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Specialists in Strategic, Enterprise and Project Risk Management

TUTORIAL NOTES: QUANTITATIVE RISK MODELLING

1 Overview

Broadleaf has been actively engaged in quantitative analysis of risk in projects and business initiatives for many years. Parts of this work have been published in three books and several papers, including:

- Dale Cooper and Chris Chapman (1987) Risk Analysis for Large Projects. John Wiley & Sons, Chichester. ISBN 0 471 91247 6.
- Stephen Grey (1995) Practical Risk Assessment for Project Management. John Wiley & Sons, Chichester. ISBN 0 471 93979 X.
- Dale Cooper, Stephen Grey, Geoffrey Raymond and Phil Walker (2004) Project Risk Management Guidelines: Managing Risk in Large Projects and Complex Procurements. John Wiley & Sons, Chichester. ISBN 0 470 02281 7.

For feasibility evaluation, investment analysis, project planning and similar requirements we use simulation modelling techniques based on Palisade's @RISK add-in for Excel. We have successfully applied these techniques to a wide range of projects and operations, evaluating uncertainty in:

- Capital and operating costs and budgets;
- Project schedules;
- Process efficiencies and throughputs;
- Revenue forecasts;
- Net cash flows, headcounts and other time based characteristics of projects;
- Public sector bid evaluation where value for money involves a trade-off between risk and tender price.

Cash flow analysis typically includes a probabilistic assessment of both an uncertain cash flow profile over time and standard summary measures as:

- Net present value;
- Internal rate of return;
- Payback period; or
- Maximum exposure.

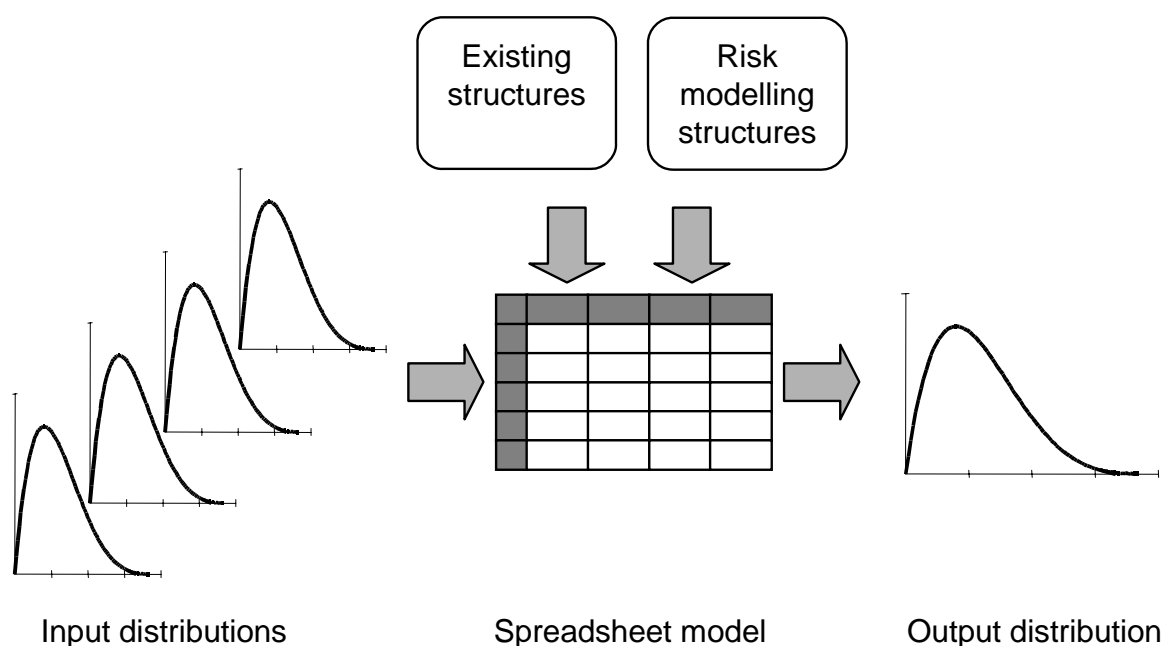
Quantitative analysis yields both direct and indirect benefits. Direct benefits include a clear view of the uncertainty in the key measures of a project's performance, which form a sound basis for setting targets and contingencies or accepting commitments. Indirect benefits are the rigour that modelling brings to the plans and estimates on which it is based, and the insight it yields into the relationship between the uncertainty in individual estimates and the uncertainty in the project as a whole.

2 Modelling Process

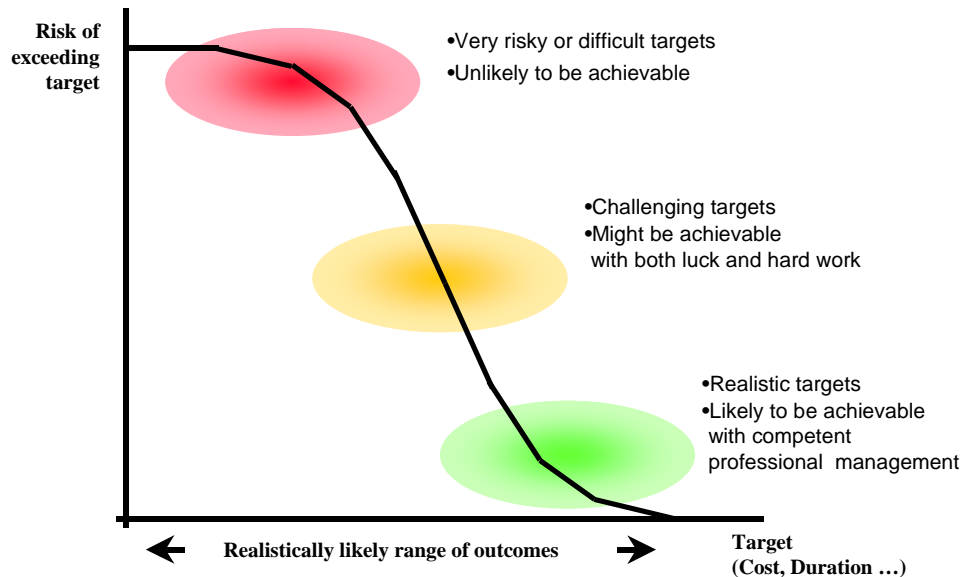
Forecasts of costs, revenues, durations, throughputs and other numerical measures of a business are all subject to uncertainty. Anyone making a commitment to achieve a particular outcome for a project or an organisation in the face of uncertainty is taking a risk.

Because the subject can be confusing and very few professionals are educated to deal with uncertainty, quantitative risk assessment is often seen as mysterious, but it need not be so. Large complex estimates can be decomposed into small manageable pieces and then reassembled into an estimate of a whole job. In the same way, the uncertainty associated with a large complex undertaking can be broken into manageable components that can be described separately and then brought together in a view of overall uncertainty. Each component, such as the cost or duration of a task or the chance of a particular isolated risk, can be described more easily than the uncertainty in a project or operation as a whole. Simple spreadsheet tools are now available that make it possible to represent how the individual component uncertainties are related and to evaluate their net effect.

Models of cash flow, costs, timescales, production levels, process efficiency all have essentially the same features. Key values are represented by probabilities and distributions instead of fixed numbers, and the output is described by a distribution that shows the likelihood of particular values within the realistically likely range of outcomes. This is illustrated schematically here.



The output of such a model is often presented in the following form, showing the risk associated with targets set within the realistically likely range of outcomes. For a measure you wanted to maximise the curve would generally be presented the other way around, showing the risk of failing to exceed a particular target.



A model represents a snap shot view of a project or business, taking account of the inherent uncertainties associated with the work and the controls in place to manage them. Some caution is required when interpreting the risk profile of the outputs, the range of realistically likely outcomes and the likelihoods of values in those ranges.

In particular, it is important to avoid the temptation to interpret the risk of missing a target in the simplistic terms that might be appropriate to the roll of dice or a bet on the horses. A project or business differs from such familiar random processes in having active and highly motivated human control seeking to influence its outcome, striving to minimise costs and maximise benefits.

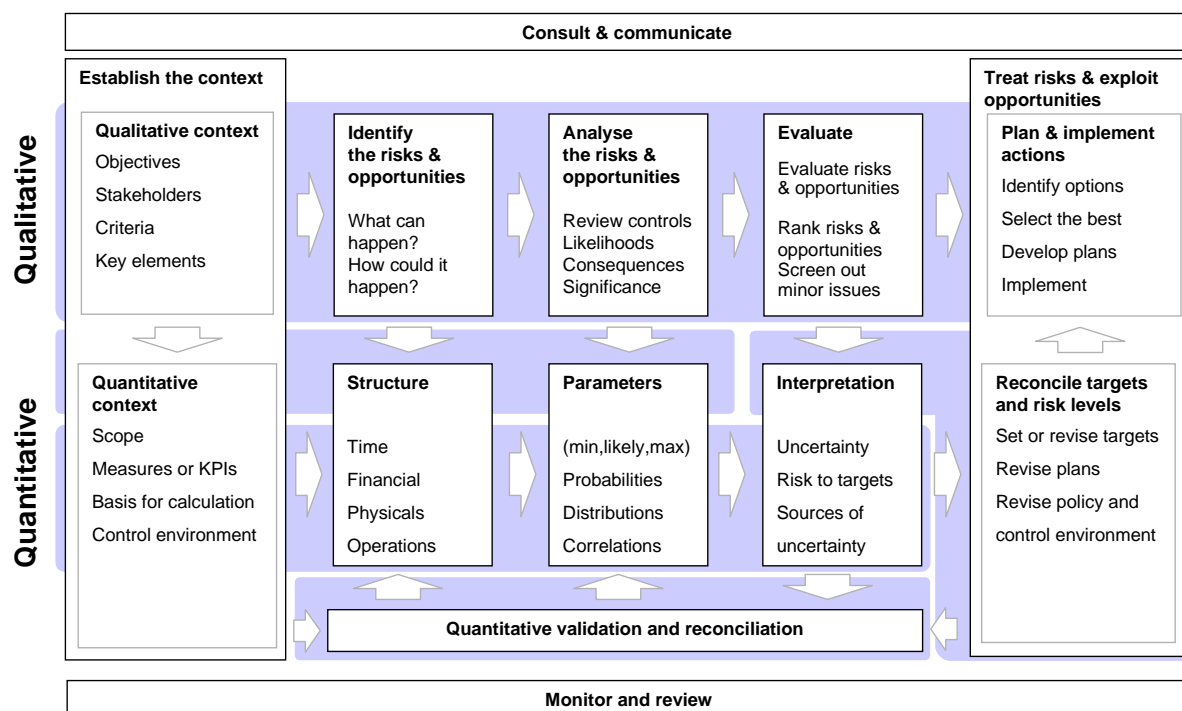
The output of a risk model can be viewed as a measure of difficulty as well as a measure of risk. The riskier the target the more difficult it will be to achieve and the greater the danger of failure.

Risk profiles are an effective basis for agreeing targets and contingencies. They can be used to illustrate the danger of over optimistic expectations and demonstrate the realism of your plans.

In addition to yielding a valuable outcome, risk modelling makes explicit many of the assumptions and complexity that might have been glossed over in conventional estimating and planning. The process of developing the model serves to improve a team's understanding of the task they face and where they need to focus their energies.

Risk modelling must be seen against a general understanding of the risks and opportunities affecting an investment, such as will generally be developed using the approach defined in the Standard AS/NZS 4360. The relationship between the qualitative and quantitative

approach to risk analysis can be structured along the lines illustrated in the following figure in which the top line is the AS/NZS 4360 process.



3 Interpreting Risk Model Output

Risk modelling can generate valuable information but some guidance might be needed to interpret it when you first enter the field. A few common difficulties are discussed below from the standpoint of a project. Essentially the same issues affect business models but it is easier to confine the discussion to one type of model rather than keep referring to both.

– Most likely values

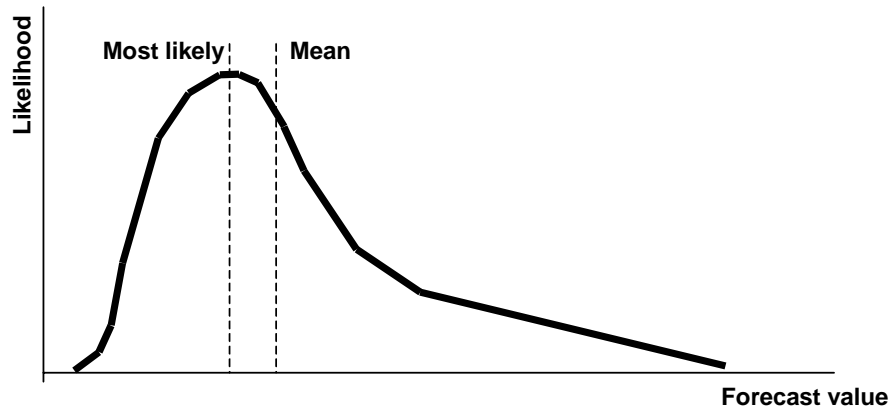
The cost of a project calculated from the most likely values for the components in a model is often taken as a starting point for a budget. It generally falls towards the risky end of the range of likely outcomes though. This can cause consternation among those unfamiliar with this type of analysis. However, it is a real phenomenon and relates to features of project estimating and planning that are often overlooked.

There are two main reasons why a target based on most likely values is inherently optimistic and risky:

- the fact that individual cost and duration estimates almost always display more scope to over run than they do opportunity to improve; and,
- the fact that where two or more predecessors have to be complete before later activities can proceed, a project suffers the worst of the predecessors, rather than their average.

– Skewed distributions

Most estimates of cost and duration include some scope to improve, but there is rarely as much opportunity for improvement as there is danger of getting worse. The most likely value of an activity's cost relates to the estimators' memories of the most frequent outcomes of related work in the past. This may be perfectly well founded but it fails to take account of the skewed nature of the forecast outcomes illustrated schematically in the following figure.



The most likely value relates to the most frequently observed events of the past. The mean value takes account of the distribution of values throughout the range they might take and will always fall towards the end with the long tail, the high end in the case of most cost and duration estimates.

This means that the sum of a set of costs' most likely values will be somewhat lower than the sum of their mean values. The sum of their mean values will generally be the mean of their total, a useful measure, but the sum of their most likely values can be markedly lower and will not generally be the most likely value of the total.

– Multiple predecessors

Where an activity depends on two or more predecessors being complete before it can proceed it picks up the worst case of its predecessors. This is sometimes likened to the familiar problem of getting a group of people to attend a meeting on time.

If there are ten people attending a meeting and each has a 10% chance of being late, the chance of them all attending on time is 0.9^{10} which is approximately 35%, meaning that the meeting has a 65% risk of starting late. Simply because the activity is structured in a way that makes it dependent on several other events, ten individuals arriving on time, the risk of one of them being late is magnified more than six times. A 10% risk has become a 65% risk.

Projects suffer the same way and a calculation based on the most likely durations of a set of activities can not take account of the effect in a meaningful way. The mean duration of a project incorporating several points at which activities have to wait for multiple predecessors (node points), will often be significantly greater than the duration calculated from the

individual activities' most likely durations, even in the absence of skew. Where you suffer from both skewed distributions and node points, the difference can be dramatic.

4 Summary

The output of risk models is a valuable decision tool. It can be used to ensure that realistic targets and commitments are established as well as to choose between alternative courses of action that offer different levels of risk and costs, savings or other financial consequences.

Options available to the parties controlling an investment or line of expenditure can be integrated into the analysis to evaluate their impact on the overall value of a particular course of action.

The quantitative analysis process must be consistent with a general assessment of risks and opportunities and these two can be drawn together in a structured fashion.

The relationship of risk model output to single point estimates is not always obvious and there are influences at work that can lead to surprising discrepancies. These discrepancies are not artefacts of the model though. They represent real effects with which a project has to contend and are a more realistic forecast than a single point analysis can offer.

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