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Uncertain outcomes: Techniques to support decision making

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UNCERTAIN OUTCOMES – TECHNIQUES TO SUPPORT DECISION MAKING

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The way uncertainty is accounted for in a decision making process determines the usefulness of the outcome. Professor Danny Samson of Melbourne University Private looks at two powerful analytical tools that quantify uncertainty and its associated risks.

All important decisions involve uncertainty. We make decisions and allocate resources today that have consequences in the future and we cannot know the future in advance. This is clearly the case with public infrastructure, in which resources are committed well in advance of the resolution of technical and commercial uncertainties.

The initial stage of a major new piece of infrastructure is the decision to establish it and the associated decisions of its overall design, capacity, level of technological sophistication, location and the nature of structural entities and ownership, as well as operations mechanisms that surround the physical asset. At the early stages of feasibility study and then of 'go/no go' decision making about whether to proceed and how to structure the project, there are already numerous uncertain quantities that are relevant to the decision. These can be considered as ranging from purely technical through to commercial. Ultimately all technical aspects have commercial consequences.

As a result of the uncertainties associated with the project, there is substantial risk to those who are engaged in the project, including both the government and the private sector stake holders. One of the most important aspects of public infrastructure policies, such as Victoria's Public Private Partnerships policy, is associated with the transfer and sharing of risk. In order to properly transfer risk and price risk, it is first important to be able to measure risk.

Once a decision has been made to proceed with the construction of an asset such as a road system, and the contracts are struck for financing, design, construction, ownership, operation and maintenance, then uncertainties begin to resolve themselves in real time. However, new uncertainties appear and sometimes, despite best efforts, there are uncertainties that appear in real time that have not been anticipated. An example would be a major leak in a tunnel, or a safety event during construction.

A characteristic of good decision making and good decision-makers is that they are more likely to anticipate more of the risks in advance than would otherwise be the case. However, even though some uncertain factors may not have been anticipated, it is important to do a very thorough job on analysing, which begins with measuring, the risks that were foreseen.

TOOLS THAT SUPPORT DECISION MAKING

The best way to measure and communicate information about risks associated with decisions is through the use of decision trees and risk analysis methods. Decision making under uncertainty is a field of management science that was developed some forty years ago and first came to prominence as applied to business decisions when articles were published in the Harvard Business Review in the 1960s and 70s. The underlying probability theory was developed may decades before that and breakthroughs in measuring appetite for risk occurred through publications about utility theory well over fifty years ago. There are now very powerful and practical tools and techniques that are available that should be in common use for important strategic decisions. They are particularly appropriate for decisions involving public infrastructure in which risk and uncertainty are centrally important.

DECISION TREES

Decision trees are diagrams that show the temporal sequencing of choices made by decision-makers and the resolution of chance events. They are useful as models of important decisions in which uncertainty features. A whole literature exists in respect of decision trees. They have been found to be very useful by executives and managers in a wide variety of contexts. They are also used in many other fields, for example medical decision making when one wishes to understand the relative risks associated with the consequences of various types of treatment for serious diseases.

Decision trees are useful as models of decision problems which are relatively complex, although they can also be used even when decisions are reasonably straight forward. The decision-maker follows a process of listing the alternatives open to the decision-maker and the sources of uncertainty that are relevant, which are then assembled into a decision tree diagram. That diagram shows decision nodes and chance event nodes as a model of the anticipated real world situation. Consider for example, a decision facing a Government that was considering whether to construct and operate an asset itself or to enter into a partnership with a private organization. It also had to choose between three major technologies and could build the asset to be either large or small. Uncertain quantities related to the technical performance of the asset and the demand for services associated with the asset. A decision tree illustrates all these factors effectively and quantitatively in a single, simple diagram.

QUANTIFYING THE OUTCOMES

Once the decision tree is constructed, quantitative assessments should be made of the likelihoods of various outcomes and the magnitudes of those outcomes. This is a core part of the value add of decision tree analysis. Deterministic analyses suffer from the 'blindness' associated with ignoring uncertainty factors that really exist in the decision problem. If there really is technical risk then it should be modelled rather than assumed away, and the same obviously applies for commercial risk whether it be on the cost of construction side, the operating costs or the revenue stream. Probability is the language of uncertainty. For all important uncertain quantities, probability distributions should be assessed. It is possible after some training to become very skilled at avoiding biases in probability assessment for uncertain quantities no matter whether there is little experience or data available about this uncertain quantity or not.

The probability data and the quantitative data about costs, benefits and technical performance are plotted onto the decision tree and decision rules are applied to the decision tree which determine the optimum strategy, depending on whether the decision-maker is risk-neutral or risk-averse.

Sensitivity analysis is usually undertaken in which the robustness of the decisions that are recommended, based on the analysis, are tested through varying the assumptions inherent in the base case. There are many benefits of decision tree analysis. They require rational thought, reflection and the correct setting out of decisions. This is done according to the core elements associated with decision making, namely alternative actions open to the decision-maker, uncertain quantities relevant to the decision and the payoffs, costs and other consequences associated with the course of action and the set of outcomes. Another great benefit of the use of decision trees is that they provide a 'thinking algorithm' for decision-makers and a relatively cheap tool through which insights can be generated and hence, better decisions can be taken.

GAMBLING IN MONTE CARLO – RISK ANALYSIS AND PROBABILITY

Risk analysis usually involves the numerical integration of probability distributions when there are multiple sources of uncertainty acting simultaneously that impinge on a decision. For example, if there are a number of different forms of technical risk, revenue risk and other forms of uncertainly such as of construction costs, then the decision-maker is faced with the question of trying to get a handle on the total degree of risk associated with the project. This is an important picture that needs to be assembled so that the value of the project can be compared sensibly and rationally with the value associated with alternate projects or other uses of the investment assets. This value needs to be 'risk adjusted'.

The most common technique used for establishing this integration of probability distributions is that of Monte Carlo simulation, in which random numbers are used to simulate a large number (e.g. thousands) of possible scenarios of the combinations of the various uncertain quantities. Numerical methods which are simple yet powerful then provide an aggregate picture of the simulated total probability distribution for the decision variable. The decision variable may be Net Present Value, Internal Rate of Return or any other key parameter upon which the decision hinges. Monte Carlo simulation technique algorithms are commercially available at low cost and easily integrated into spreadsheets and other forms of calculating algorithms.

THE ALL-POWERFUL SPREADSHEET

Since so many public and private sector decision-makers use spreadsheets these days, it is worth illustrating just how this works. Consider a spreadsheet being used to evaluate the feasibility of the construction and operation of a public asset in a particular way. This spreadsheet might be used to calculated the Net Present Value associated with a particular way of structuring that asset. This will be

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compared to another spreadsheet outcome that calculates the Net Present Value of an alternative way of structuring the asset that may involve a different way of splitting the ownership or risk with a private sector partner. There may be quite a large number of alternatives available which are being evaluated. Within any spreadsheet, the deterministic way of doing the analysis is to enter a 'best estimate' of the parameter: for example this may be a set of revenue numbers for a toll road where these revenue numbers must be estimated looking five, ten or even thirty years forwards in time.

There is great uncertainly associated with what these numbers really will be and rather than ignore that uncertainty and assume the best estimates represent reality in some precise way, risk analysis techniques allow the decision-maker to estimate and correctly process complete probability distributions. Wherever an uncertain quantity actually exists as such, then through the simulation technique discussed above an aggregate probability distribution for Net Present Value for that alternative is produced. The decision then is made based on comparing probability distributions of Net Present Value, rather than point estimates that essentially ignore the uncertain quantities and factors involved in the decision.

RISK ANALYSIS IN PROJECT MANAGEMENT

Once a project is framed and the decision to go ahead is taken, professional project managers use critical path (arrow-network) diagrams and other tools to plan and execute important phases of a project such as construction. Again, the naive way to do this is to assume perfect certainty associated with the costs and the amount of time required to complete key tasks within the project framework. In reality, when decisions are made up front to allocate resources, especially the scheduling of critical resources, estimating cash flow spend rates and so on, there is substantial uncertainty about costs, task times and other elements of the decision. Rather than do deterministic project analysis, risk management can be effected very well using probabilistic project management techniques. These simply apply the same procedures of Monte Carlo risk analysis and simulation techniques to a project network or arrow diagram system and calculate probabilistically the critical path, the beginning and end times of important tasks and other decision variables. They reflect the judgements about degree of uncertainty associated with these values and very rigorously combine the sources of uncertainty to provide valuable decision support data.

CONFRONTING REALITY

Decision trees and risk analysis techniques provide excellent sources of information such that decision-makers can quite accurately process their judgements, quantify their beliefs about the degree of uncertainty and then, to their best of their ability, use that information to make decisions.

The great benefit of these techniques is that they confront the decision-maker with the realities of uncertainty and require them to explicitly quantify their beliefs. This leads to better decisions, although there is no doubt that by its very definition, uncertainty means that no decision-maker will always get it right. However, when it comes to risk and uncertainty, hiding ones head in the sand and ignoring uncertainty is a recipe for disaster. Even qualitatively attempting to account for risk factors is not nearly as good as using probabilistic techniques, which are now widely available and well supported by good, user-friendly software systems. Risk analysis in particular and its antecedent, decision tree analysis, are powerful techniques that should be standard tools for executives who make decisions about assets, particularly those with long life cycles.

Every public and private sector decision-maker who is involved in managing public infrastructure should be competent in risk analysis and decision trees techniques and thinking algorithms.

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