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Specialists in Strategic, Enterprise and Project Risk Management

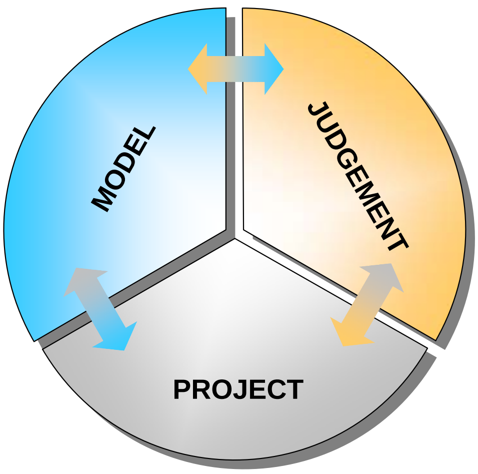
TUTORIAL NOTES:
INTERPRETING RANGE ANALYSES IN QUANTITATIVE MODELS

1 Introduction

There is a growing need to understand the uncertainty remaining in cost and schedule estimates at the time capital is committed to major projects. Risk models are becoming accepted as valuable tools for this purpose. However, misunderstandings about the relationship between a project, the components of a model, the outputs and the way these can be used to support project implementation are widespread. This note outlines some of the more common difficulties and explains how they can be understood.

There are many ways to view risk modelling in relation to projects but a particularly useful framework is illustrated in Figure 1 to set the context for the remainder of this note.

Figure 1: Project, model and judgment



This is a simplified view but it draws attention to the following important points.

1. The models we build are only one way of understanding projects. The experienced judgement of the project team and others is another and this must be given at least as much weight in any modelling exercise.
2. The process of building a model and the results it generates can inform the project team and help them refine and consolidate their understanding of the work.
3. Experienced judgement is one of the key inputs to modelling and the main test of the validity of a model's outputs.

4. There is an interchange between a modelling exercise and the project team's views in which both should be adjusted until they come into balance with one another.

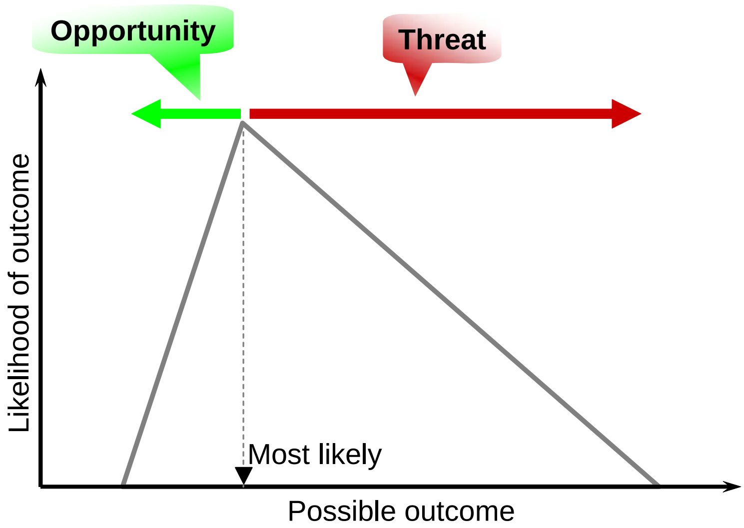
The specific issues addressed here are:

- The relationship between skew in the distributions of individual components of a model and the aggregate output;
- The significance of using optimistic and pessimistic values as minima and maxima or other percentile points in defining component distributions;
- Why base estimates and forecast completion dates might fall well below the peak of the distribution forecast by a risk model.

2 Skew In Component Distributions

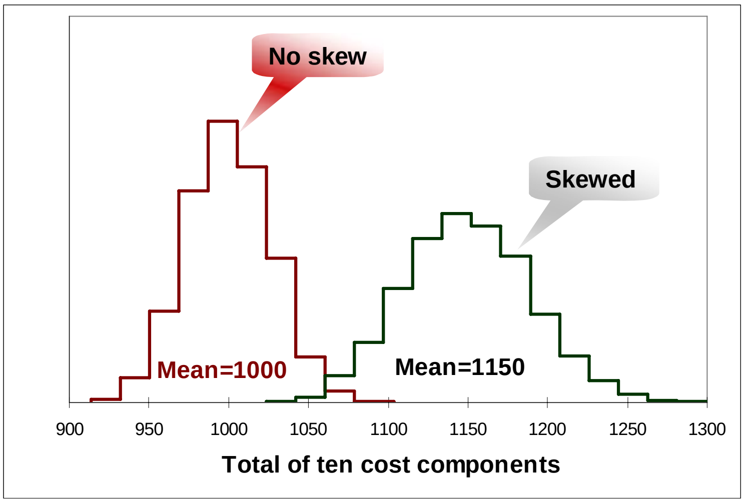
At the time a project goes forward for sanction, most estimates and duration forecasts embody little opportunity for improvement but are subject an appreciable threat of being exceeded. This stems from optimism in project teams and what is often significant pressure to demonstrate that a project can be delivered below a predetermined capital value that makes the business activity economically viable. The effect on a single cost or schedule component of an analysis is illustrated in Figure 2. This is a schematic representation of a distribution that might represent a work package cost or major activity duration forecast.

Figure 2: Typical component distribution



There may be an expectation that this skew will carry through to the aggregate outcome of a model. This is incorrect. To illustrate what actually happens, a very simple cost model has been used to produce the histograms in Figure 3.

Figure 3: Effect of skew in cost model component distributions



The results labeled 'No skew' represent the sum of ten independent symmetrical cost components each with the following characteristics:

- Most likely outcome = 100;
- Optimistic outcome = 80;
- Pessimistic outcome = 120.

Those labeled 'Skewed' are the sum of ten independent skewed cost components each with the following characteristics:

- Most likely outcome = 100, as in the no skew model;
- Optimistic outcome = 95;
- Pessimistic outcome = 150.

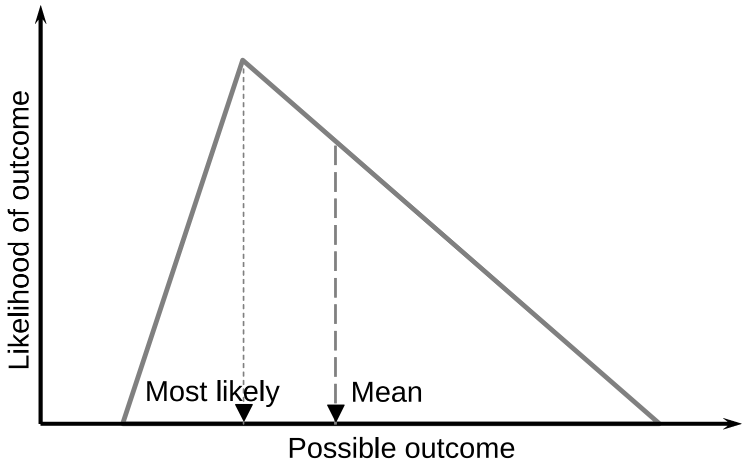
The skew in the components has affected the outcome but it has not caused any skew in the total cost distribution, it simply shifts the mean value of the distribution. Both outcomes are symmetrical.

The shift in the mean can be understood in terms of two factors:

- The mean of a skewed component distribution is higher than the most likely value, as illustrated in Figure 4, which shows the mean falling at the 'centre of gravity' of the distribution's shape;
- The mean of the sum of a set of costs is the sum of the means of the components, so the mean of the total cost is raised above the base estimate to the extent that the means of the components exceed their most likely values.

The symmetry of the outcomes is due to the fact that the sum of a set of uncorrelated distributions always tends towards a Normal distribution, a symmetrical bell shaped curve. This happens with as few as six component distributions, irrespective of their individual shapes, due to the Central Limit Theorem. It is not a flaw in the modeling process nor an indication that the model is failing to represent the real situation in a project – it is the real situation in a project unless there are other factors at work.

Figure 4: Relationship between mean and likely value



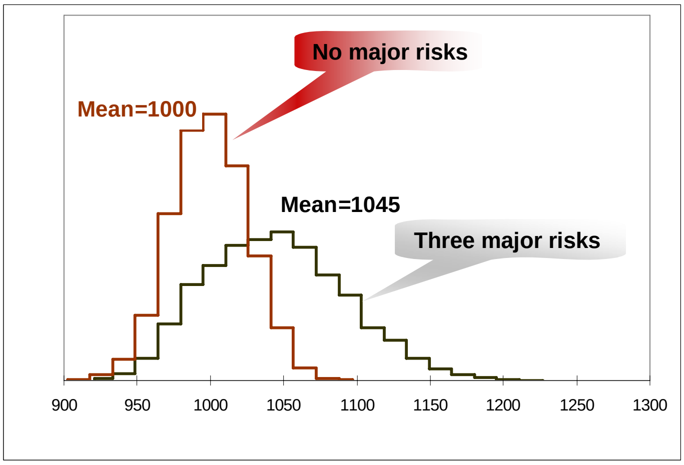
Referring back to Figure 1, it may be that the initial outcome of a cost risk assessment produces a symmetrical distribution but the team's judgment suggests that there should be some skew in the forecast for the project as a whole. If this is so, the skew in the component distributions cannot be the source of that aggregate skew, as just discussed. Accordingly, there must be other reasons for it, and these should be identified and included in the model.

The most likely source of skew in a major capital forecast is the presence of one or more major risks that:

- Offer no opportunity for savings;
- Might not happen at all; but,
- If they do arise will introduce significant additional costs.

The effect of such major risks is illustrated in Figure 5.

Figure 5: Effect of major risks



The symmetrical curve is the same as in Figure 3. The skewed curve is derived from the same model with the addition of three major risks having the following characteristics:

- They each have a 30% chance of occurring;
- If they do not occur they make no contribution to the cost;
- If any of these risks occurs, it adds an amount between 10 and 150 to the total with a most likely value of 50.

The output with the major risks has a slightly higher mean value than the original but the main difference is that is has a much longer tail on the right hand end of the distribution. This is the behaviour that might be seen in a project where:

- A long lead item could be lost or damaged in transit;
- A key process component might fail to operate as expected; or,
- Systems integration could expose intractable software systems faults during commissioning.

If there is a strong expectation that there will be skew in a project's cost distribution, it will not be due to skew in the component distributions. The judgment that this is a real feature of the project must mean that there is something else at work. The feeling that this is so might not be clearly expressed at first and the cause may be wrapped up in a multitude of interacting issues. The mismatch between the model and experienced judgment should be the trigger for exploring and understanding the specific risks that might arise.

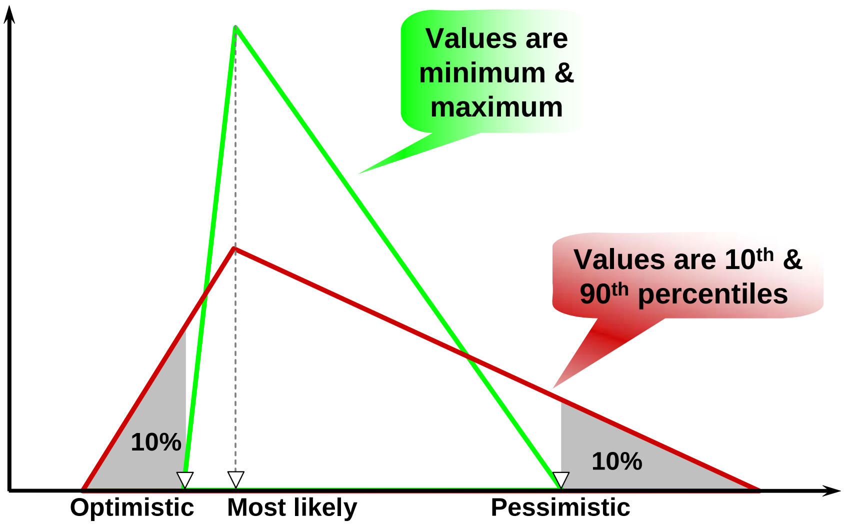
In principle, correlations between skewed component distributions could introduce skew into the output but it would only be significant if all components were correlated with one another. This is a much less potent source of skew than the presence of major risks and is much less likely to be the source of a long right hand tail in the distribution.

3 Using Optimistic and Pessimistic Values as Percentile Points

When a project team is asked to describe optimistic and pessimistic variations from the most likely value of a cost or duration, there is always a danger that they will understate the range of possible outcomes. This may be because they fail to appreciate how much uncertainty there is in the project, have undue confidence in their ability to control the work or both. In addition, a powerful 'anchoring and adjustment' bias arises when judgments are made in sequence, starting from the most likely estimate – people tend to 'adjust' from the starting 'anchor', and even experienced estimators adjust by too small an amount and the spread of the estimate is too low.

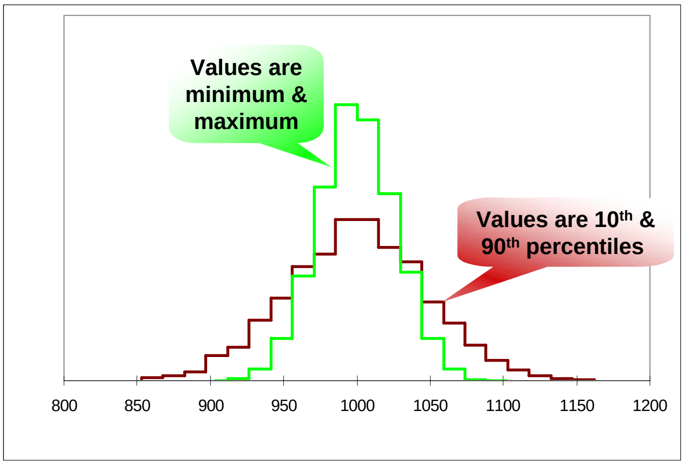
One response to this phenomenon is to assume that there is a significant chance of the outcome falling outside the range the team specifies. A simple and widely accepted means of modeling this is to extend the range of the distribution so that there is a 10% chance of outcomes falling below the stated optimistic value or above the pessimistic outcome. This is illustrated in Figure 6.

Figure 6: Extending the range of the input distribution



The effect of this is to increase the range of the component distributions and so increase the range of the outcome. This is illustrated in Figure 7.

Figure 7: Effect of extending the range of the input distributions



The representation of extended distributions in the form shown in Figure 6 is sometimes misinterpreted as meaning that the distribution is truncated and the shaded regions are excluded from the analysis. This incorrect and may lead to the output of the model itself being misinterpreted.

Values in the shaded regions in Figure 6 are included in the simulation. The modeling tools simply calculate new minimum and maximum values for the distribution that result in 10% of the area of the distribution falling above and below the range defined by the optimistic and pessimistic values.

This mechanism can be used to allow estimators consciously to provide information as 10th and 90th percentile points, values with a one in ten chance of being breached in either direction. This may be easier than trying to think in terms of absolute minimum and maximum values.

If estimators provide information in this form and the inputs are used in the same way in the model, the model and the judgment of the estimators should be well aligned. Alignment between the way the team view their project and its representation in the model is the key to the modeling exercise adding value to the project. This can be viewed in the context of the relationships illustrated in Figure 1.

4 Base Values Falling Far From The Peak

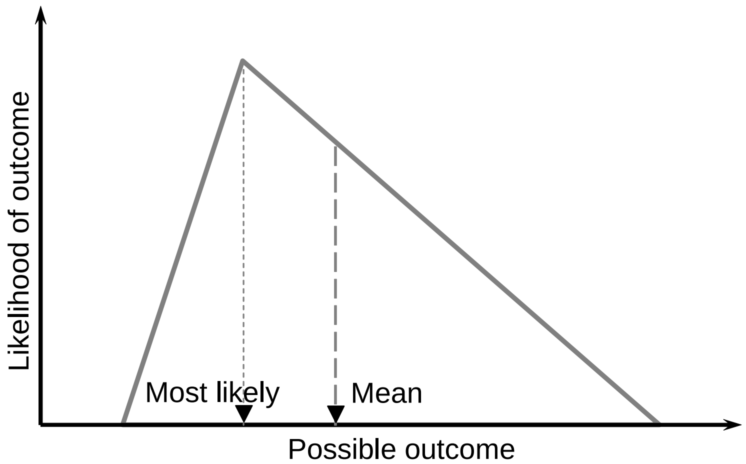
It is not uncommon for the base estimate of a project's cost or completion date to fall towards the lower end of the range forecast by a risk model or even below the lower end of the forecast range. This is often interpreted as an error in the model or a sign that the modeling exercise is flawed. However, there are sound reasons why this might happen.

One reason is that the most likely value of individual cost or duration estimates is not the same as their base estimates. This may arise when:

- The estimate or schedule are volatile and the latest release is not yet aligned with the best available information but the risk model does reflect the current view of the project;
- The base estimate or schedule were developed at an early concept or pre-feasibility stage and did not consider risks appropriately;
- There are risks that do not fit within one of the cost lines in an estimate or one of the tasks in a plan so that there is no provision for them in the base estimate or schedule.

A more subtle source of offset between a risk model and the base estimate or base schedule is the fact that the mean of the model output will be driven by the mean values of the component distributions. As noted earlier, the mean of a skewed distribution is greater than the most likely value. This is illustrated again in Figure 8.

Figure 8: Relationship between mean and likely value

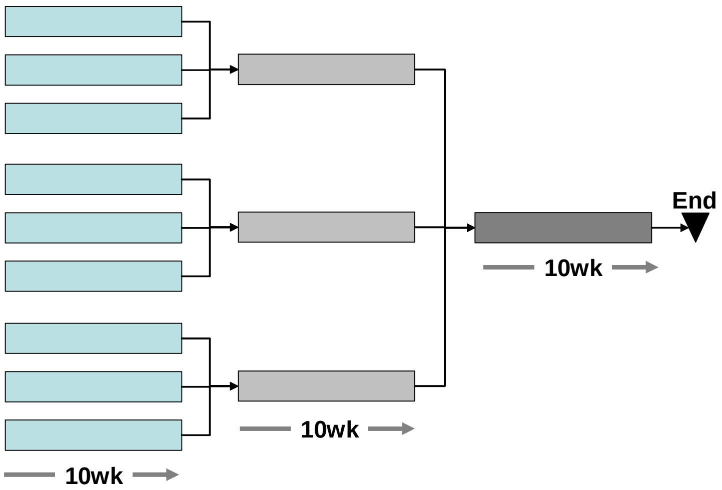


If some risks do not feature in the base estimate and, for several components of a model, the most likely value varies from the base value or skew causes the mean to exceed the most likely value by a significant amount, the model output will be offset from the base forecast.

This simply reflects the fact that the base estimates are not the outcomes the team would expect to see on average if they were executing several similar projects. There is nothing inherently wrong with such a state of affairs but it must be understood if sound decisions are to be made.

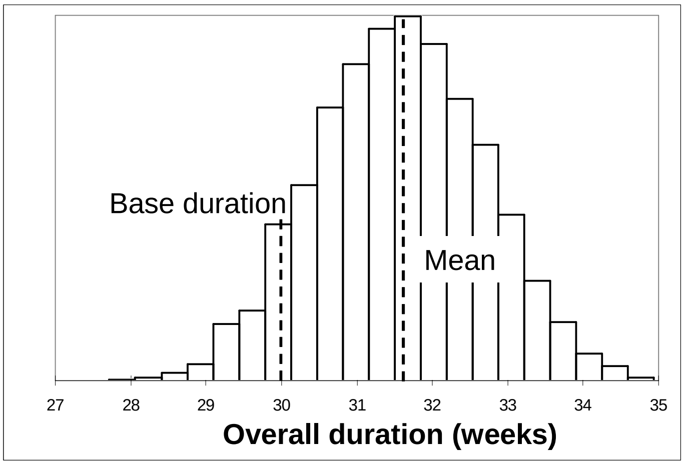
An additional source of offset arises in schedule models from the effect of nodes in the project activity network. Nodes are points at which two or more activities have to be completed before a successor can proceed. This effect can be illustrated using a simple network model shown in Figure 9. With each activity having an expected duration of 10 weeks, this network would have an overall expected duration of 30 weeks.

Figure 9: Example of nodal bias



If uncertainty is introduced to the network the result is more complicated than it is when uncertainty is included in a cost estimate. For instance, when plus or minus two weeks uncertainty is introduced to each activity, the distribution of overall project duration is as shown in Figure 10. The component distributions are symmetrical in this example and there is no correlation between the components.

Figure 10: Effect of nodal bias



The simple interaction between a small amount of uncertainty in each activity and the structure of the model introduces an offset into the outcome because each node forces the project to wait for the slowest predecessor. Even with only four places in the network where one activity has to wait for three others to complete, the base duration is extended by about 5%.

This effect is a real characteristic of schedules and is one of the reasons why managing project implementation schedules is so challenging. It is not a mismatch between the model and reality but, in this case, the model may offer an explanation for a feeling that a tight plan should really be covered with a schedule contingency allowance.

The effect of skew causing mean values to exceed most likely values, most likely values being greater than base estimates and major risks introducing step changes in the model output have similar effects in schedule models to their effects in cost models. However, nodal bias is a phenomenon that does not arise in cost estimates and can have a significant influence on schedules.

A common example of this is the observation that meetings rarely start with everyone arriving on time, even if the chance of any one person being late is not very large. For instance, if ten people need to assemble for a meeting and each one has a 5% chance of being delayed, the chance of the meeting starting on time is only 60%.

A 5% chance of one person being late has turned into a 40% chance of the meeting being late simply due to the fact that they all need to gather at once. The comfort we might have taken from feeling that 5% is small risk has been undermined by the structural relationship between the components.

5 Conclusion

Risk analysis plays a very valuable role guiding decisions about major capital investments. However, if a wrong decision is made based on a faulty analysis the impact can be quite profound. Not only might capital spend considerably exceed the allocated budget, but projects may be completed much later than forecast and may not generate the level of return expected. Such outcomes can seriously affect the credibility of the project owner and its management team.

Of equal concern are those occasions where a faulty analysis leads to opportunities not being identified or taken up, or the wrong investment option being adopted. Considerable value can be missed or destroyed by poorly founded decisions.

Confusion about the way a model works and the results it produces can lead to mistakes in both the way analyses are conducted and the conclusions that are drawn from them. The common reaction to confusion is to seek simplification of the process, but over-simplification can be as damaging as entangling an analysis in unnecessary complexity.

The key to successful exploitation of modeling techniques is to use as much detail as is required to achieve a sound understanding of the issues being investigated and no more. Too little detail will mean that the real world is not represented realistically. Too much will drag the analysis down with unnecessary effort and undermine commitment to the process.

The misunderstandings discussed here are not the only ones that can affect the value delivered by a quantitative risk analysis or the cost-effectiveness of the process. They are regrettably common, though, and they have the potential to undermine the credibility of a valuable tool.

As with any other kind of professional activity, getting it right requires experience and well-directed effort. It is easy to make simple mistakes and get results that are not credible. It is equally easy to misinterpret the outcome of a sound analysis, overlook valuable insights or discount valuable information. On the other hand, with relevant expertise, sound modeling methods can enhance the understanding of uncertainty surrounding major investments and be used to refine plans and reach sound defensible decisions.

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