

Quantitative Methods of Risk Analysis

By

Gregory. G. Betros
BE, MIEAust, CPEng, FAIPM

About the Author

As Managing Director and Technical Manager, Greg controls the operational aspects of G. G. Betros & Associates Pty. Ltd. Greg is a qualified Civil Engineer with over thirty years experience in project management, planning and control of projects across all industries.

Greg is a Fellow of the Institute of Project Management and has successfully completed over 600 projects both internationally and nationally.

Based on his experience and knowledge Greg has developed a series of procedures and processes to successfully manage projects and has introduced these procedures into many organisations who conduct their business in the national and international arena. Combined with these procedures and processes Greg provides training in all aspects of Project Management.

His knowledge is also used in litigation and arbitration cases where he acts as an expert witness in matters relating to project planning and control.

Introduction

Risk analysis is part of every decision we make. We are constantly faced with uncertainty and even though we have unprecedented access to information we are still not able to predict the future. Over the years a number of quantitative methods of analyzing risks have been developed using our evolving knowledge of statistical analysis

In the book "Risk Management in Construction Project" by N.J. Smith a number of these techniques are described. In Professor Nigel Smith's opinion the Monte Carlo Simulation is the most effective because it is not dependant on the subjective decisions of the project participants.

This paper in particular examines the Monte Carlo simulation and the reasons for its effectiveness in measuring risk and analysing the potential impacts of risks to a project. It also examines other techniques and comments on their effectiveness.

The determination of the probability of a risk occurring and its impact on a project is a mathematical calculation. It is important to realise that in any mathematical calculation where one variable is a function of a combination of other variables one cannot dictate all variables, one will be whatever the function says it will be.

Monte Carlo Technique

Monte Carlo simulation is a computerised mathematical technique that allows people to account for risk in a quantitative analysis and decision making process. Monte Carlo simulation furnishes the decision maker with a range of possible outcomes and probabilities that will occur for any choice of action.

Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values, "*a probability distribution*", for any factor that has a degree of uncertainty. It calculates the results repetitively each time using a different set of random values from the probability functions. The number of iterations is dependent upon the number of uncertainties and the ranges specified for them. The greater the number of uncertainties and ranges the greater number of iterations required. It is expected that at least one thousand iterations would be required to provide a satisfactory result.

The results produced by the Monte Carlo simulation are a distribution of possible outcome values. By using probability distributions variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis because they remove the need for a subjective determination of the probability of the risk occurring.

The common probability distributions include:

- "Normal" or 'Bell Shape Curve', which is characterised by a symmetrical bell shaped curve.
- "Lognormal", which is characterised by a positively skewed curve, not symmetric like a normal distribution.
- "Uniform" where all values have an equal chance of occurring with the minimum and maximum defined.
- "Triangular", which requires the definition of the minimum, most likely and maximum values to characterise a description of a sample with limited data.
- "PERT". This requires the minimum, most likely and maximum values. Values around the most likely are more likely to occur. However the extremes are not as emphasized as the Triangular method. (Generally used on tasks in a project management model.)

During a Monte Carlo simulation, values are sampled at random from the input probability distribution. The distribution chosen must reflect the characteristics of the total sample in order to be an effective simulation of what could occur in reality. For example, if the data set was skewed towards the lowest cost impact, one would select the Lognormal distribution for the entire risk set.

The typical high, most likely and low cost impacts are used to frame the distribution such that an appropriate standard deviation is derived. From within this standard deviation a random number is generated. This process is continued for thousands of iterations, each time recording the generated value. The result is a set of probability distribution outcomes which can be plotted on a frequency chart.

Monte Carlo simulations provide a comprehensive view of the potential cost impacts that could affect the project budget and the likelihood of that cost impact occurring.

Monte Carlo simulation provides a number of advantages over deterministic or "single point estimate analyses. These are:

- Probabilistic Results, which not only shows what could happen, but how likely each outcome is.
- Graphical Results that are easy to generate because of the data a Monte Carlo simulation generates. (This is important in communicating findings to stakeholders.)
- Sensitivity Analysis using a Monte Carlo simulation makes it easy to see which inputs have the biggest impact on the results. (This is difficult in a deterministic analysis.)

Professor Nigel J. Smith in his book, "Risk Management in Construction Project", defines the Alternative Methods of Risk Analysis and their inherent faults.

Delphi Method

"It is an established technique for obtaining consensus estimates from several experts. The general procedure for this technique is that an estimate of variable(s), or risks, is obtained from each of the experts. The experts are then informed of all of the estimates and asked to give a revised estimate. This process continues until a consensus estimate is produced."

"The Delphi method is a very subjective technique and the results gained from this should be viewed with caution."

Influence Diagrams

"The influence diagramming technique involves mapping out the project, identifying the sources of risk and possible responses to these risks. This information is then represented diagrammatically."

"This technique assists in identifying risk responses that apply to several risks. However, it is a subjective technique and if used on projects that can be divided into a number of smaller sections the diagram becomes unclear."

Decision Trees

"Decision trees, also known as decision networks, are diagrams that depict a sequence of decisions and chance events as they are understood by the decision maker."

"The main advantage of using a decision tree is that it requires the entire project to be set out in a logical sequence. This technique does not identify the best alternative or course of action to be taken, it merely sets out all the possible alternatives."

"However if the project has a large number of decision nodes then the decision tree can become complicated. The calculations become time-consuming and tedious and to some extent subjective."

Summary

The common attribute of all of the above described alternative techniques is that they are subjective and therefore prone to outcomes that are swayed by the feelings of project personnel rather than by mathematical objective calculations.

The Monte Carlo simulation technique is a process for developing data through the use of a random number generator. It eliminates the subjectivity of the other techniques. However, it stressed that the three point estimate used in the Monte Carlo simulation must be based on sound estimating principles and not subjective values.

When performing a Quantitative Risk Analysis one method should be selected. Techniques should never be combined as spurious results will occur. It is highly recommended that the technique used should not be subjective.

If an organisation wishes to perform more than one technique of Quantitative Risk Analysis the results can be compared but more credence must be given to the technique that is not subjective, that is, the Monte Carlo simulation. That is why it is such a popular process.

Adding further weight to the preference for using the Monte Carlo simulation is the fact that the distributions used imitate the randomness of the "many physical, social and biological phenomena" that occur. For example, in a coin flip or cast of a die, where the values are equally likely to occur, the uniform distribution best characterises the simulation. When any set of distributions are summed, the result (quickly) tends towards the Normal distribution." (Solver.com, 2009)

References

Smith, N. J., 1999, Managing Risk in Construction Projects, Blackwell Science Ltd.

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