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Creating value from uncertainty

www.Broadleaf.co.nz

Quantitative risk analysis

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Characterising uncertainty

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A project risk register is the usual tool for capturing risks, their analysis, and what is being done about them where necessary.

Its focus is on individual risks – you cannot determine from it how risky the project is in terms of aggregate cost, benefit or schedule impacts

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Principles

Quantitative risk assessment using tools such as Monte Carlo simulation can characterise risk in the aggregate

The purpose of the analysis is to understand the range of outcomes the project might face

Quantitative cost and/or schedule risk analysis now very common in the large project environment

The aim is realism rather than an illusion of accuracy

Uncertainty may be uncomfortable but we need to understand it

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Background

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Reasons for using QRA in our projects

1. **Helps lift the quality of investment analysis and advice**
   (in CBA, costs tend to be understated and benefits overstated)

2. Providing fiscal advice (e.g. around financial recommendations)
QRA helps answer the following questions:

- Where do the figures come from?
- What do they mean?
- How much confidence should the decision maker place in them?
- Where should we target our monitoring/ risk management efforts?

	$M – increase				
Indicative annual spending profile	**2014/15[4]**	**2015/16**	**2016/17**	**2017/18**	**2018/19[5]**
Operating	$13.1	$13.1	$18.6	$48.5	$17.6
Capital	$0.55	$4.1	$3.2	$0.1	$0.00

3. It's part of BBC method (part of Cabinet expectations)
(QRA of costs is mandatory as part of the development of a DBC for high risk or major projects, or programmes monitored by the Treasury)

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QRA's should be considered even when they are not required by the Better Business Cases framework

- Provides a much better contingency estimate than a flat percentage
- Given that a lot of project risk lies in the plan, schedule QRAs should be being used more widely
- The QRA process itself highlights risks that often don't appear in project risk registers

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What a QRA won't do….

- Treat the risks
- Accommodate changes such as a fundamental change in scope
- Assist when you are "flying blind" (unaware of what the risks are)

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Quality management and risk management

- Applying quality management techniques is one of the ways of treating (modifying) the risks of not achieving the standards or objectives that are the measures of success
- The tighter the specification (or the more challenging the objective), the higher the risk of not achieving it
- QRAs dispel the fiction that we can specify the cost, benefits, duration etc with 100% accuracy before the project starts
- Quality assurance is a "third line of defence" risk management tool – it increases the likelihood of the project or programme outcomes being achieved, through structured reviews of processes, practices, procedures etc and the way they are applied to the project or programme

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Background

1. Components of an estimate
2. Sources of uncertainty
3. Historical developments

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Background 1: Components of an estimate

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Direct and indirect costs

Direct costs

- Usually developed in an estimating package
- Typically follow a Work Breakdown Structure (WBS)
- Quantities and rates for some items
- Some lump-sum items

Indirect costs

- Project management, preliminaries, mobilisation and demobilisation, overheads
- Margin

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Fixed and variable costs

These must be separated if there is schedule uncertainty

Fixed costs remain fixed, irrespective of the schedule

- Most direct costs are fixed under many forms of contract

Variable costs increase as the schedule increases

- Indirect costs have large variable components
- Because variable costs are often large, schedule uncertainty can be a dominant driver of overall cost

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Cash flow and escalation

Cash flows are important in most major projects

- They are needed for escalation calculations
- They determine funding requirements and draw-downs

Schedule uncertainty is a major driver of uncertainty in cash flow and escalation

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Background 2: Sources of uncertainty

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Continuous uncertainties

Most elements of an estimate are subject to uncertainty

- Rates can rarely be known in advance, as final contracts can't be signed before approval
- Productivities of labour and equipment vary according to site conditions and other factors
- Quantities may be uncertain because designs are not finalised

These uncertainties are usually 'continuous'

- There are ranges across which they may vary, without big or discrete changes

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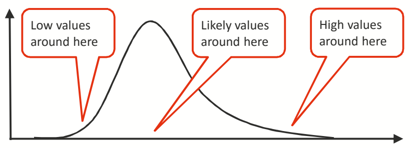
Representing continuous uncertainties

Continuous uncertainties are usually represented as distributions

They are often characterised by three-point estimates

- Low, likely and high values
- A 'standard' shape assumption is usually made



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Discrete risks

Discrete risks are events that may or may not happen

- Usually there are quite different impacts if the event arises compared to no-event

Discrete risks are developed in a risk register

In practice, there should be very few discrete risks

- Risk treatment actions should be in place
- Major threats are usually covered by insurance, or by specific contractual terms and conditions

If a project has a long list of discrete risks, watch out!

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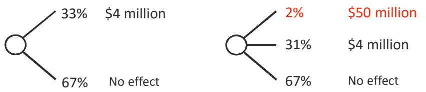
Representing discrete risks

Discrete risks are usually represented as probability trees

The simplest have only two branches: the event occurs or it doesn't

More interesting circumstances require several branches

The consequences may be represented as distributions



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Schedule uncertainty

For important or long-duration projects, schedule uncertainty is best developed in a separate quantitative analysis

Cost and schedule uncertainty are linked

- Productivity affects the schedule
- The schedule affects variable costs and escalation

Schedule uncertainty covers

- Uncertainty in the start date (e.g. due to approval delays)
- Uncertainty in the project's elapsed time to completion

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Background 3: Historical development

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Methods of assessing contingency

Model structures
- Risk events
- Line items in the estimate
- Risk factors

Calculation
- Manual
- Computer assisted
- Monte Carlo simulation with distributions

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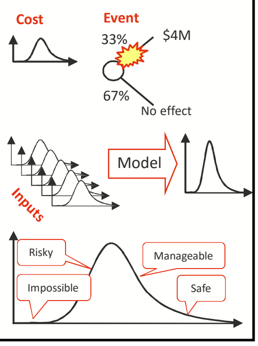
Monte Carlo simulation

Very brief summary

Distributions represent values and probabilities represent events

Thousands of examples of possible outcomes – sampling distributions and calculating outcomes

Interpret the results as an indication of what could happen in reality



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Risk event models: all the risks

Risk	Probability	Impact	P x I
Risk 1	P_1		$P_1 \times I_1$
Risk 2	P_2		$P_2 \times I_2$
Risk 3	P_3		$P_3 \times I_3$
Risk 4	P_4		$P_4 \times I_4$
…	…	…	
Risk n	P_n		$P_n \times I_n$
Total			$\Sigma P_i \times I_i$

Monte Carlo simulation

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Line item models

WBS Item	Labour	Materials	Total	Contingency
Annnn	$	$	$	
Bnnnn	$	$	$	
Cnnnn	$	$	$	
Dnnnn	$	$	$	
…	…	…	…	…
Znnnn	$	$	$	
Total			Σ$	Σ$

Monte Carlo simulation

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Risk factors model

Cost estimating relationships (e.g. Cost = Quantity x Unit rate)

Simulated cost = Base estimate x (1 + ΔQuantity) x (1 + ΔRate)

Project estimate summary	Labour	Facilities	Super-vision	Materials	Sub-contracts	Services	Expenses	Total
Earthworks								?
Concrete								?
…								?
Overheads								?
Project Total	?	?	?	?	?	?	?	?

Uncertainty about quantities of concrete (m^3)

Uncertainty about rates for cost of concrete ($\$/m^3$)

The only practical way to evaluate a risk factor model is to use Monte Carlo simulation on a computer

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Why the risk factor approach?

Problems with risk event models

Many risks are not really events but variations from the estimating assumptions – vary continuously across a range

- Staff productivity
- Rates for labour, office space, equipment hire
- Quantities of anything that is to be purchased
- How long the work will go on and incur overheads

Some risks affect more than one part of the cost

One part of the cost will be affected by more than one risk

Trying to represent uncertainties as discrete, separate events is inefficient and confusing

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Correlation in line item models

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Sources of correlation and linkages

Correlated: all high or all low together

- Development size uncertainty affects a number of cost items
- Labour cost uncertainty affects every item with labour content

Proportional, e.g.,

- Preliminaries = 24% of direct costs
- Contractor's overhead = 13% of direct costs plus preliminaries
- Maintenance = 10% of purchase price

Common cause

- Costs driven by schedule (e.g. project management effort, overheads)

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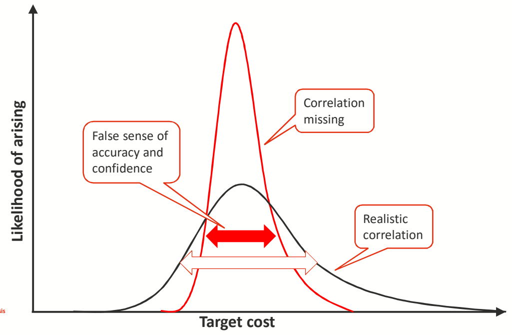
Effect of missing correlation



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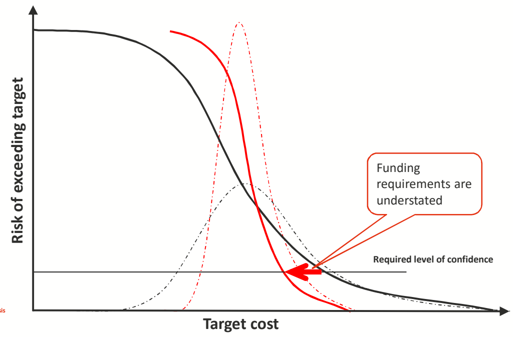
Why does missing correlation matter?



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Why is correlation important?

Separate lines are often not independent of one another

In practice, line item uncertainties are correlated

- In principle, it is technically feasible to model the correlations
- Realistically, it's problematic in a line item structure

Line item models often either:

- Understate the uncertainty in the total cost, because they ignore correlation, or
- Lack credibility, because they rely on correlations that cannot be justified

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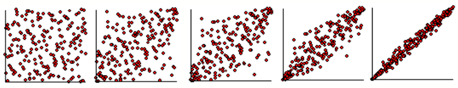
It is hard to estimate correlation

Few people have a sound understanding of correlation

It is a statistical concept most often used to describe historical data rather than for prediction

- For most projects we don't have useful data for this

It often becomes a vague factor that is adjusted to get an outcome that 'looks right'



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Dealing with linkages between items

- Identify all major sources of dependence links
- Estimate correlations directly, or
- Modify your model structure

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Defining distributions and estimating parameters

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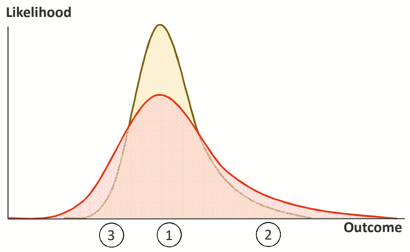
Assessing individual ranges – pitfalls



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Anchoring and adjustment bias

Once our minds have focused on one value, it is difficult to move away

- The first value becomes the anchor
- Subsequent estimates are adjustments from the anchor
- Typically the adjustments are not large enough

If we start from the centre and work out we tend to understate the range

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Avoiding anchoring

Work in from the extremes rather than out from the centre

The extremes may be difficult to estimate but they help us think about the true range we might face

- They are a valuable part of the *process* even if they are not reliable for modelling

Explore the issues at work before fixing on any numbers

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Estimating the spread

The extreme values are rare

- You might never see a 1:100 event let alone 1:1000
- Minimum and maximum estimates are unreliable
- Using them to define a distribution may not produce a reliable forecast

However, we do see 1:10 events and can estimate them more reliably

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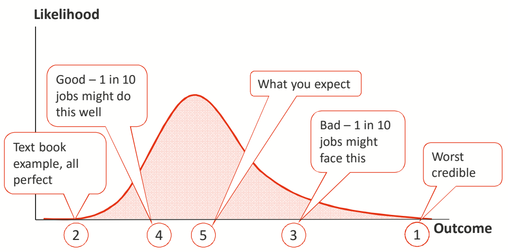
Recommended approach



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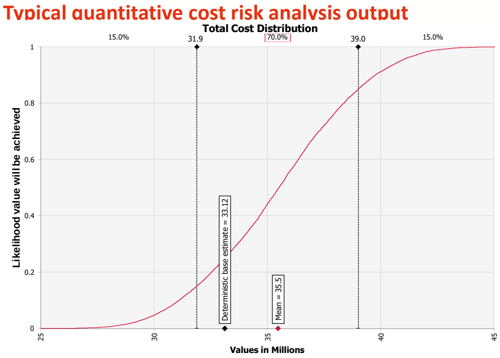
Typical quantitative cost risk analysis output



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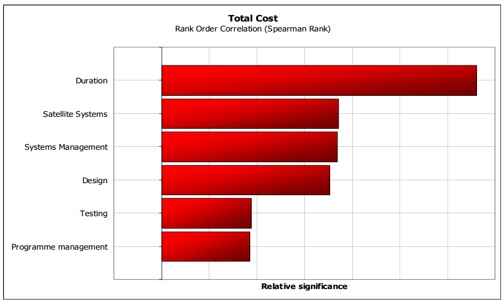
Quantitative risk analysis – sensitivity analysis



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Schedule uncertainty

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Schedule uncertainty affects the costs

The estimate is based on a planned schedule

Fixed costs

- Fixed costs are spread over the uncertain project duration using a standard S-curve

Variable costs

- A variable cost rate is calculated from the planned duration (assumed constant over the project life)
- Variable costs increase or decrease in proportion to the actual duration

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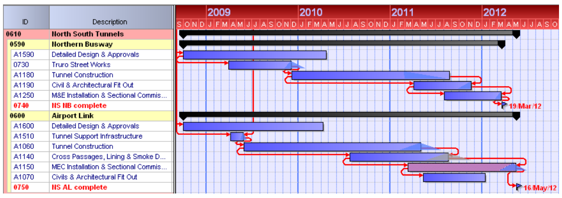
Model



Simplified model focuses on major tasks

SS and FF links often required at this level

Some tasks can be left out – never the critical

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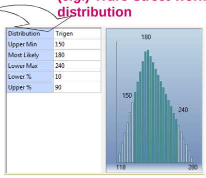
Uncertainties

ID	Description	Rem Duration	Minimum Duration	Most Likely	Maximum Duration
0610	North South Tunnels	1324			
0590	Northern Busway	1266			
A1590	Detailed Design & Approvals	570			
0730	Truro Street Works	180	150	180	240
A1180	Tunnel Construction	630	450	450	630
A1190	Civil & Architectural Fit Out	230	170	230	230
A1250	M&E Installation & Sectional Commis...	230	200	230	230
0740	NS NB complete	0			
0600	Airport Link	1324			
A1600	Detailed Design & Approvals	556			
A1510	Tunnel Support Infrastructure	55	40	55	70
A1060	Tunnel Construction	703	613	703	790
A1140	Cross Passages, Lining & Smoke D...	392	294	392	490
A1150	MEC Installation & Sectional Commis...	420	360	420	480
A1070	Civils & Architectural Fit Out	249			
0750	NS AL complete	0			

(e.g.) Truro Street works distribution



Optimistic and pessimistic duration estimates

Distributions instead of fixed durations

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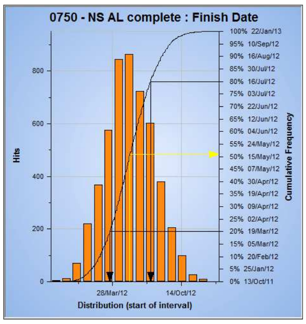
Milestone date distribution



Deterministic date

16 May 2012

50% risk

Two month slip

20% risk

Three month slip

10% risk

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Milestone date uncertainty

Sensitivity = spread of outcomes, not total duration