple Gambling. The paper draws upon the following three themes:

1) Human Factors: No matter how precise the mathematics of risk analysis, ultimately decision making relies upon individuals who are subjective by definition. A group of similar but independent professionals will have a different perception of risk and their own biases depending upon the number of parameters used to calculate for example, chance of success and different biases on marking at extremes of a range.

2) Statistics: One solution to deal with the human variable is to attempt to take individuals out of the decision making process completely and trust mathematics instead. Unfortunately, many decision makers have forgotten what assumptions exist in Portfolio Theory and often use the methods blindly, placing too much confidence in the predictions and unaware of other equally likely outcomes.

3) Popular Decision tools:

a) Expected Monetary Value – ‘Expected’ is a subjective term and numerically tends towards the Mode of the distribution. The authors question whether EMV really has any true meaning and instils a false sense of confidence in the outcome.

b) Hurdle Rates - The Theory of Inevitable Disappointment highlights how a decision maker who fails to understand uncertainty can often fall short on forecasts.

Conclusion: There are no simple rules when decisions involve information which contains uncertainty and interpretation. The responsibility for decision making should rest with individuals with 'skin in the game'. A decision maker should be aware of all assumptions and always question those assumptions. In the end, if a decision maker does not use a spectrum of tools to examine all possible outcomes, then they are simply relying on luck. Whatever the process, review, feedback and calibration are critically important.

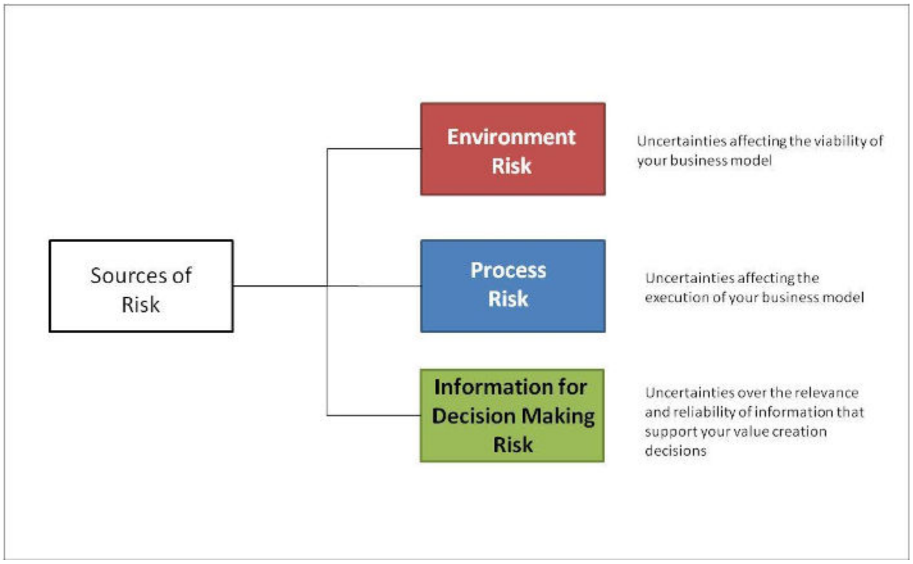
Introduction

This paper is intended to highlight some of the misconceptions that enter decision making whether as a consequence of human bias or as statistical inaccuracies and misuse of mathematically robust equations.

Management of uncertainty is central to many industries and indeed in our personal lives. RISC reviews many oil and gas projects and the outcomes are often very different to what was predicted at project sanction. Simplistically, we can categorise oil and gas projects into surface & subsurface components, each with very different characteristics, yet as an industry we are poor at predicting the outcomes of both subsurface & surface.

There are many methods used by a number of industries and professions to manage risk and uncertainty from the simple toss of a coin with one clearly defined outcome to complex mathematical algorithms drawing upon data and statistical mathematics. However, despite the rigor of the analysis, companies frequently make poor investment decisions. Decision making techniques or metrics have different outcomes depending upon how you interpret the results, use the information and implement your decision. Calibration and consistency of inputs and minimization of bias is critical to managing uncertainty. No matter how precise the inputs and mathematics of risk analysis, ultimately decision making in the oil and gas industry relies upon individuals who are subjective and prone to bias.

Figure 1: Master Risk model (Berard & Burk, after Arthur Andersen)



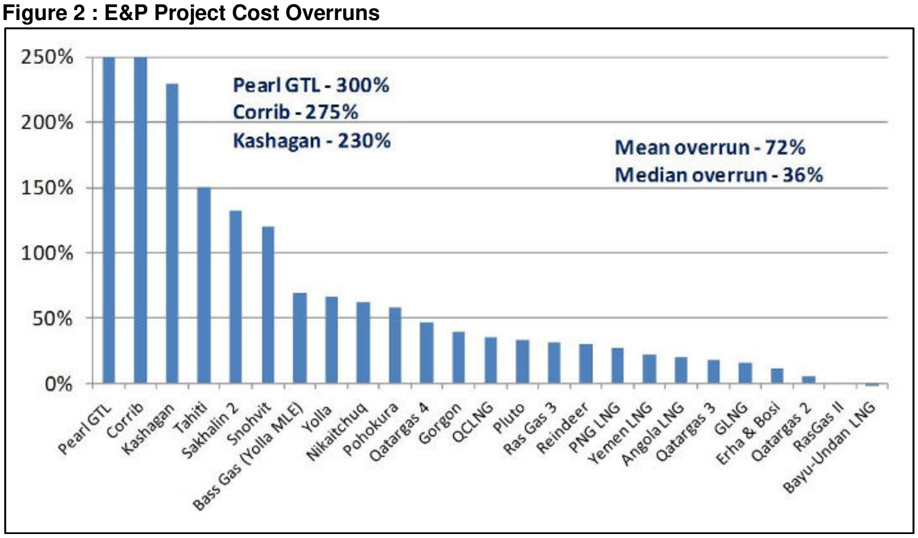
Our Industry has a lot to be proud of but our management of capital projects is very poor. Flawed forecasting is also evident in project cost, schedule and resource estimation. This paper summarizes many of the techniques used for managing uncertainty in decision making in the oil and gas business (Figure 1) but also illuminates how these techniques can be misused or misrepresented resulting in poor business decisions. It is hoped that an improved understanding of these matters will lead to better decision making.

Result of Poor Forecasting

The oil and gas industry is poor at predicting the outcomes of both subsurface & surface outcomes. RISC's analysis of projects concludes that failure is largely caused by insufficient front end loading. Press announcements often put project cost or schedule overrun down to factors such as weather, productivity, labour costs, exchange rate etc., with the implication being these are outside the operator's influence to control. However, in reality the reasons are more complex and some are within the operator's control.

RISC has gathered data on twenty five major projects, spanning the last ten to fifteen years (Figure 2). When gathering this data we did not set out to find projects that had overrun their budget, the dataset is purely based on information available in the public domain. The total cost of over runs for the twenty five projects is USD $287 billion. To put that into perspective Greek debt to private banks in 2012 was approximately USD $300 billion. The three projects that more than doubled the Financial Investment Decision (FID) estimate skew the distribution such that the mean overrun of all twenty-five projects is 72%, the median overrun is 36%. Most companies target cost estimates with an accuracy of 10-15% at FID. It is arguable whether it is even possible to quantify the cost of complex projects to this degree of accuracy. Notwithstanding this, it is clear that the industry has a tendency to underestimate project costs. We found similar results when researching project schedules. In general, the larger the project the greater the potential for overruns. Reasons include poor project management, underappreciation of the variables and interdependencies that go into the estimates and bias by the project proponents. One might argue that this sample is biased as bad news makes the headlines and good projects go un-noticed. However, if we include a larger sample of projects, which are not in the public domain, the message is similar though less dramatic with P50 overrun of 15% and Mean overrun of 37%.

Figure 2 : E&P Project Cost Overruns



Source: Analysis of twenty five projects compiled from RISC data spanning the last 10-15 years

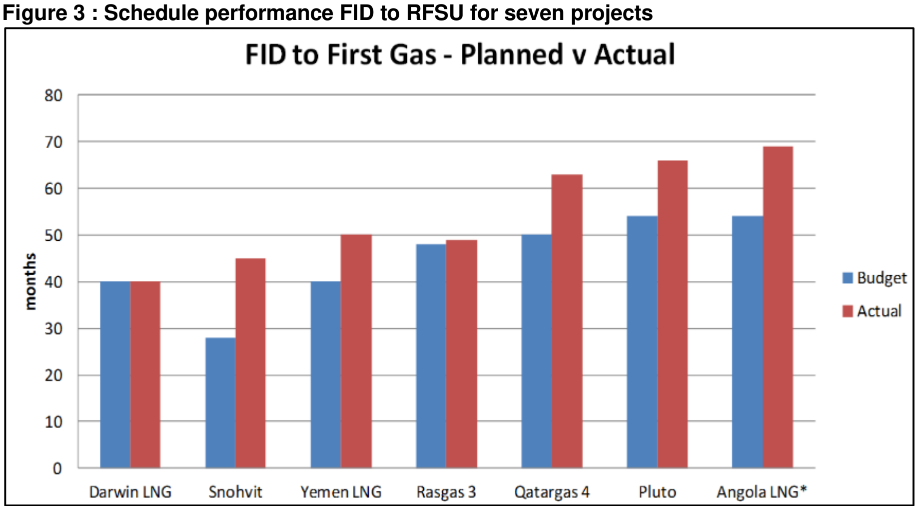
This leaves us to ask, is it poor forecasting and estimating, or is it poor project management and execution? The truth, as always, is a bit of both. Our database of Australian LNG projects demonstrates this, though the themes are similar globally. Perhaps a new inherent optimism or naivety has evolved, which is eclipsing the hard-worn project experience of Project Managers? Or it may just be simple complacency of project owners who think that the mistakes of the past will not be made again in the modern era. However, experience shows that they do. Seven out of the nine Australian projects (Table 1) failed to meet their planned FID dates, which demonstrates that many global operators have problems in the pre-execution phase.

Table 1 : Comparison of targeted FID date to actual FID date for ten Australian LNG projects

Project	Operator	Target FID	Actual FID
Pluto 1	Woodside	2007	August 2007
Gorgon 1-3	Chevron/Exxon/Shell	2004/2008	September 2009
QC LNG	BG Group	Early 2010	November 2010
GLNG	Santos/Petronas	Mid 2010	January 2011
APLNG (Train 1)	Origin/CoP	End 2010	July 2011
Wheatstone	Chevron	End 2011	September 2011
Ichthys	Inpex/Total	End 2010	January 2012
APLNG (Train 2)	Origin/CoP	End 2011 to Early 2012	July 2012
Browse		Mid 2012	TBA

Similarly, our studies of LNG projects shows (Figure 3) that project execution time from FID to Ready For Start UP (RFSU) is an issue for operators also, with an average overrun of ten months (23%) with only one project (Darwin LNG) coming in on schedule.

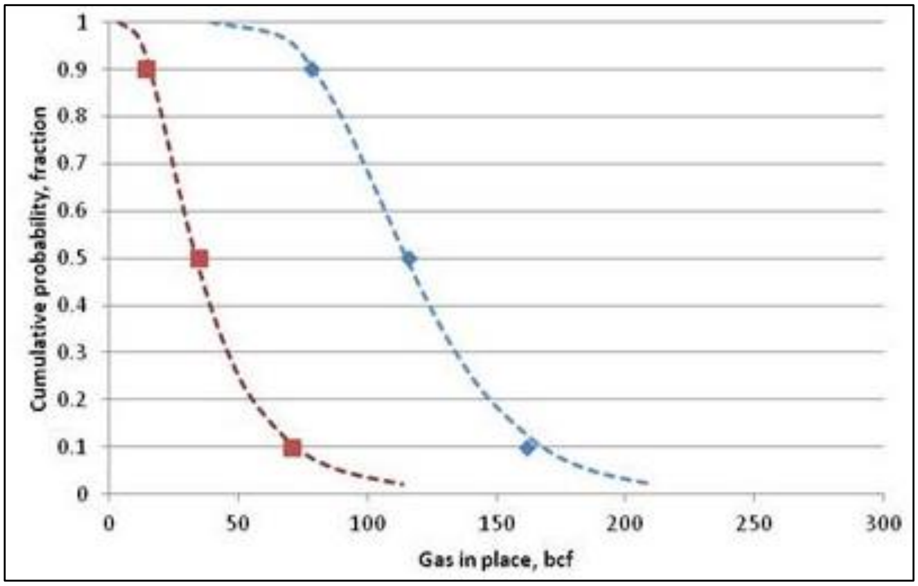
Figure 3 : Schedule performance FID to RFSU for seven projects



Poor subsurface estimation is also common in our experience. Indeed the advice we most commonly give our clients is that they have under represented uncertainty in their volumetric ranges.

We recently came across an example of this in our consulting work where the P90-P10 gas in place ranges estimated by two independent experts didn't even overlap (figure 4) and we were requested to review these estimates as a third expert opinion.

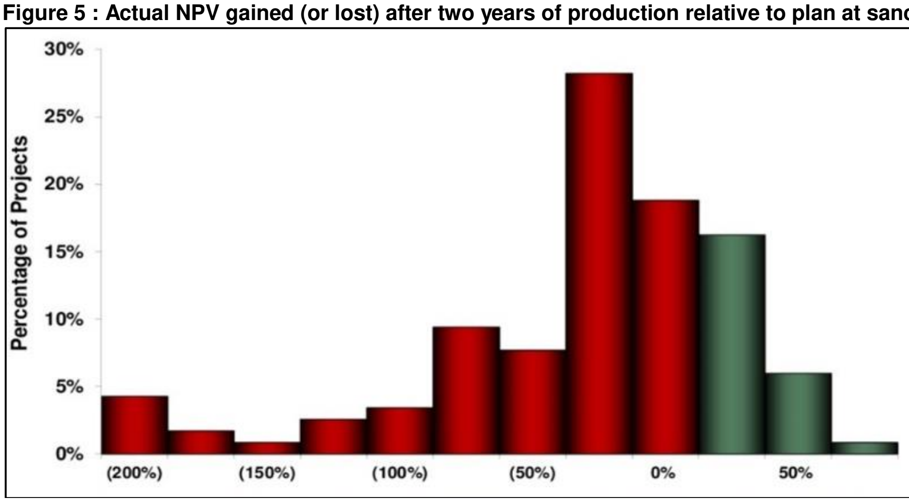
Figure 4 GIIP Range Estimates by 2 Independent Experts Source: RISC acting as third expert



A recent study[1] confirmed this is not an isolated incident. It showed that in 40% of cases the reserves assessed a few years after production started lie outside the P90-P10 reserve range estimated at FID, whereas of course this should only occur for 20% of estimates.

The impact of poor input estimates and flawed decision making is shown in Figure 5. This shows project NPV after two years (corrected for production and normalized for oil price) gained or lost relative to that forecast at project sanction. It can be seen 70% of projects sampled over the last ten years had lower NPV than forecast at FID, the average NPV was 41% lower than planned.

Figure 5 : Actual NPV gained (or lost) after two years of production relative to plan at sanction[1]



[1] Source: Declining Terms of Trade: Why Only The Most Efficient Will Survive The Cost Price Squeeze, Neeraj Nandurdikar, Independent Project Analysis, OTC 2014

Reasons for the value destruction include the following:

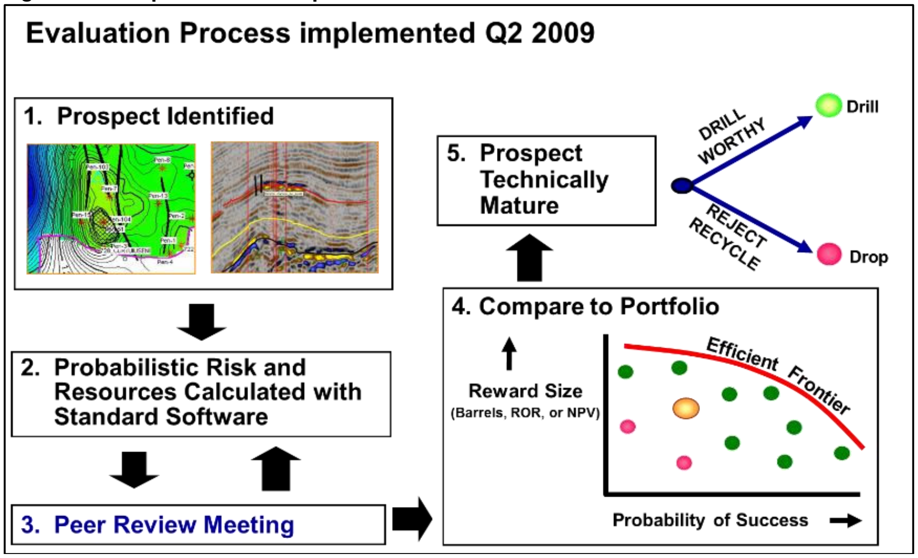
- Poor estimating of the inputs used in the NPV calculation
- Inappropriate project 'shaping' i.e. the wrong development for the resource
- Confusing accuracy with confidence as information increases
- Believing sophistication reduces risk
- Under-estimation of time to complete tasks
- Scope changes: poor definition, lack of rigor in approval process, poor communication
- Ignoring dependencies and inter-dependencies
- Poor risk management: Lack of contingency plans, ineffectual contractual protection
- Inadequate project management: poor communications, low resource utilization
- Planning or Front End Loading
- Undisciplined project selection

A factor underlying many of the above reasons is the *cognitive biases* that affects all humans and distort our decision making abilities. These are discussed further below. It is human nature that professionals champion their projects and want to see them progress through the development lifecycle to production. This tends to introduce bias and optimism into forecasting, resulting in unrealistic expectations of project value. This should be an enormous concern for decision makers who are held accountable for the performance of these projects.

Estimating in Oil & Gas Companies

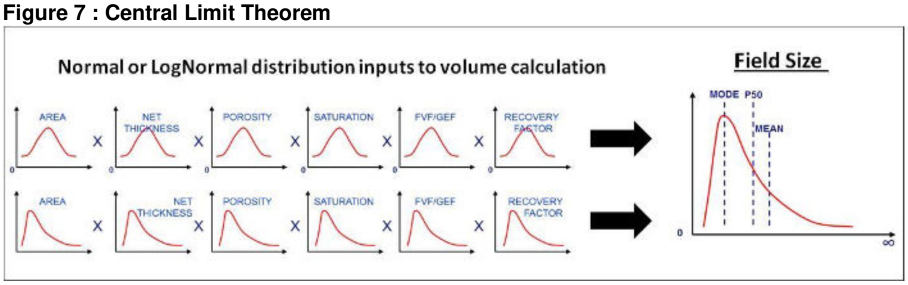
The typical evaluation process for maturing subsurface prospects consists of first identifying a prospect (Figure 6), carrying out a preliminary estimate of in-place and recoverable volume and estimating the chance of geological success and also commercial or economic success. These estimates are fundamental to budgets and cash flow forecasts and require a genuine peer review by an independent assessor, typically a set of technical chiefs and/or senior technical staff in the same company or firm of independent expert consultants. Once the volume and probability of success has been evaluated and calibrated with the rest of the portfolio, the drilling opportunity or 'investment' opportunity can be evaluated on a risk versus value trade off, with value being measured as IRR, NPV, Return on Capital employed, Profit/Investment ratio etc, and risk measured typically as probability of geological success (Pg), probability of commercial success (Pc) or probability of economic success (Pe). Expected Monetary Value (EMV) combines the value, cost and risk metrics.

Figure 6 : Prospect evaluation process



We are familiar with Normal distributions as they exist in everyday life, such as the range in height and weight of individuals in SPE, or the number of miles travelled per day by commuters. However, the volume of in place hydrocarbons in oil and gas fields follows a Lognormal distribution (Figure 9). The Central Limit Theorem states that a Lognormal distribution results from the multiplication of independent random variables (Figure 7). Lognormality exists in oil field sizes because the volume of hydrocarbons is the result of multiplying several inputs together each having a Normal[2] or Lognormal[3] distribution themselves.

Figure 7 : Central Limit Theorem



Forecasting

Modern day oil field portfolio theory is based upon stock market portfolios and early work carried out by Harry Markowitz in his article written in 1952 (ref Markowitz). Markowitz drew attention to the practice of portfolio diversification and showed how an investor can reduce the standard deviation of portfolio returns by choosing stocks whose performance is not correlated. He went on to work out basic principles of portfolios and much of his work is the foundation of what has been written about the relationship

[2] Porosity and Water Saturation (S_w)/Hydrocarbon Saturation (S_g, S_o) for a prospect or field will tend towards a Normal distribution as they rely on average values, which is an additive process, These parameters are also restricted to Normal, as the tails of the distribution are limited to 100% and cannot have Lognormal tails.

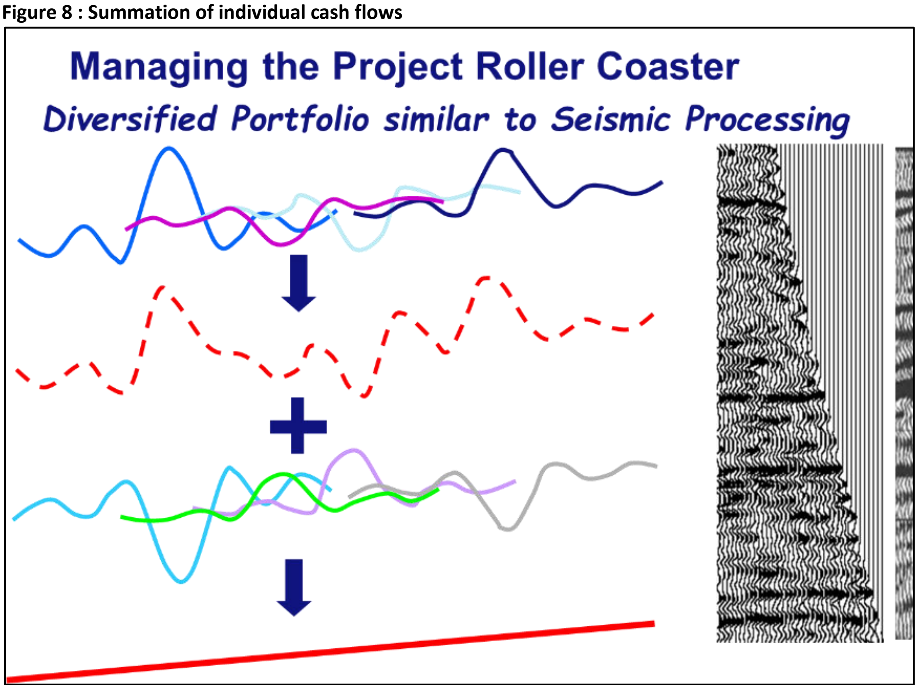
[3] Area and Net Feet of Pay tend towards Lognormal distributions as they are generally derived from a multiplicative process.

between risk and return and the foundation for oil field investment practices in use today.

Every Finance Manager wants to be able to both forecast and grow the value of the company. This is a difficult task given the cyclical nature of the business and 'roller coaster' like performance of oil field portfolios. Nonetheless, given an adequate number of projects in different stages of execution or with different cash flow profiles, it is possible to consolidate the cash flows to derive a flat and predictable profile if project start times are moved (Figure 8). However, this is often not carried out, as slipping start times has a negative effect on project economics such as Rates of Return and NPV due to the time value of money. This is the same process that seismic processors use in stacking the Common Depth Point gather or by adding varying degrees of random white noise to cancel out the coherent noise which has been recorded.

The oil industry has modified Markowitz's theory, which was based on portfolios of shares and has applied it to individual prospects. There are two major differences between the financial returns of stock market portfolios of shares and oil field portfolios of wells. The first is the shape of the distribution of possible outcomes. Share portfolios are Normally distributed (Figure 9) and oil field sizes are Lognormal (ref: Capen, Kaufman). Significantly, as we all know in the oil industry, there is also a chance of total loss or a series of dry holes.

Figure 8 : Summation of individual cash flows



Stock market portfolios are also able to chosen from a large number of stocks. However, most oil companies, particularly small to mid-sized independents, have a limited pool of investment opportunities to choose from. It is easy to forget that the portfolio may no longer represent a statistically significant population and that the smaller population creates a wide and unpredictable range of outcomes. The wiser oil companies make their portfolios more predictable by investing in more prospects but still retaining capital discipline and managing cost and budgets with working interest, farm-ins, swaps, near field opportunities and strategic alliances (Figure 10). It is better to have ten investment opportunities at 10% working interest rather than one investment opportunity at 100% working interest, if you want to be confident of success and predict the outcome with reasonable accuracy (Figure 10). Calibration of estimates using post-mortems and feedback typically adds further accuracy to the estimates.

Figure 9 : E&P projects versus stock market returns

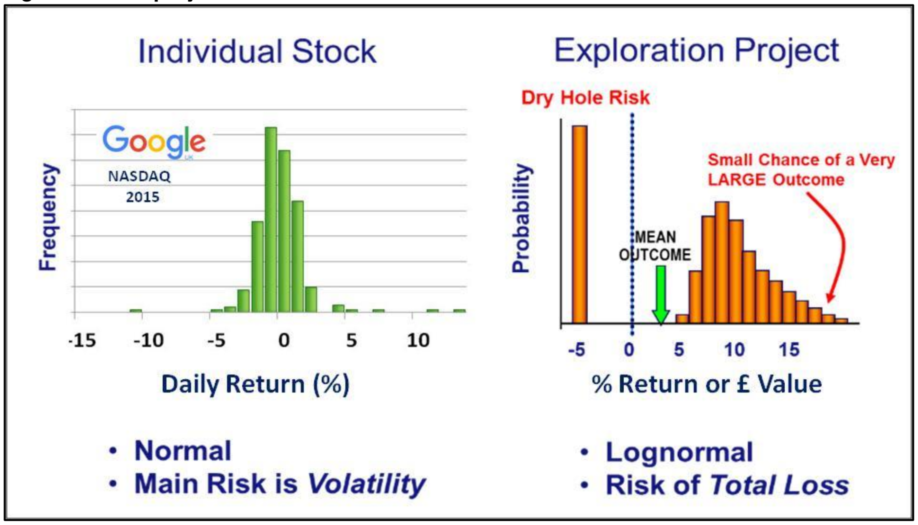
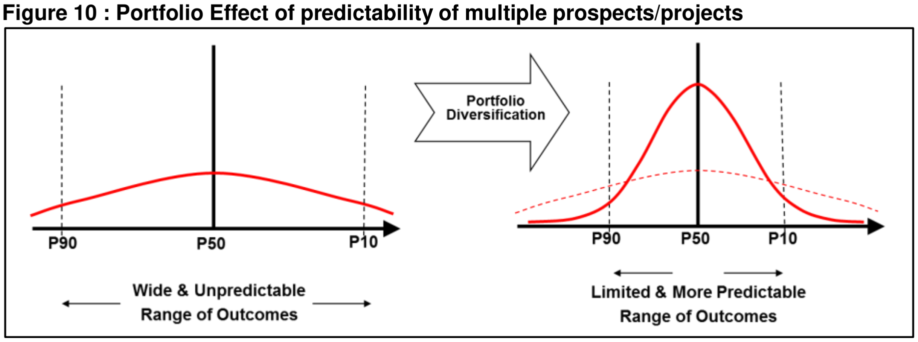


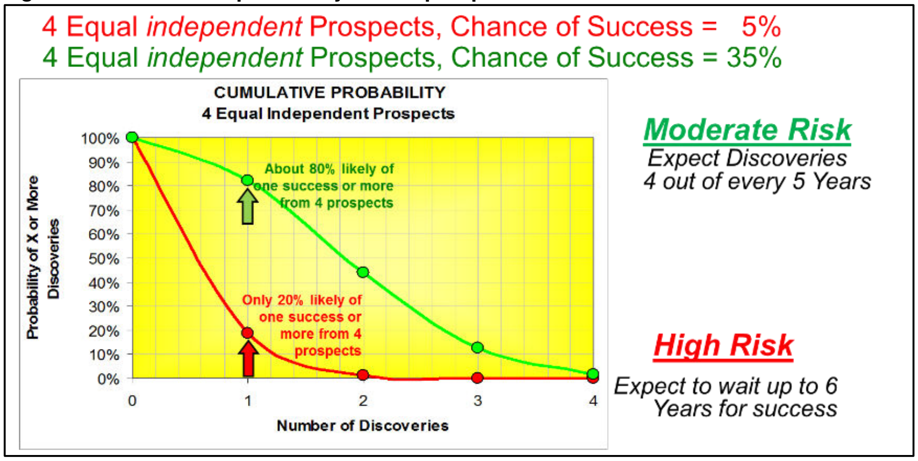
Figure 10 : Portfolio Effect of predictability of multiple prospects/projects



A challenge for every company is predictability of the forecast returns. It is common sense that the more prospects you drill, the more likely you are to have a success, but there is no guarantee that the successes will be the large finds and the dry holes will be the cheap wells. It is worth reminding our industry, and in particular small independents and their investors about Cumulative Probability.

If a there is a small and limited drilling budget where only four wells can be drilled per year, then one or more discoveries can be expected for four out of every five years for four moderately risky wells with 35% chance of geological success (Figure 11). However, if the portfolio contains four more risky prospects drilled each year with 5% chance of geological success, the expectation is to wait up to six years for one success. This is simply cumulative probability (Equation 1) and does not take into account cognitive bias and the subsurface professional's inability to estimate accurately at the extremes of the range. It is often said for most or all companies that a 'Risk Floor' exists. This is effectively the probability of success below which the result is actually zero. For most companies this figure is typically in the 10% to 20% range.

Figure 11 : Cumulative probability of four prospects



Equation 1 : Cumulative probability, p(x)

$$p(x) = \frac{n!}{x!(n-x)!} S_x(1 - S)\ n\text{-}x$$

Theoretical Models

A financial analyst (ref: Brealey & Myers, 1981) once asked "Why is an MBA student who has learned about discounted cash flow, like a baby with a hammer? Answer; is because to a baby with a hammer, everything looks like a nail". His point is that we should not always focus on discounted cash flow and ignore the forecasts that are the basis of every investment decision. Senior managers are continuously bombarded with requests for funding and all these are supported with NPV's from discounted cash flows. As Brealey & Myers point out "how then can managers distinguish the NPV's that are truly positive from those that are merely the result of forecasting errors?" Even worse, it is not unknown for the inputs to the NPV calculation to be 'engineered' to achieve a desired result.

Expected Monetary Value (EMV)

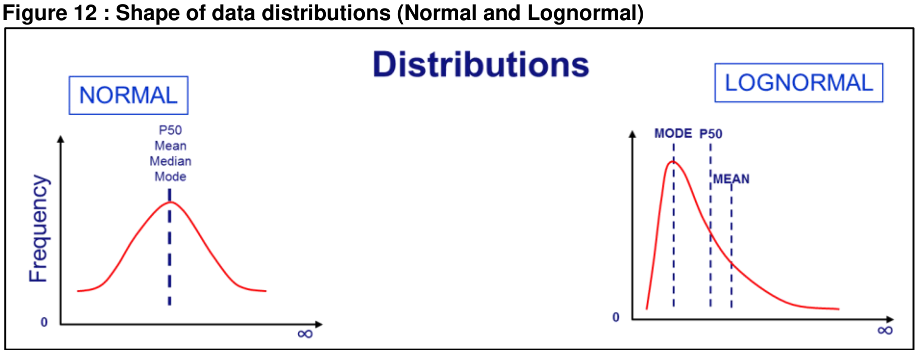
The 'Prospector Myth' (ref: Rose, 2001) is the petroleum explorationist's version of the hero 'wildcatter', 'oil finder' or perhaps even 'visionary'. We are told of and inspired by the image of the courageous prospector who struggles against Mother Nature, financiers who only understand money not rocks and big company processes that do not recognise the art of geology. These 'plucky' oil finders may be good subsurface professionals but need to realise their pet prospect is one of many and is part of a portfolio. We manage exploration and production investment by managing the portfolio and if this is to succeed, each investment must be assessed consistently and objectively. The inherent uncertainty can be handled with improved technology and geostatistics, but what really distorts the portfolio is human bias, which can over-value some prospects so that the value of the portfolio is not optimised. Company owners are short-changed by the 'Prospector Myth'.

The odds of each gaming device and table in a casino are well known to the operator of a casino and they are set to be slightly in their favour. The casino owner is playing a statistically significant set of repeated trials in which the Expected Value (EV) of each trial for the casino is positive. In this paper the definition of EV is the probability of success multiplied by the value of success, minus the probability of failure multiplied by the cost of failure (Equation 2). If the casino knows the number of tables, the number of players and average bet sizes, then they can predict with a good degree of precision what the profit will be. The casinos, just like Actuaries in a life insurance company have well calibrated sets of data to draw upon, so when EV is positive they're investing and when it's negative it becomes mere gambling. You could get lucky, but it is not predictable and it is not a recommended way to run a business.

Equation 2 : Expected Value
EV = (Probability of Success x value of success) – (Probability of failure x Cost of failure)

Expected Monetary Value is defined as an expected value but it in reality it is also a subjective term and numerically this tends towards the Mode of the probabilistic distribution (Figure 12). The Mode for Lognormally distributed oil field sizes and NPV's typically ranges between a P90 and P70, but oil field investment decisions are typically made on probabilistic outcomes between the P90 and P50 cases. The reality being that the more cautious you are (i.e. tending towards the P90 end of the spectrum), the more confident you are in achieving a minimum value, but that there are many investments that you do not make and as a result are not exposed to any upside. This is called the 'Theory of Inevitable Disappointment' and is discussed later in this paper. Hence, if a Decision Maker only uses the EMV or EV rather than a mix of information, they are typically making decisions based on P90 to P70 outcomes as field sizes are Lognormally distributed and the Decision Makers are therefore predicated to playing safe. They are unlikely to grow the business.

Figure 12 : Shape of data distributions (Normal and Lognormal)



We have seen that statistically small populations of data result in unpredictable outcomes (Figure 10) and that oil and gas accumulations have a Lognormal distribution. We can derive a Lognormal distribution for a hydrocarbon accumulation with the P90, Mode, P50, Mean and P10 volumes or NPV's and associated probabilities. However, in reality we often rely on a single figure resulting from an EMV calculation for a single well and delude ourselves that we truly understand the investment decision we're facing. Too many Decision Makers view the results of an EMV calculation without considering the uncertainty and assumptions used in the inputs and do not understand that the EMV is approximately the same as the Mode of the distribution, which can have a wide range of probabilities associated with it.

Theory of Inevitable Disappointment

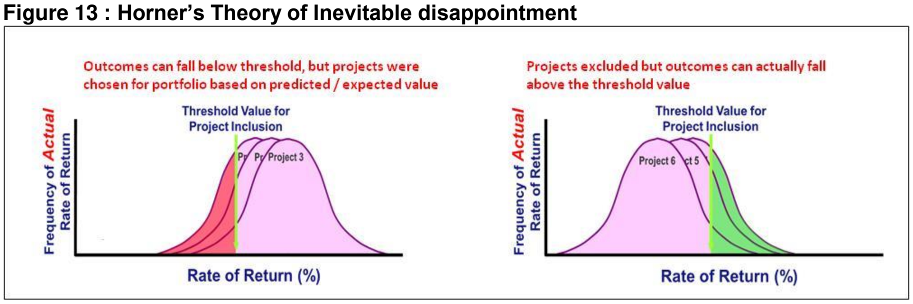
The inadequacy of EMV with small populations leads the authors to ask "Can you really make meaningful decisions using EMV with just one well?" The Theory of Inevitable Disappointment (Horner, 1982) helps highlight this inadequacy. A troubling and persistent oil industry conundrum is that actual returns from E&P portfolios rarely seem to meet expectations. Since the 1980's, Dennis Horner's unpublished[4] but widely circulated "Theory of Inevitable Disappointment" has been cited as demonstrating that actual performance of a portfolio of assets must inevitably turn out to be worse than predicted.

Simply put, Horner states that if we assume a perfectly unbiased prediction with dispersion, then there

[4] Republished by Peter Rose in 2004 at AAPG to credit Horner

will be portfolio outcomes below the 'company hurdle rate' or threshold, but projects were chosen for investment in the portfolio based on their predicted or expected value (Figure 13). Equally there will be portfolio outcomes above the 'company hurdle rate' or threshold but the projects were rejected from inclusion for investment in the portfolio based on their predicted or expected value. After modelling 255 projects, Horner found that although the portfolio predicted an economic Rate of Return of 27%, the actual outcome was a much smaller Rate of Return of 18%.

Figure 13 : Horner's Theory of Inevitable disappointment



Cognitive Bias

There is a historical recognition of problems with assessing uncertainty. This was documented in a seminal paper[5] 'The Difficulty of Assessing Uncertainty' by Ed Capen in 1976, whilst working at Arco on the concept of overconfidence by oil and gas professionals, where he noted "…Is there some deep psychological phenomenon that prevents our doing better?" The paper refers to project delays, massive capital overruns and low industry returns demonstrating that the issues we documented above are not new. One of the factors attributed to this is that if we do not have a quantitative idea of uncertainty there is a universal tendency to underestimate it. This was demonstrated by Capen who asked over 1,200 attendees at SPE talks to put a 90% confidence interval around ten questions to which they were not expected to know the answer, such as when was a city in Florida first settled by Europeans, and how far it is from San Francisco to Hong Kong. If they did put the appropriate uncertainty and ranges in their estimates, then the real answers should only be outside their ranges in one of the ten questions. Ironically, the less we know about something the more likely we are to attribute too narrow a range and sadly, for the 1,200 attendees, six to eight questions were answered outside their ranges of estimate. This is the foundation of work carried on by Peter Rose, Ed Capen and Rob Megill through the 1980s to 2000's. Glenn McMaster and Peter Carragher (2003) then applied this at BP following the Amoco merger in 1998 and the Arco merger in 2000, where they demonstrated how effective, what RISC would call 'Calibrated Estimating' could impact the accuracy of hydrocarbon volume and cost estimates.

Capen asked if there was some deep underlying reason that prevents us doing better. The answer is "Yes", and it's called Heuristics and Biases. All humans are subject to heuristics and biases, regardless of technical competency or level of education.

Kahneman & Tversky (1974) argued that as the brain evolved processes used for perceptual/intuitive analysis, presumably when the human race were hunters & gatherers, we used tools for higher level cognitive thinking, leading to us to an over-reliance on intuitive judgement for complex decisions. Behavioural economics is recognised within industries such as finance and marketing to take advantage of biases residing in others (e.g. people you are marketing to), but few corporate strategists consciously take cognitive biases into account when making important decisions. It is not widely used in the oil and

[5] Ed Capen; SPE Paper August 1976

gas industry either, although Professor Steve Begg of the University of Adelaide regularly makes the point of biases leading to sub-optimal decisions and has addressed biases & heuristics in a number of papers. One of his conclusions is that intuition is over-rated and we need to use the appropriate tools and frameworks to address the uncertainties and decisions. In fact, do not use intuition to propagate or amalgamate assessed uncertainties, use the rules of probability, or statistical simulation.

Most people tend to conform to the dominant view of the group we belong to and what we term 'Group Think'. This is most graphically demonstrated by the Asch Conformity Experiments[6]. It is often witnessed in Peer Reviews, where there is a tendency for participants to have very similar backgrounds and training and therefore be constrained in their thinking and for less experienced members of a team to repeat the views of the most senior person present. All peer reviews require participants without a vested interest in the outcome in order to flush out the issues and identify the potential 'cracks' in a project. RISC believes many of the peer reviews conducted in the industry lack genuine independence and the participants can be prone to overconfidence, social and motivational biases.

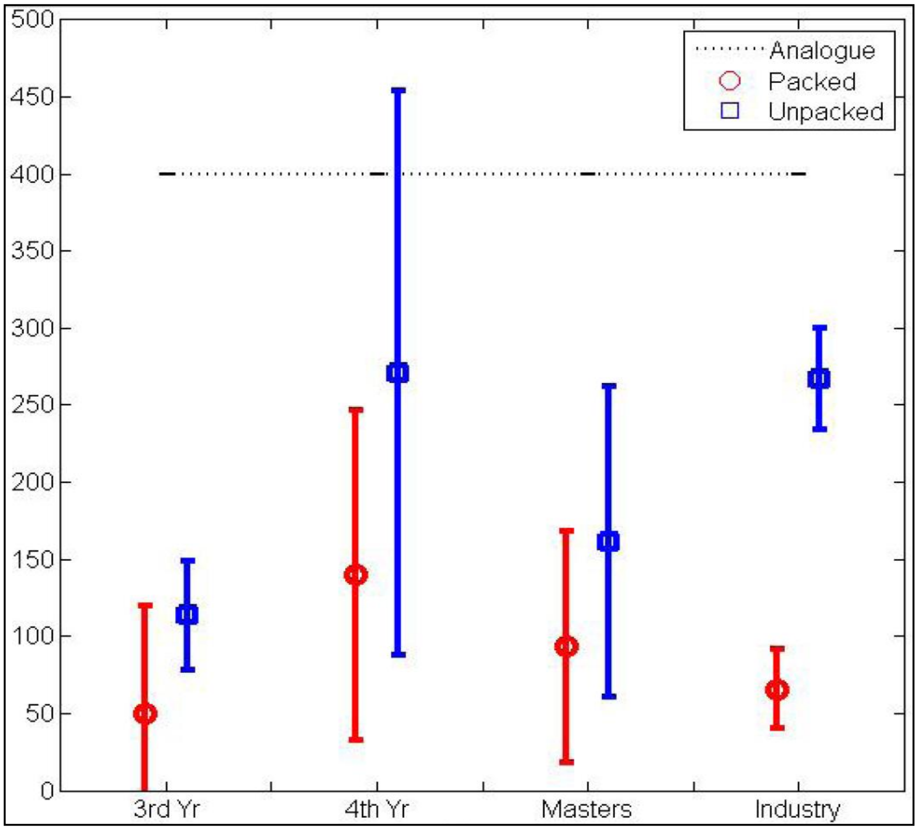
Bias in Forecasting

It is well documented that Thomas J. Watson, Chairman of IBM in 1943 said "I think there is a world market for about five computers." and a similarly over confident, but less well quoted Lord Kelvin, British mathematician, physicist, and President of the British Royal Society, proclaimed in 1895 that "Heavier-than-air flying machines are impossible" less than 10 years prior to the Wright brother's historic first flight. Both these individuals thought they knew more than they did. They were the wrong side of a major breakthrough or what might be called a 'Black Swan' event where the chance of an outcome is exceedingly small and unexpected. However, after evaluating the surrounding context, domain experts (and in some cases even laymen) can usually conclude: "it was bound to happen". Black Swan events come as a surprise but have a major effect, and are often inappropriately rationalized after the fact with the benefit of hindsight. This is just like some dry holes where the reservoir was missing because it pinched out down dip of the well location, or that the seismic amplitude anomaly was not a Direct Hydrocarbon Indicator but in fact an effect created by very high porosity not thought to be possible in that particular sandstone pre-drill due to perceived diagenesis. The oil company well post-mortem process often reveals that not all data was reviewed pre-drill, and that a different view on risk may have been taken if it had been included.

The overconfidence of 'experts' (as well as the way information is presented) affects the result of its analysis) was demonstrated in a paper by Begg et al. Figure 14 shows the range in the estimates of the time to a drill a well by 4 cohorts: 3rd and 4th year undergraduates (the latter having had formal training in management of uncertainty), graduates and 10 year industry practitioners. The red and blue colours represent different ways in which the data was presented. In all cases, if the information was 'unpacked' i.e broken out into more components, uncertainty was better recognised. More interestingly the so called experts (industry practitioners with at least 10 years' experience), generated the narrowest range of estimates. The cohort with training in uncertainty management had the widest range and, in the case of those presented with the input data 'unpacked' were the only participants whose range included the correct answer.

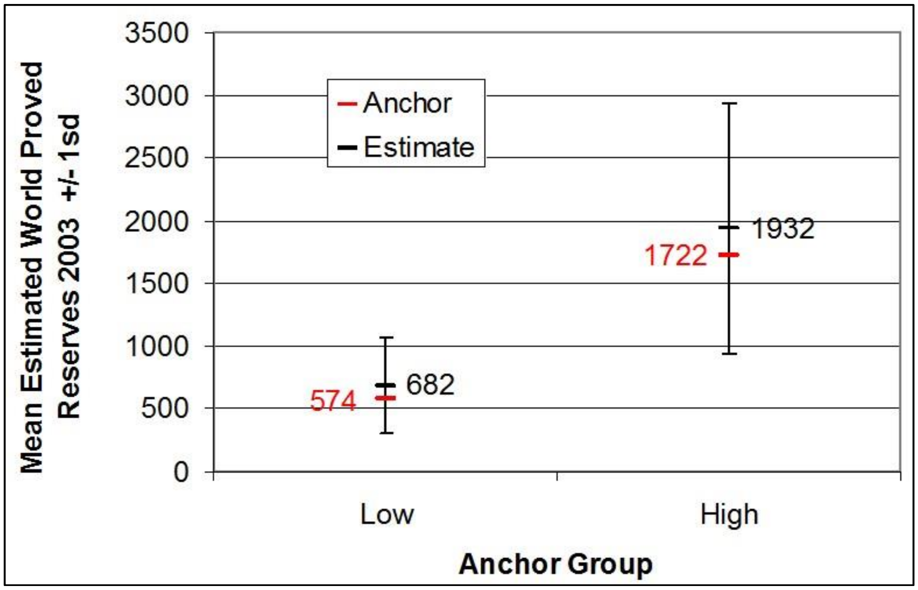
[6] Asch, S.E. (1951). Effects of group pressure on the modification and distortion of judgments.

Figure 14 : Estimates of time to drill a well (Welsh 2010)



The surprise around Black Swan events can also be the result of complacency when oil industry staff think they know more than they really do. They anchor on small pieces of information or data which they give unwarranted significance. An example of this can be found in the work of Begg (2010), where he shows the results of anchoring by two large industry sample groups who were given alternate versions of a question with high and low Anchors. He asked a similar question of two separate groups. The Low Anchor group were asked “Were world proved oil reserves in 2003 greater or less than 573.9 Billion Barrels?” and the High Anchor group were asked “Were world proved oil reserves in 2003 greater or less than 1721.6 Billion Barrels?” He then asked both groups the same question, “What is your best estimate of the world proved oil reserves in 2003?”The responses (Figure 15) show that the estimate is significantly dependent upon the way the question is asked and the apparently irrational tendency to rely on a few (not necessarily representative) data points.

Figure 15 : Effects of anchoring on estimating (Welsh 2006)

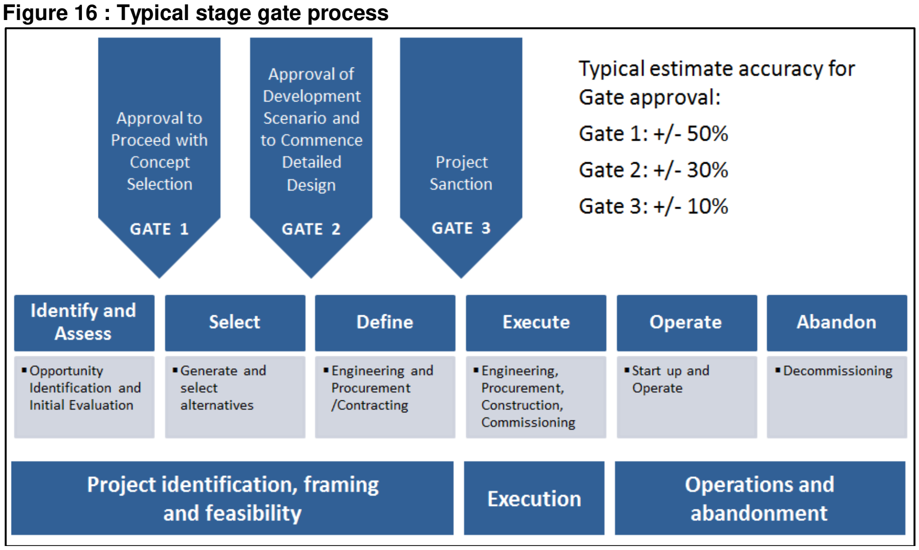


Motivational Bias

There is another bias in many companies, which is rarely addressed and that is Motivational Bias.

Most companies require obligatory compliance with the ‘Gated Project Process’; i.e. typically +/-10% cost estimating accuracy at FID (Figure 16). However, for many Greenfield projects in new areas, employing different technology, developing reservoirs without analogues or with volatile labour markets, the +/-10% confidence level in final costs and schedule is unrealistic. The criteria generates wrong behaviours and the way the Gated Project Process is used by some companies is fundamentally and critically flawed.

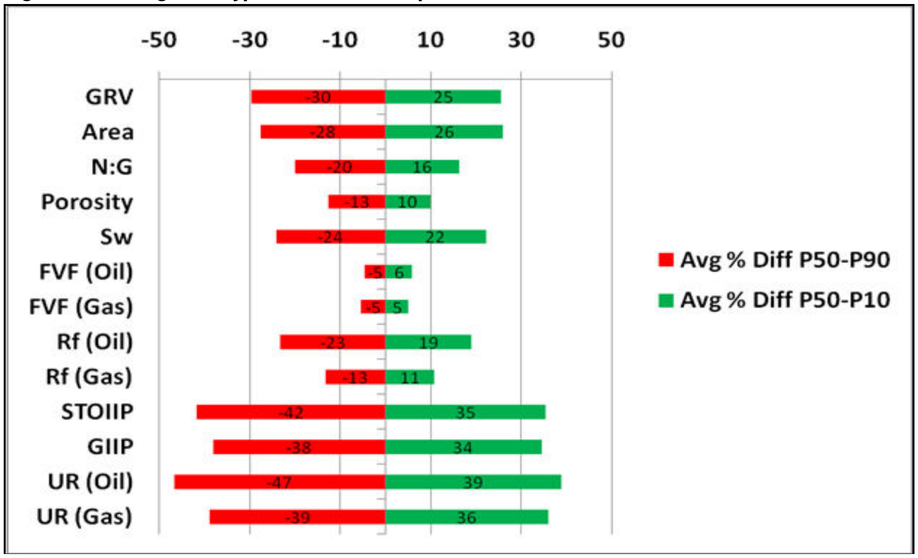
Figure 16 : Typical stage gate process



This can be contrasted with subsurface uncertainty analyses of in-place and recoverable volumes, where a range of +/-40% is commonly accepted by decision makes (appropriately in the opinion of the authors)

(Figure 17). This will often have a larger impact on project NPV than costs and schedule, yet Boards will approve projects with this uncertainty while still demanding +/-10% on costs.

Figure 17 : Ranges of typical subsurface parameters Source: RISC



In summary, the major components of flawed thinking relevant to project related cost/time estimates can be grouped into the following:

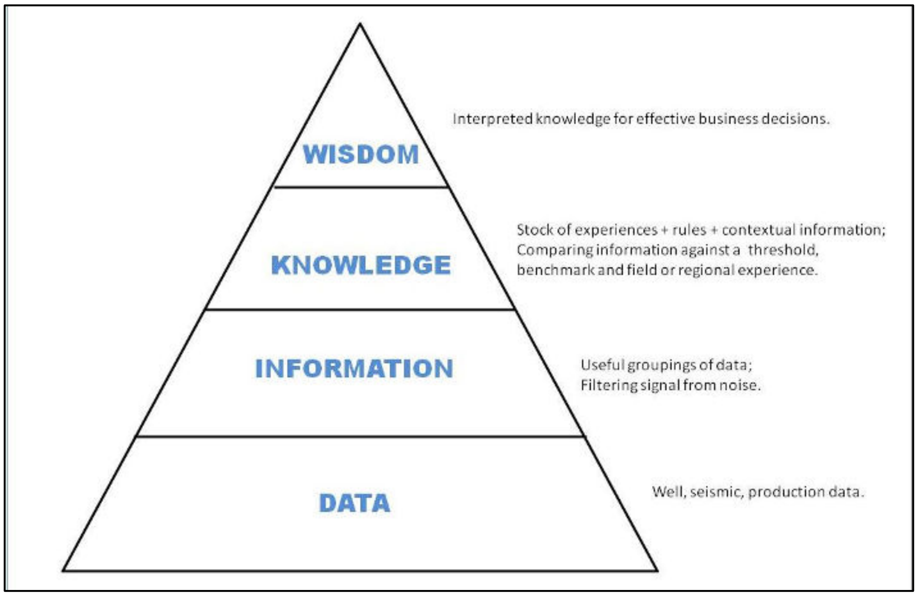
- Pragmatic : Focus on these which have biggest impact
- Overconfidence : People tend to think they are better than most
- Anchoring : Reliance on a few (not necessarily representative) data points
- Packing : Answer depends on how question is presented
- Planning Fallacy : Tendency to hold a confident belief that one's own project will proceed as planned, even while knowing that the vast majority of similar projects have run late (Kahneman and Tversky, 1979)
- Availability : Skewed by recent or more vivid events
- Social biases: Human tendency to conform to the views of the group to which we belong

Results and Calibration

The Decision makers, like a detective must use every clue. Simulation (Monte Carlo or Latin Hypercube) should be regarded as one of several ways to obtain information about expected cash flows and risk, but the final investment decision usually involves a single NPV. We know that even raw data is not one hundred percent certain as we often process or filter it first before interpretation (e.g.: seismic). The Knowledge Pyramid (Figure 18) highlights that we need to take into account several levels of understanding and are only truly making effective decisions when we combine these with an understanding of their uncertainty, source, subjectivity and bias.

The job of a decision maker is not easy, as the oil industry is full of multiple definitions for what appears on the surface to be a simple parameter. The term 'Risk' or 'Chance of Success' is one of these. When a geoscientist is asked about Risk they often mean Probability of Geological Success (Pg). However, an oil company does not want to just discover hydrocarbons, it has to make money from these discoveries. Decision makers want to know what the Probability of Commercial Success (Pc) will be when they make their decision (e.g.: should the well be completed as a producer if it finds X Boe?). Their decision is after $Y million has been spent drilling the well into the reservoir and this cost is therefore now a sunk cost and should be ignored when considering whether to complete or abandon the well. The decision is a 'Point Forward' commercial calculation that if they spend more money, the resulting producible hydrocarbons will meet or exceed certain economic metrics. However, oil companies cannot afford to ignore sunk costs routinely as the company needs to make a return on a 'Full Cycle' basis including apportionment of overheads, regional seismic, licensing fees etc. The Finance Manager is therefore only interested in Probability of Economic Success (Pe).

Figure 18: The Knowledge Pyramid[7]

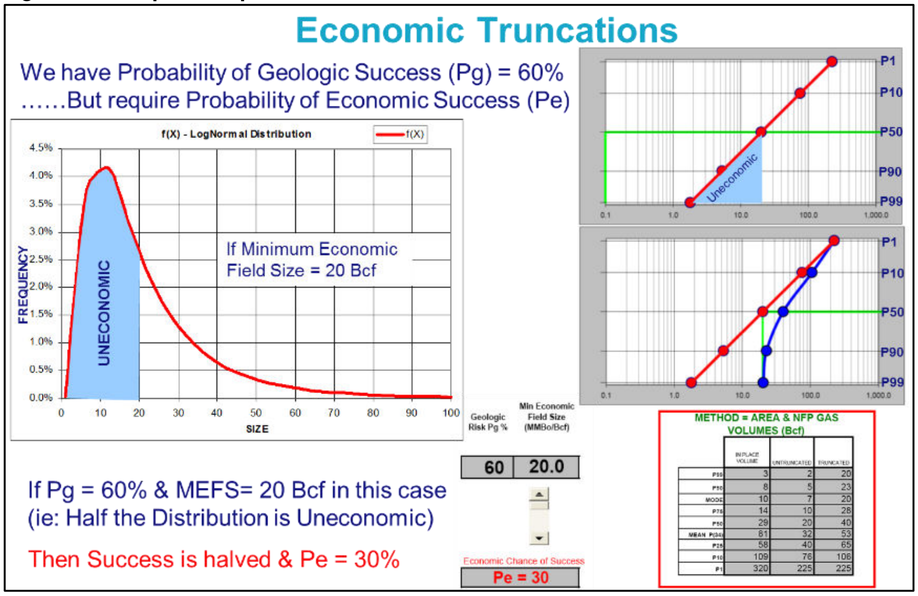


The calculation of Pe is relatively simple but often not understood by many subsurface professionals. The calculation requires adjusting the initial distribution of the opportunity sizes (exploration resource distribution or additional volumes accessed by sidetrack or perforating) for the Minimum Economic Field Size (MEFS[8]). The volume distribution is truncated by the MEFS, such that the volumes remaining are only those that are economic. The Pe is calculated as the ratio of uneconomic volumes defined by MEFS to the untruncated volumes multiplied by Pg (Figure 19). Similarly for Pc with Minimum Commercial Field Size (MCFS[9]) substituted for MEFS

We have seen that diversification is a good method to reduce and manage risk but it can come at a price if left unchecked. Push it too far with limited resources and the 'diversification' evolves into 'spread too thin' with the consequence of a drop in quality and ultimately returning back to gambling rather than portfolio management. Conversely, an undiversified portfolio operated by some small companies can seem exposed with 'all your eggs in one basket'. However, get the trade off between Time, Cost and Quality right and it can evolve into a 'Focused Portfolio' where portfolio risk is reduced by addressing and removing smaller, individual project risks.

[7] Modified from Drucker 1999 & Schollnberger & Nelson 2000
[8] Minimum volume with full cycle costs, which results in positive NPV, sometimes referred to as Breakeven volume
[9] Minimum volume with point forward costs, which results in positive NPV

Figure 19 : Graphical representation of truncation of volume distribution



Conclusions

RISC has evaluated several hundred projects from a subsurface (reserves and resources) and surface (costs and schedule) perspective. No one individual or company has all the answers. The environment keeps evolving and no two projects are the same. We'd like to think that there is continuous improvement in the industry but the evidence does not support this as many of the issues documented in this paper were recognised in the 1970's or earlier, and have been repeated on projects every decade since upto the present day. As an industry, we learn, but we also forget.

Our suggestions to improve oil and gas industry decision making include:

a) Recognise the reality of "black swan" events, identify effective risk mitigation strategies or at least making some allowance for these in the form of contingency.
b) Be wary of over confidence and experts: Introduce genuinely independent peer reviewers.
c) Risk registers are generally compiled by discipline experts within the project team who will generally have similar experience and thought processes by virtue of their training and positions.
d) Awareness of the culture of many organisations that suppresses uncertainty and rewards behaviour that ignores it (e.g. an executive who shows greater confidence in a plan is more likely to get it approved than one who lays out all the risks and uncertainties).
e) Learn from previous experience (feedback and post-mortems).
f) Education and awareness of the effect of heuristics and biases on our decision making abilities.

Oil field decision making whether above or below the mud line requires an evaluation of risk. This can often mean that a number of parameters are sometimes either lumped together or split into separate categories, and with dependencies either estimated or independence assumed. Whatever the process, **calibration is KING**.

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