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The search for efficient use of CAPEX:

Integrating the analysis of uncertainty, risks and rewards in economic modelling, valuation and decision-making

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- **The information in this presentation is based on our understanding of current taxation law, proposed legislation and HM Revenue & Customs practice, which may be subject to future variation.**

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Who am I?

- Read Economics at Cambridge
- Stumbled across actuarial work!
- Joined Duncan C Fraser in London (1978)
- Took ages to qualify!
- Finally did so in 1986 …
- … and then Mercer took over DCF
- Stayed until 1989 …
- … and then set up Barnett Waddingham

Who am I?

Institute and Faculty of Actuaries

- Various positions incl Council
- Elected as President 2014 – 2015
- Theme of Diversity
  - People (gender etc)
  - Actuarial skill set
  - Areas of work
- Responsible for some overseas liaison
  - USA, Canada, Africa, Middle East

Who are actuaries?

- **Actuaries have a great platform of professional skills:**
  - **highly numerate;**
  - **data analysis;**
  - **create models that comprehend and communicate the complex;**
  - **able to explain these models in accessible way;**
  - **scepticism not to take models at face value;**
  - **problem solvers.**

- **Well respected within financial services industry**

- **But can do more than the traditional small box**

Role of actuaries

- Less requirements in pensions/insurance?
- Yes and No!
- Changing landscape
- Use traditional skillset to diversify opportunities
- Risk work post 2007/8
  - ORSA
  - Solvency II
  - FRC Corporate Governance Code
- Actuaries have even more to offer than before
- The opportunities are there

New areas

- **Banking**
- **Supermarkets**
- **Climate Change**
- **Infrastructure projects**
  - **Transport/ housing**
- **Strictly come dancing**

Barnett Waddingham

- **Harnessing skillset that our actuaries have and encouraging development in different areas**
- **Risk consultancy**
- **Oil and Gas**
- **Can offer new services to existing clients**

Efficient use of CAPEX: a framework

Our starting point:

- **(almost) everything which is done in a physical project has a financial counterpart**
- **Risks which cannot be mitigated, transferred, shared, hedged, insured or avoided are "self insured" – whether consciously or not**

To improve costs and efficient use of capital we need:

- **To look at uncertainty, risk and reward as objectively as possible**
- **To incorporate risk management into a workflow which includes the economics, and capital management**

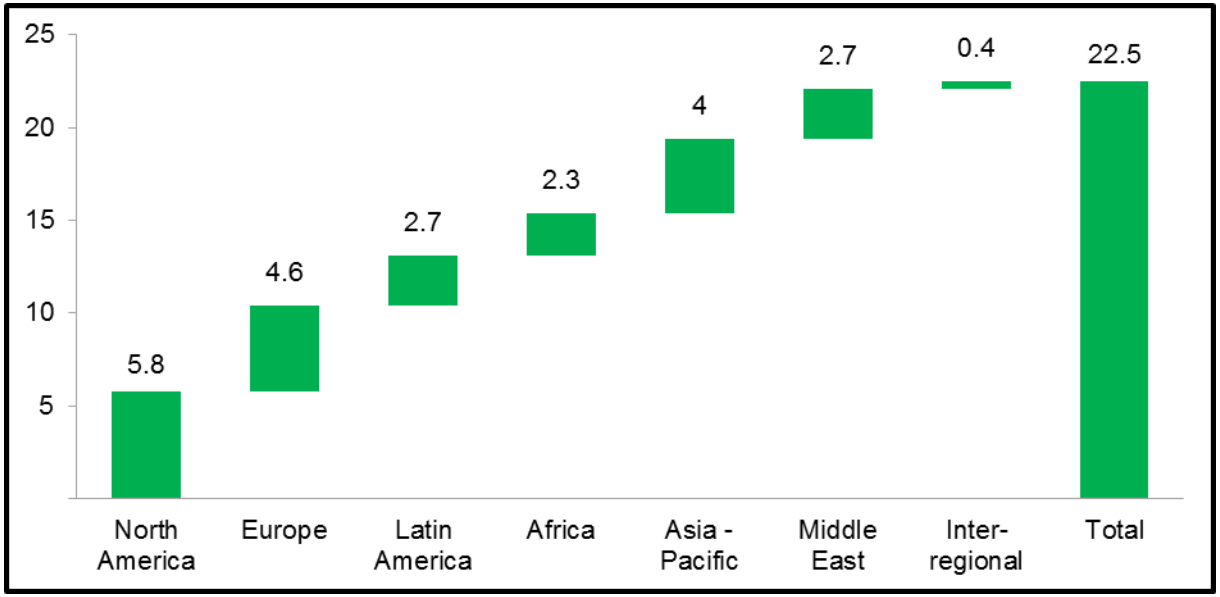
Operating Capital	Risk Capital	Opportunity and "Solvency" Capital ("Signalling")

- **If risk events occur, plan for concerns such as the loss-absorbing ability of the company, and cost and availability of any additional capital needed**

Efficient use of CAPEX: a framework

- Talk about Variation in either direction from a base case or scenario, rather than risk
- Integrated workflow
- Understanding and mitigating “Model Risk”
- Value of Information and Decision Analysis
  - Incorporating “economics” as fully as possible into the value criteria used for decision-making
  - Valuing risk and opportunity separately (in addition to the “main” criterion (such as expected NPV).
  - Include changes in risk and opportunity profiles in decision criteria
  - Assessing the “robustness” of decisions
- Governance
  - Methods should permit review and comparison, to reduce Model Risk and bias
  - Preparation for Delay analysis and possible cost recovery

Regional cumulative Oil and Gas investment between 2014 and 2015 (US$ trillion)



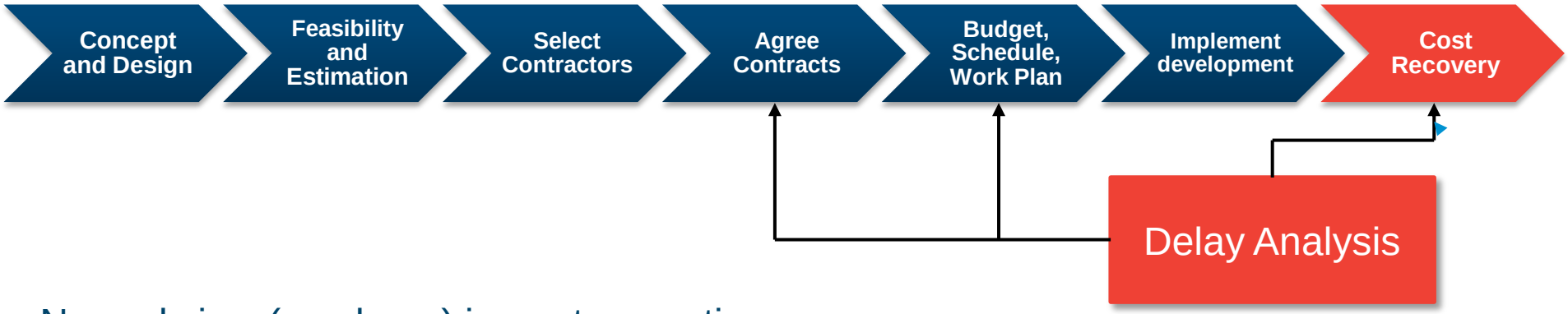
				Proportion of projects facing:		
	US$ billion	Number of Projects	Average size ($ billion)	Cost Over-runs	Delays	Average Budget Over-run
Upstream	1080	163	6.6	65%	78%	53%
LNG	539	50	10.8	67%	68%	70%
Pipeline	348	46	7.6	64%	50%	41%
Refining	607	106	5.7	62%	79%	69%

Source: Spotlight on oil and gas megaprojects: EY Research and Analysis 2014.
Next slide is also based on the EY report, modified by BW

Factors responsible for cost over-runs and delays

Internal				External	
Portfolio and Project commercial context	Project Development	Project Delivery	Natural Hazard	Regulatory challenges	Geopolitical challenges
JV conflict and relationship	Planning: over-aggressive forecast	Ineffective Project Management		HSE Risk and local content	Diplomatic and Security issues
Access to funding	Procurement of Contractors	Contractor management		Regulatory delay and policy uncertainty	Financial and supplier market uncertainty
Portfolio management and changing risk appetite	Aggressive estimates and Optimism Bias	Human Capital Deficit		Inadequate infrastructure	Civil and workforce disruption

Delay analysis



Normal view (as above) is a retrospective one:

Delay analysis can be difficult, and done only when there are

- significant cost or schedule over-runs
- *and* the potential for financial recovery.

There are (more or less) five "standard" approaches acknowledged by the courts

- The choice depends mainly on the availability of supporting evidence

We suggest:

- Reverse the arrows: take a prospective view and plan in advance
- Design workflow to capture the best information available to support possible DA
- We can model and value the (possible) outcomes, taking account of "masking" risks such as weather

Project Uncertainty : nine steps (Petrobras)

Example - going towards the benefits of integration: data and workflow

1) Qualitative analysis and documentation of scheduling risks
2) Development of a specific schedule based on a work breakdown structure
3) Risks are matched with schedule activities
4) Probabilistic estimates for the duration of schedule activities are obtained through databases or interviews with subject mater experts
5) Attribution of each probabilistic estimate to a given schedule activity, and the definition of points of interest (which are set as outputs)
6) Running of a schedule simulation with software
7) Results evaluation through the output's probabilistic distributions and sensitivity analysis (which helps define the inputs that could have greatest impact on a project)
8) A risk assessment associated with the most impactful variables to first oil and ramp-up helps determine the most important risks within the project
9) Review of the risk-response plans made during the qualitative risk analysis for maintenance, monitoring and control, thus re-starting the evaluation cycle for a simulation of mixed scenarios

Source: summarised from OTC-26309-MS

Reservoir-Schedule Coupled Uncertainty Analysis for PD Projects: Optimization Opportunities and Improvements for More Robust Production Forecasts. V.C. Silva and J.W. Pinto, Petrobras

VOI Definition

Usual Industry definition: VOI =

- **Expected Value ("payoff") of taking the optimum decision with the benefit of additional information**

Minus

- **Expected Value of taking the optimum decision *without* the additional information**

The VOI depends therefore on the probative power of the additional information, its reliability, its cost, and whether or not it may, potentially, alter the optimum strategy.

- **It can be thought of as the maximum amount which a decision-maker should pay for specified additional information**

VOI Definition

The academic definition strictly differs from this.

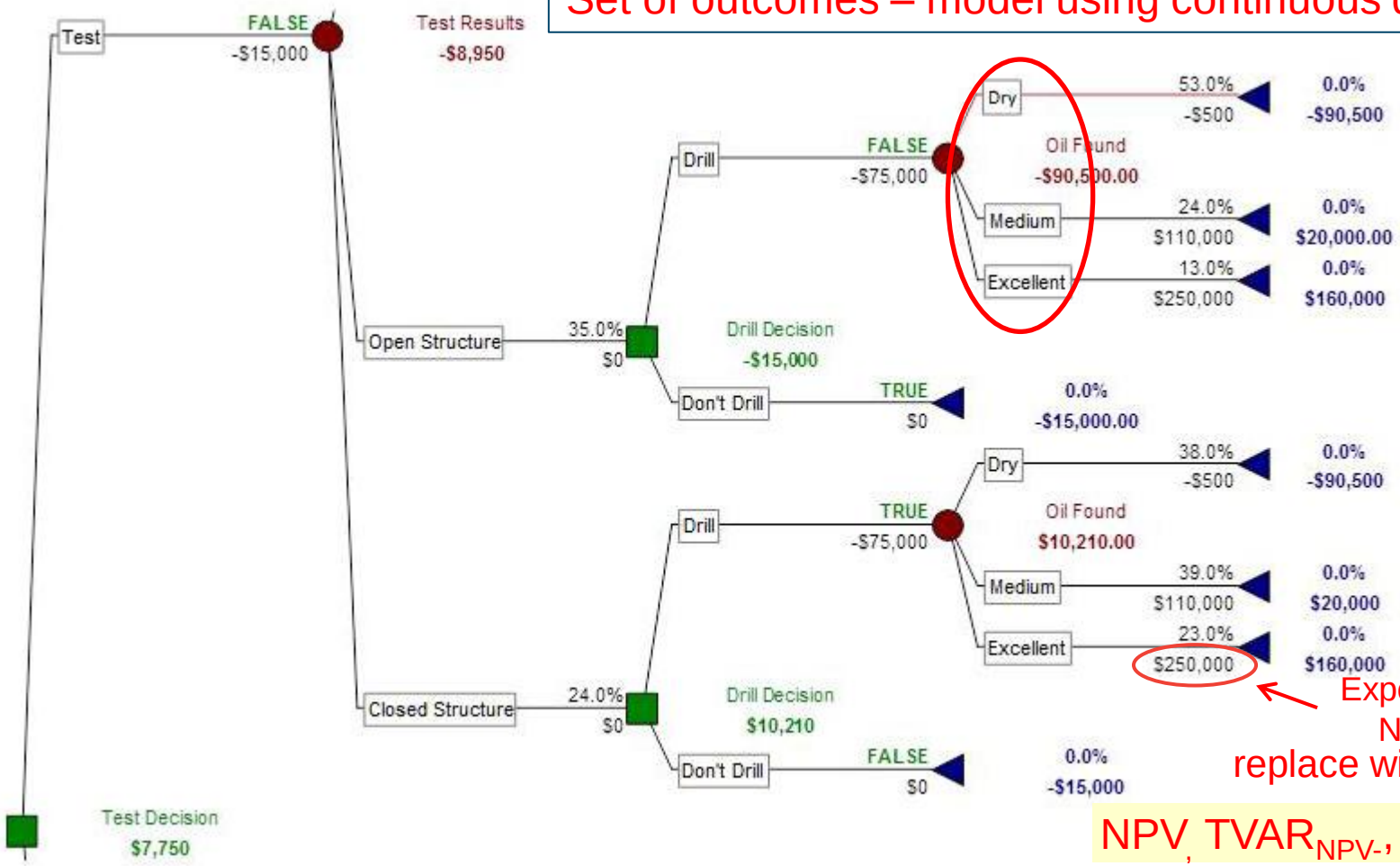
- Formal definitions, developed decades ago, adjust the value criterion to account for “risk aversion”
- substituting a “utility function” for values such as NPV which are based just on money.
- apart from this, formal definitions take “no account” of the profile of risk and opportunity
- Academic definition = Industry practice only when decision makers are “risk neutral” (which is very rare)

We would argue that the formal definition is misleading and not useful: it is better to look at risk and opportunity as scientifically as possible.

- Avoid attempting to capture subjective “risk aversion” in a mathematical form; it can be allowed for later

Value criteria in a decision tree context

Set of outcomes – model using continuous distribution



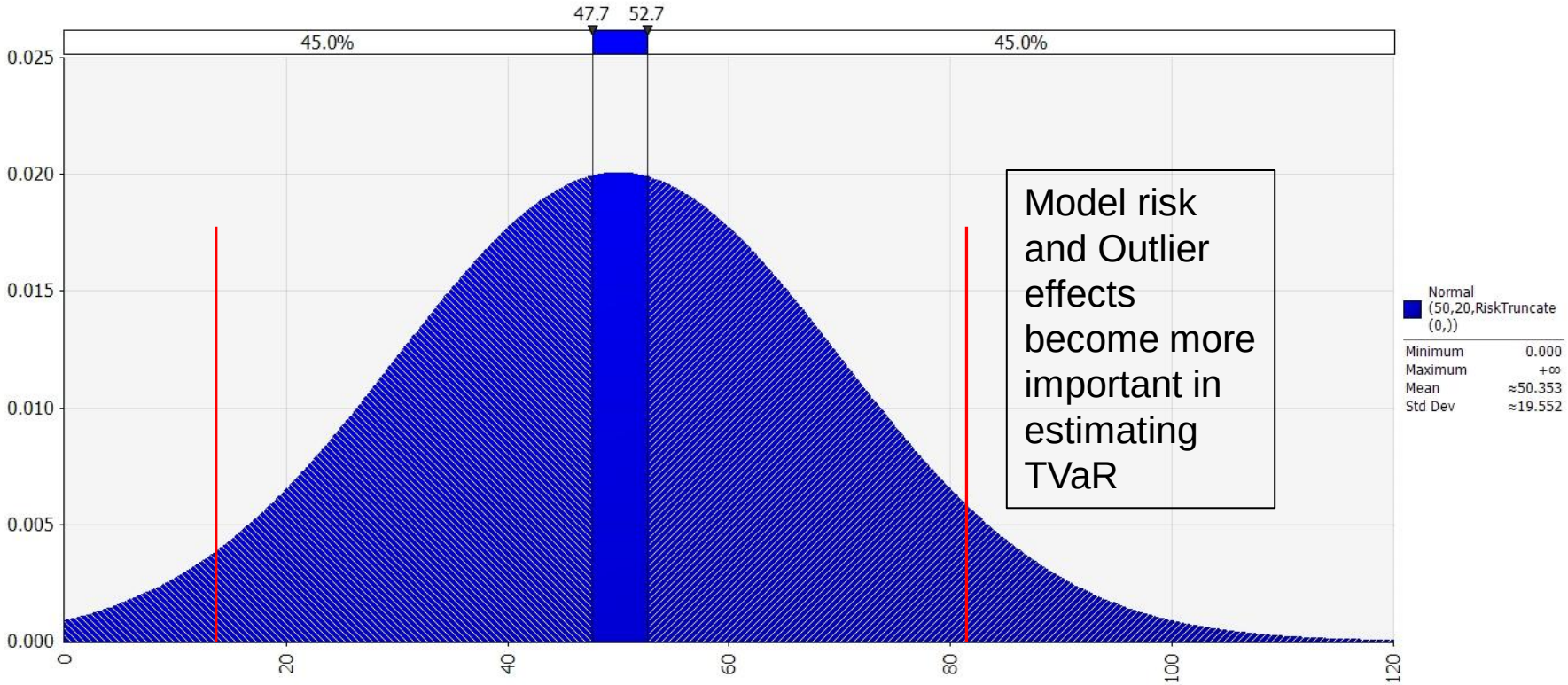
Expected value of NPV for branch replace with expected:

NPV, $TVAR_{NPV-}$, $TVaR_{NPV+}$

or corresponding sets of values for IRR, PI, CAPEX etc.)

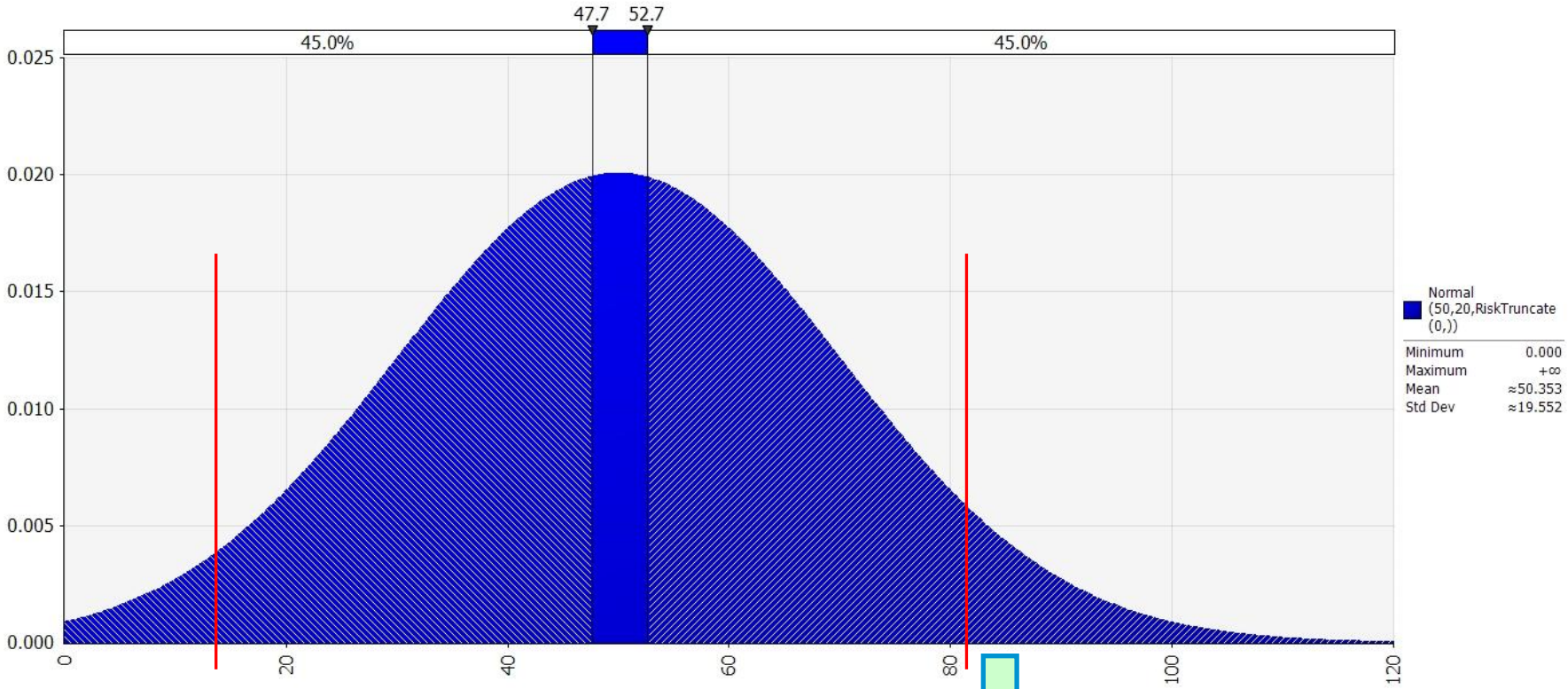
Two perspectives on Tails

Essentially equivalent to P50, or the mean, for a Decision Analyst (boundaries set by policy)



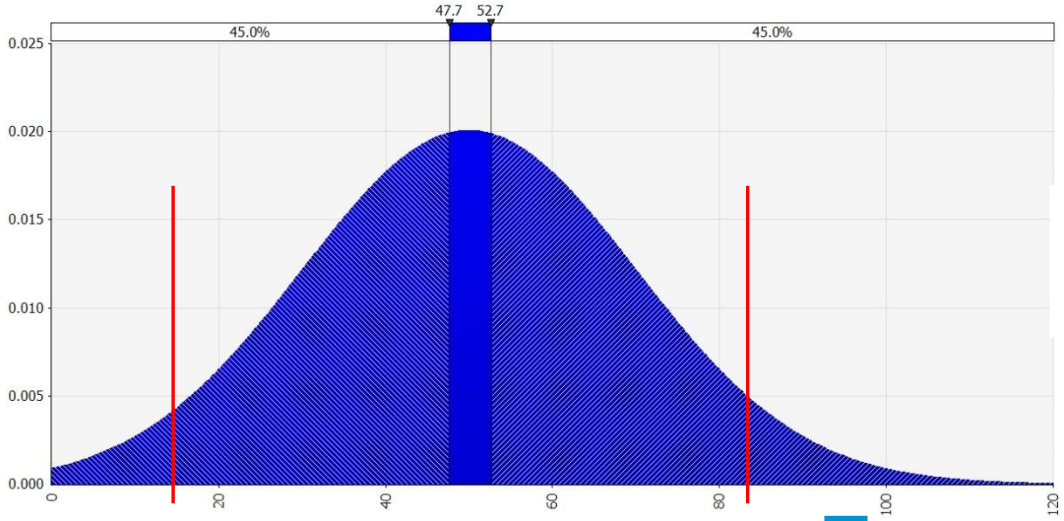
Model risk and Outlier effects become more important in estimating TVaR

Two perspectives on Tails



Operating Capital	Risk Capital	Opportunity and “Solvency” Capital (“Signalling”)

Incorporating Variation analysis in the workflow: the benefits



An ideal:

- Integrated workflow from Subsurface, Reservoir through to Economics and Strategy
- Embedded analysis of *variation* (both Risk and Opportunity, considered separately)
- No loss of data across Stage Gates

Operating Capital	Risk Capital	Opportunity and "Solvency" Capital ("Signalling")

Better estimation of Operating and Risk capital requirements enables:

- Investor confidence
- Better estimation of capital available for other opportunities
- Better planning in light of questions such as:
  - If additional capital is needed, will it be available, and at what cost?

Model Risk: characteristics

- The risk: Adverse consequences arising from decisions based on incorrect or misused model outputs and reports.

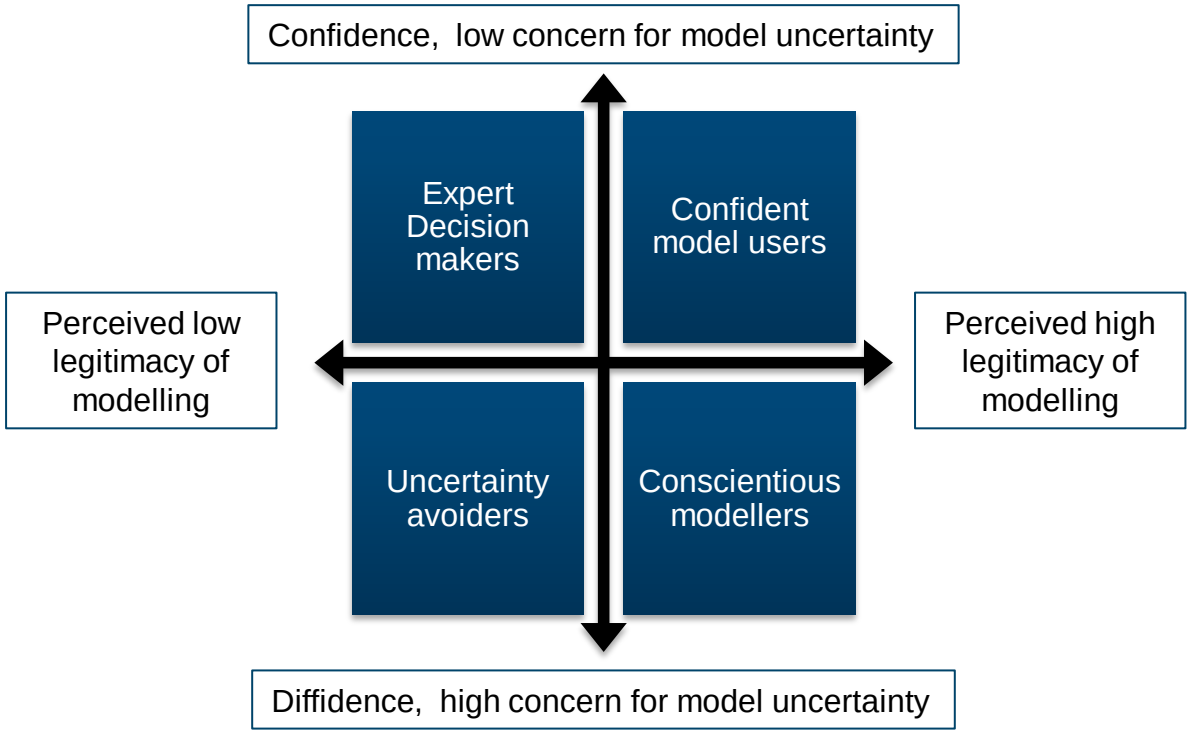
- Can lead to financial loss, poor capital management, poor business and strategic decision making, misleading valuations

- Two main causes:
  - Model has fundamental errors and produces inaccurate or misleading outputs
  - Model may be used incorrectly or inappropriately (“Use risk”).

- Should be managed like any other risk:

Model Risk is difficult to manage

- Specific attributes which make it hard to manage:
  - It cannot be eliminated entirely: some aspects are subjective and cultural (bias)
  - It is a quantitative risk, but hard to quantify
  - All models are wrong, so focus of models should be on fitness for purpose
  - “Use” risk is unique to model risk



Model Risk: assessing the mathematical model

Difficulties arise in mapping model errors to actual financial impact. In the case of irreducible model uncertainty, it is necessary to employ a variety of measurement approaches, based on: statistical inference, fitting multiple models, and stress and scenario analysis.

Data

- Accuracy, completeness, relevance, up to date?
- Relationship between data quality and level of confidence levels in results

Assumptions (Choices of PDFs, Time series models, Dependencies)

- Reasonableness
- Have the assumptions been documented, with alternatives and defensible rationale for the choices?
- Do the *Explicit* and *Implicit* assumptions reflect objective data and expert opinion adequately?
- Are all material risks modelled? How material is anything excluded, or modelled poorly?

Multiple Models

- What alternative models are credible?
- If chosen, what is the effect on the results?

Stress testing and scenario analysis

How robust are the conclusions?

Characteristics of a development cost model

A large number of sums of products, for example

- Day rates for a type of labour x amount required
- model may sum these products across many types of labour
- Estimates of day rates from benchmarks
- Estimates of amounts of labour may be from benchmarks or expert judgment specific to a project (every project is unique)
- Expert judgment may be expressed as low / medium /high, or as P90 / P50 / P10 aligned with a familiar PDF such as the Normal distribution

Components vary considerably in weight

Many components are not independent, e.g.

- Rig rates, labour rates and accommodation costs may be positively correlated, as all are affected by the competitiveness of the market at a given time and location.
- Is correlation modelled correctly?

Characteristics of a cost model

If components were of similar weight, and independent, the Law of Large Numbers should mean:

- **that the estimated total cost or schedule time would be Normally distributed, or nearly so:**
- **specific PDFs assumed for each component would have little effect on this result**

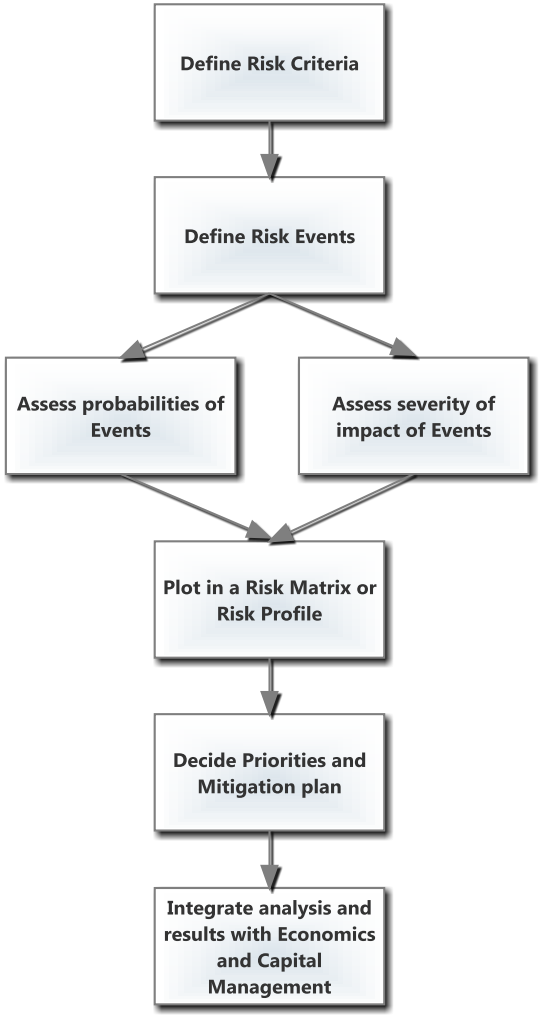
In practice, the PDFs or other models assumed for the most important components will cause "loss of Normality"

Traditional Sensitivity Analysis / Tornado diagrams do not represent the sensitivity very well

- **Because they perturb one variable at a time**
- **Often using simplified parameters, e.g. plus or minus a percentage**
- **More complex approaches such as MCMC simulation may suffer from sampling error**

Producing a good estimate of sensitivity is not straightforward

A common workflow for analysing risks using Risk Matrices



Probability					
Very High					
High					
Medium					
Low					
Very Low					
Severity	**Very Low**	**Low**	**Medium**	**High**	**Very High**

Key:

	Accept
	Unacceptable, must be mitigated

Risk Matrices

Perceived benefit: intuitive appeal and simplicity.

- **Recommended in many international standards such as ISO, API and NORSOK**
- **Easy to construct, explain and score**
- **They may appear authoritative and intellectually rigorous**
- **"Risk" is defined as a product of consequence (monetary) * probability (which yields the expected downside or expected loss)**

However…

"The development of Risk Matrices has taken place completely isolated from scientific research in decision making and risk management" *

They can be a very efficient and attractive way of capturing bias and unacknowledged implicit assumptions

- **Anchoring effects, Availability heuristic…**
- **I want to be optimistic / pessimistic. How far can I go without losing credibility?**

***Source: "The Risk of Using Risk Matrices" (SPE 166269), Thomas, Bratvold and Bickel 2014 (SPE Copyright)**

Estimating P_{90}, P_{50} and P_{10}

- **Data Analysis**
  - **Fitting PDFs, trend lines, time series, option models**
    - Data accuracy, sufficiency for required confidence levels, completeness, relevance?
    - Influence of Outliers?
    - Model Risk
  - **"Big data", fuzzy logic, Neural nets, AI**
    - Effort required to understand patterns
    - Correlation implies causal relationship?
- **Analogues**
  - Widespread use and acceptance; history matching may be possible.
  - Are the analogues really appropriate? Often needs revision, and often wrong.
- **Expert Judgment**
  - **Just Expertise**
    - Most convincing if reasoning is logged, explaining the alternatives considered, and reasons for the choice, sufficient for review by other experts
  - **Familiar PDFs**
    - Anchoring, Availability and other sources of bias
    - What are the explicit assumptions?
    - What are the implicit assumptions? (underlying any PDF; Uniform, Normal, Lognormal, Triangular …)
  - **Gut feel (mixed with other approaches)**
    - I want to be optimistic / pessimistic.
    - How far can I go without losing credibility?

Robustness

- **Making good decisions without requiring agreement with or confidence in predictions**
- **Traditional analysis:**

Assemble available evidence → Into best-estimate predictions of the future → Then suggest the best course of action given these predictions

- **This works well when:**
  - **Predictions are accurate and uncontroversial**
  - **There is a decision option which is clearly the best under all or most possible circumstances that might emerge**
- **Otherwise:**
  - **The approach can encourage gridlock, over-confidence**
  - **argument over projections rather than solutions**

Robustness: running the analysis backwards

Assemble the model as usual, but without scenarios or predictions

Use multiple runs of the model to:

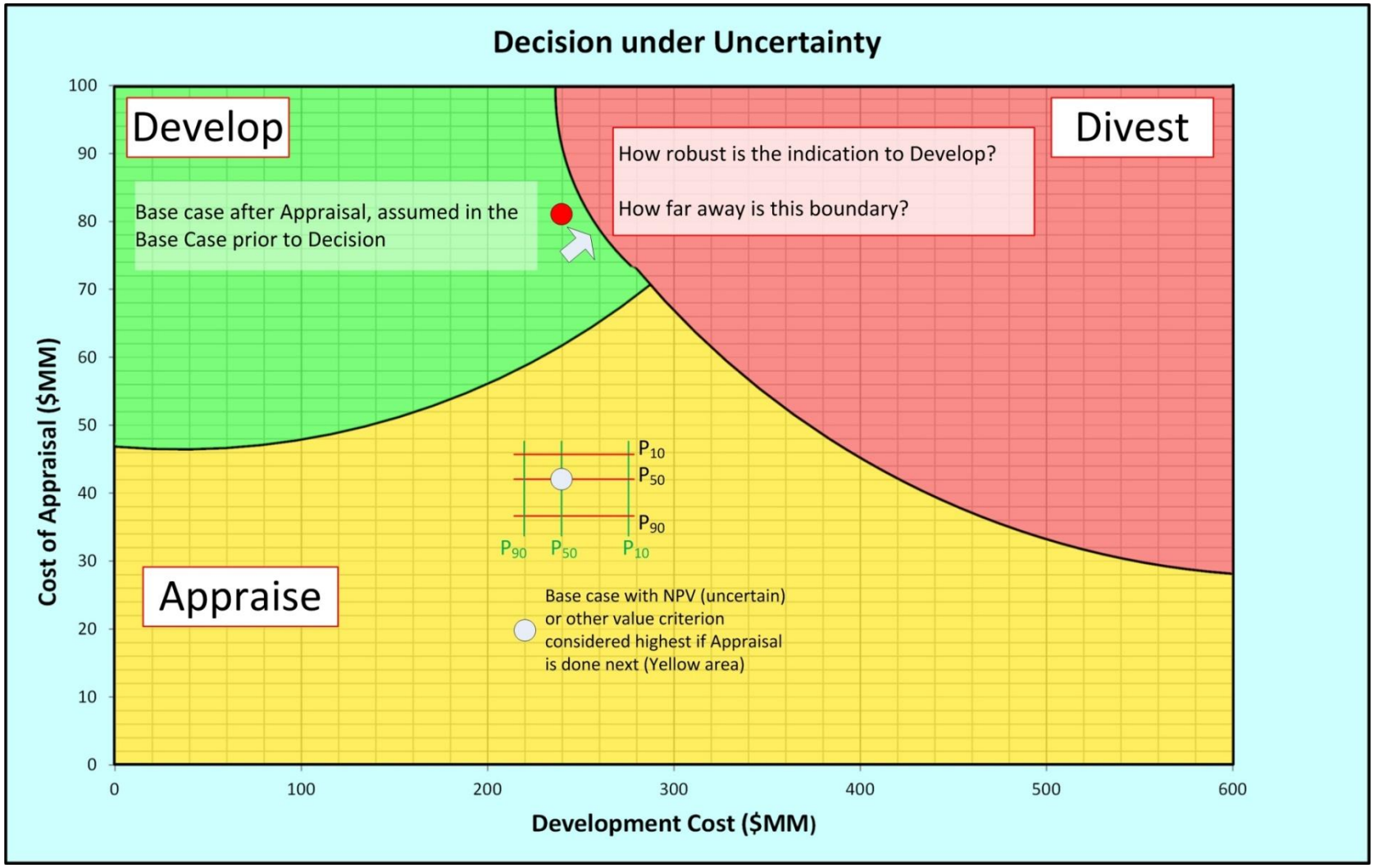
- **Identify the possible futures most relevant to success**
- **and find the boundaries between such futures**

  (where the decision made *now* which will turn out to be optimal changes from one strategy to another)

and address questions such as:

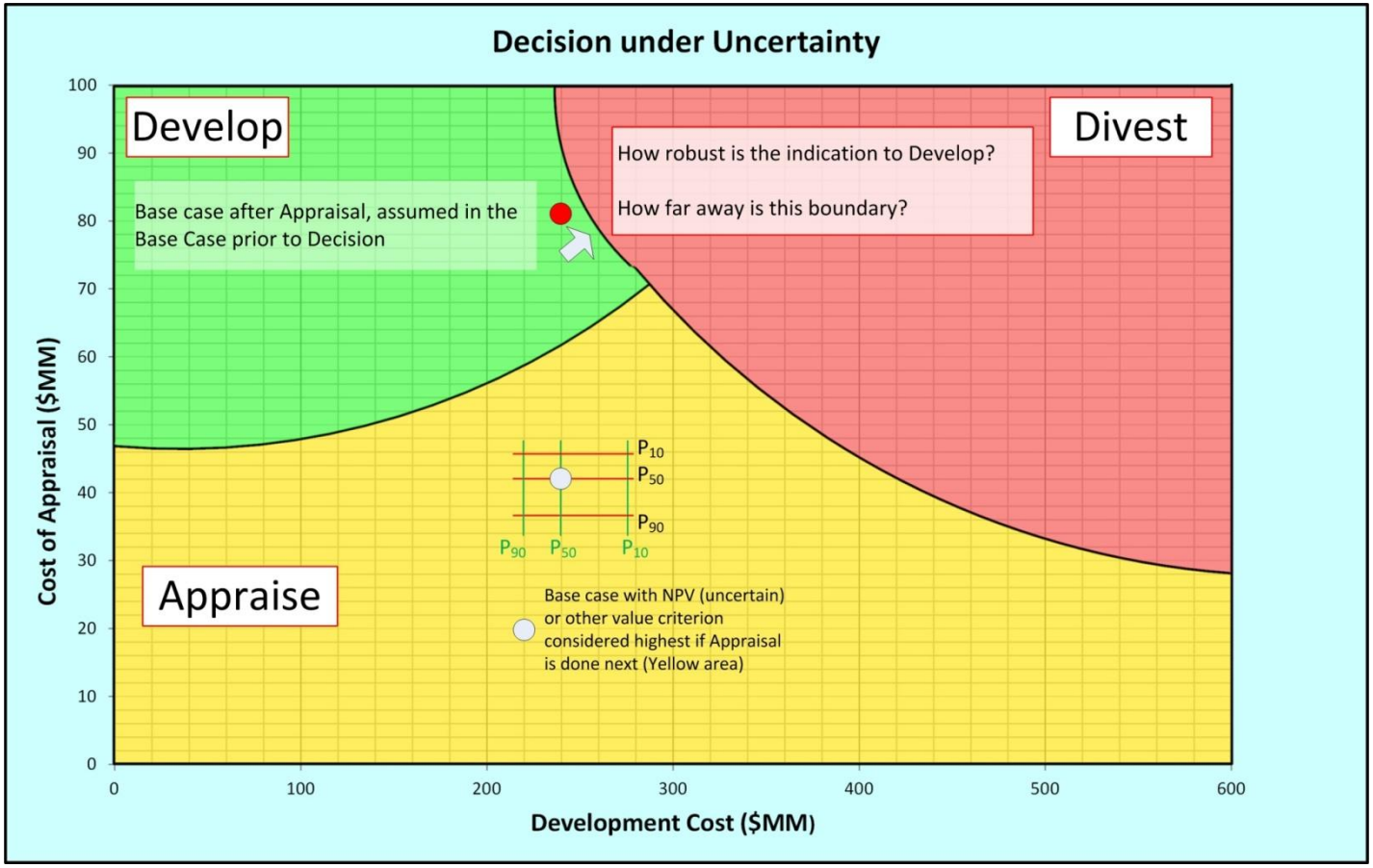
- **What steps can be taken so that a plan will be optimal over a wider range of futures?**
- **What are the key characteristics which differentiate the futures in which a plan succeeds from those futures in which it fails?**

Assemble available evidence into a model → Simulate to model many different plausible futures → Then identify which combinations of which uncertainties suggest one strategy rather than another



Strategy choice: the expected impact of all variables except those on the axes will be reflected in the boundaries between strategy regions

Illustrating Robustness



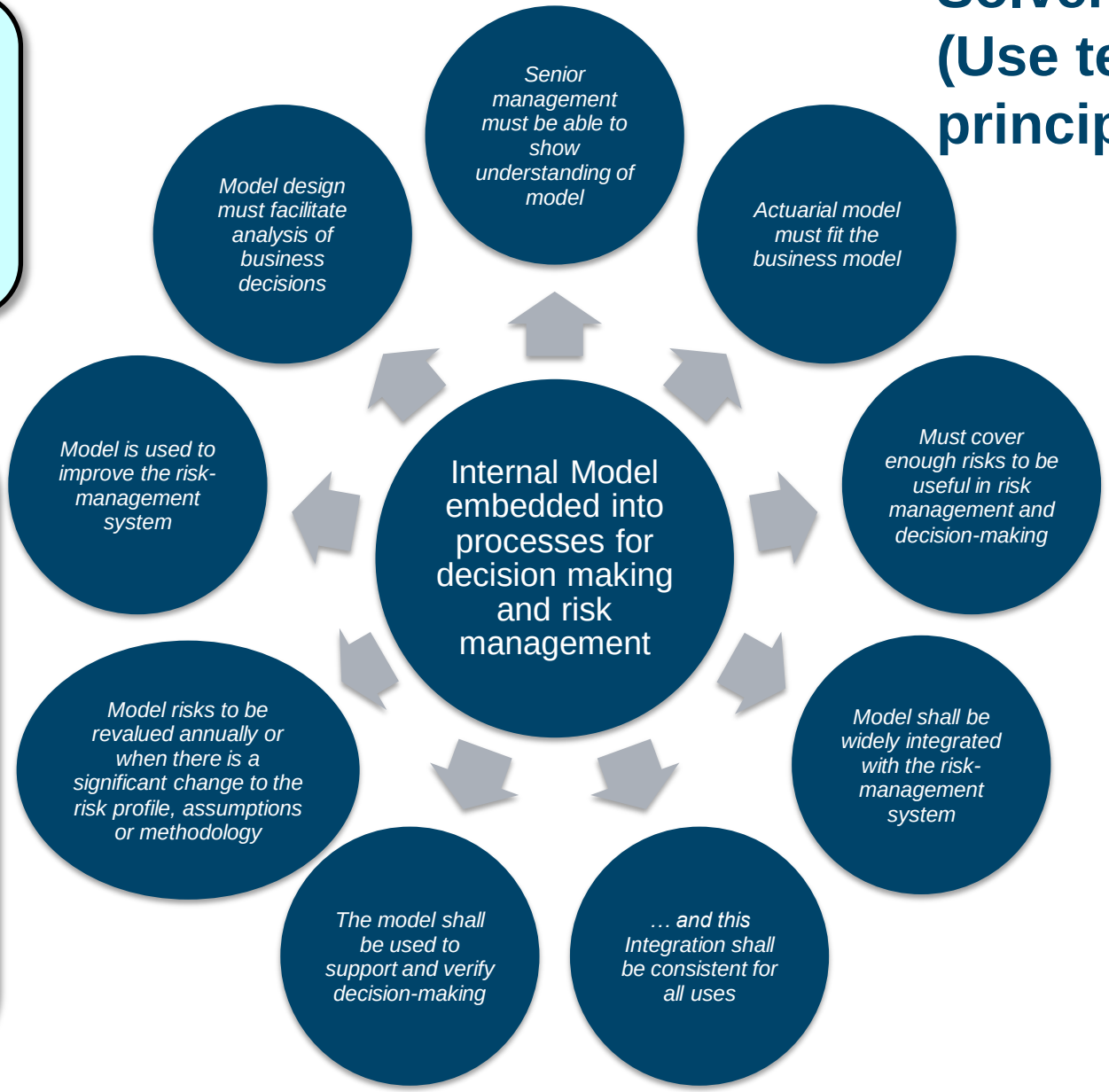
- Difficult or impossible to depict in 2D if (as usual) there are more than two dimensions, when:
- The strategy boundaries are likely to be fuzzy, and may be in very different positions, relative to the scenario, for other pairs of uncertain variables
- Distance to a boundary, given a scenario (red dot), may not be derived from a perpendicular straight line
- We need a simple measure of robustness, to enable comparisons

Solvency II (Use test) principles

"Use of the (internal actuarial) model shall be sufficiently material to result in pressure to improve its quality"

Best Practice Governance objectives:

- *to generate evidence showing compliance with these principles*
- *(as well as validation and use of the model)*



Any questions?

Appendix: Decision process for selecting and managing a development – there are many sources of uncertainty