Risk and uncertainty exist in any proposal where the desired outcomes cannot be predicted with complete confidence.

This paper outlines different approaches to addressing risk and uncertainty in economic assessments, such as cost-benefit analysis. It is intended to support analysts specifically undertaking economic assessment, such as for business cases, policy analysis and regulatory impact analysis. The paper outlines the various tools and approaches available and discusses their use.

The basics

What are risk and uncertainty?

Risk and uncertainty exist in any proposal where the desired outcomes of the policy or initiative cannot be predicted with complete confidence. This could be because some of the influencing factors vary widely or there are many interactions that could impact on how things play out. Together, risk and uncertainty capture the degree to which the future is unknown.

While in most cases the terms ‘risk’ and ‘uncertainty’ can be used interchangeably, they refer to slightly different concepts. DTF’s Economic Evaluation technical guide (2013) explains the difference:

***Risk*** *exists when a potential event or outcome can be identified and estimated with a certain degree of confidence, i.e. can be given a probability. Risk is expressed as the ‘expected outcome given the probability and impact of the event based on data and expert judgment’. Examples of common risks are economic, environmental, political, construction and technology risks.*

***Uncertainty*** *exists when the event cannot be reasonably identified or the probability of an event occurring is unknown. Forecasts (e.g. of population, economic growth, and transport demand), assumptions, judgements and conditional outcomes in investment projects often involve uncertainty.*

Risks usually apply to the delivery of a project, for example:

* the risk that the loss of key staff leads to delays in project implementation, which means that key project milestones are missed
* the risk that commodity prices are higher or lower than forecast, which means that actual constructions costs are different to estimated costs
* the risk of the discovery of environmental hazards, such as soil contamination, asbestos etc. which may affect project budget and delivery timelines.

In comparison, uncertainties are usually found in regard to the outcomes of a project, for example medium to long term population growth, and the location of that growth, can affect whether infrastructure investments meet their forecast usage.

Why is it important to address risk and uncertainty in economic assessments?

An analysis of risk and uncertainty explores the likelihood that desired outcomes will eventuate and can highlight where estimates of costs and benefits are unreasonable based on the likelihood of those outcomes occurring. Ignoring risk and uncertainty can have significant implications for the economic assessment of an initiative, for example:

* benefits and/or costs may be under/overestimated
* the options provided for economic assessment may not include any risk management activities, which may affect the likelihood of achieving desired outcomes.

The overall impacts of not addressing risk and uncertainty are that:

* decisions may not be informed by a realistic assessment of costs and benefits over time,
* initiatives which have higher costs but are less risky may be overlooked as alternative options,
* risk mitigation opportunities may be missed.

Being able to identify, assess and control for risks and uncertainties that may emerge during the course of a policy or initiative in a structured manner supports better decision-making.

An understanding and analysis of the risk and uncertainty present in a proposal can also play a role in countering optimism bias. Optimism bias is when the benefits of a proposal are overestimated and/or the costs are underestimated.

Uncertainty may impact on value for money. In some circumstances a preferred/proposed solution may no longer offer the best value for money response. However, uncertainty relates to both negative and positive factors. That is, managing uncertainty not only means cutting losses, it also means capitalising on opportunities and enhancing benefits.

Of course, while most proposals will involve some risk and/or uncertainty, the principle of proportionality should guide the effort undertaken to address it. This guidance presents a range of ways for addressing risk and uncertainty to match the different scales of initiatives being assessed.

In what circumstances is risk and uncertainty influential in the choice and delivery of an option?

Economic assessment is the process of identifying, calculating and comparing the costs and benefits of a proposal in order to evaluate its merit, either absolutely or in comparison with other options. Risk and uncertainty can be particularly influential in economic assessments because they can impact on which option is preferred and how an option is implemented.

There are five key areas of an economic assessment where risk and uncertainty can be influential in the choice and delivery of an option. Each call for a particular type of response:

1. *Risk around the baseline state of the world*

Some projects are highly dependent on particular states of the world, for example, continued rates of demand for a certain product or certainty about a particular government policy. Understanding the circumstances where a government action has net benefits and where it does not can assist in developing triggers for policy review, sunset clauses and to understand the value of delay until risks and/or uncertainties are reduced.

1. *The value of delay and additional information*

For decisions that are irreversible and have uncertain consequences, it may be worth delaying the decision and collecting additional information in order to decrease or better manage the risk and uncertainty.

1. *Weighting the probability of costs and benefits*

The costs and benefits in a cost-benefit analysis (CBA) should take account of the likelihood that different options will have different pay-offs over time. This is critical when it comes to evaluating the value of benefits from the investment.

1. *Considering the timing of options and the interaction of multiple options to address the problem*

The consideration of risk and uncertainty can lead to better outcomes because it means that proponents understand that there are different possible scenarios for outcomes that are more or less favourable for alternative project options.

Understanding project interactions and considering these in combination can lead to a better portfolio of options than the typical ‘do minimum’ versus ‘with project’ scenarios.

1. *Sensitivity analysis can offer a way to test and understand risk and consider the circumstances when one option is preferred to other options.*

Sensitivity analysis should seek to understand risks specific to the project, scenarios where the choice of preferred option would change and how greater confidence can be gained as to the preferred option.

What kinds of initiatives (policies, projects, programs) are likely to involve risk and/or uncertainty?

Every proposal will involve some **risk** in project delivery and you should address this by, at the very least, identifying and documenting these risks. Leading practice project and program management would guide you to undertake the following for each identified risk:

* Document existing controls – what measures are in place to manage/mitigate for the risk?
* Analyse the likelihood and consequence of the risk based on the current controls and their effectiveness
* Evaluate the risk and develop a treatment plan – is the level of risk acceptable given current controls? If not, develop a treatment plan. Options for treatment may include developing processes, policies, practices or devices in order to:
  + Avoid the risk
  + Remove the source of risk
  + Change the likelihood of the risk occurring
  + Change the consequence of the risk
  + Share the risk with another party

The Department of Treasury and Finance (DTF) provide guidelines on [addressing risk in project design, costing and implementation phases](https://www.dtf.vic.gov.au/infrastructure-investment/investment-lifecycle-and-high-value-high-risk-guidelines) through the ‘investment lifecycle’. The [Victorian Government Risk Management Framework](http://www.dtf.vic.gov.au/Publications/Victoria-Economy-publications/Victorian-risk-management-framework-and-insurance-management-policy) also provides a minimum risk management standard for the Victorian public sector. The Victorian Managed Insurance Authority helps public sector agencies be prepared for risk and provides a useful [practice guide](https://www.vmia.vic.gov.au/risk/risk-tools/risk-management-guide) and templates.

Any proposal for which there is a significant time between inception and the achievement of outcomes, or for which there are multiple influencing factors will involve **uncertainty**.

Generally, the longer the time period in a project, the more risk and uncertainty there is likely to be; although this depends on the individual project. For example, there is lower risk and uncertainty in a project procuring new computers within the next year than in a major technological investment in three years’ time because there is more uncertainty about how technology will change over this period. Similarly, a small-scale road upgrade would have fewer risks and uncertainties compared to a big infrastructure project.

What kinds of initiatives (policies, projects, programs) are likely to need to address risk and/or uncertainty in their economic assessment?

Alongside the leading practice risk management described above, a proposal may need to address risk and uncertainty in its economic assessment where:

* the risks to project delivery are significant enough to suggest that there may be superior option for delivering the project
* the uncertainties about proposal outcomes are significant enough that further analysis is required to do due diligence on the realistic merits of the proposal
* the uncertainties about proposal outcomes are enough that proceeding further could lead to investment regret.

As a rule of thumb, proposals of a ‘significant’ scale and/or risk/uncertainty (where ‘significant’ is defined relative to the types of proposals prepared for your portfolio) should address this risk and/or uncertainty in their economic assessment.

How to incorporate consideration of risk

Besides addressing risk through the project/program management process as described above, when it comes to the economic assessment of an initiative, there are several ways that risk can be incorporated in an economic analysis. Techniques include calculating expected impacts, sensitivity analysis, Monte Carlo analysis, and probabilistic approaches to calculating costs. These are illustrated here using a cost-benefit analysis framework.

As a general rule, different projects within a similar asset class should address risk in a CBA in a like manner to allow projects to be properly compared or prioritised.

Addressing risk through the calculation of ‘expected’ impacts

Cost benefit analysis (CBA) is applied across a wide range of sectors in making decisions about whether a proposal has net benefit to society or which of a set of alternative proposals provides the greatest net benefit. It is the primary and preferred economic assessment tool used in government to inform many major public expenditure and regulatory decisions.

A CBA often relies on the estimation of costs and benefits that are generally not known with certainty; known as ‘expected’ impacts. Risk can be incorporated in a CBA by calculating the expected benefits and expected costs of a proposal, using probability weighted estimates. The existence of probabilities indicates that we are dealing with risk rather than uncertainty. The expected benefits and costs are then used to calculate the net present value (NPV), the benefit-cost ratio (BCR) and internal rate of return (IRR) of proposals.

Sensitivity analysis

As part of CBA, sensitivity analysis is undertaken to analyse how different assumptions or values for key variables affect the value of a proposal, thus addressing the risk that some assumptions and/or variables may be incorrect. Specifically, the decision maker can observe the effect of changing prices, and other assumptions on the estimates of benefits and costs and the associated effect on the NPV of a proposal.

There are a number of ways to undertake a sensitivity analysis: worst/best case analysis, partial sensitivity analysis, or a full risk (Monte Carlo) analysis (see below).

*Monte Carlo analysis*

Monte Carlo analysis is a computer simulation methodology that uses multiple values for each of the key variables (such as costs and benefits) and randomly selects them hundreds or thousands of times to give a large number of possible outcomes (NPVs). From this, the likelihood or probability distribution of the possible outcomes can be calculated, rather than there being a single-point estimate.

Before undertaking or commissioning such an analysis, it is important to consider how data will be fed into the model, how the results will be presented, and how decisions may be affected by the information generated.

Monte Carlo analysis is a significant exercise. It may be most useful where risk is a major issue, and where the expected impacts of the proposal justify additional analysis.

BOX 1: ALLOWING FOR RISK IN THE ANALYSIS OF COSTS

Table 1 below presents the costs of various parts of a construction project, broken down into excavation (E), foundations (F), structure (S), roofing (R), and decorations (D). All costs are independent of each other. The model for total cost is as follows:

Total cost = E + F + S + R + D

Table 1: Costs for a construction project at a minimum, maximum and best guess

| Costs for construction project ($) |  |  |  |
| --- | --- | --- | --- |
|  | **Minimum** | **Best Guess** | **Maximum** |
| Excavation (E) | 30,500 | 33,200 | 37,800 |
| Foundation (F) | 23,500 | 27,200 | 31,100 |
| Structure (S) | 172,000 | 178,000 | 189,000 |
| Roofing (R) | 56,200 | 58,500 | 63,700 |
| Decoration (D) | 29,600 | 37,200 | 43,600 |

From this information we can produce a best guess of $334,100 for the total cost of the project. However, we can also conclude a possible range from $311,800 to $365,200. Suppose the project would not go ahead unless the total cost is unlikely to exceed $350,000; how much assurance can we take from these figures that the total cost will be less than $350,000?

By undertaking a Monte Carlo analysis, we can simulate many possible values of the input variables, weighted so that the ‘best guess’ value is more likely than the extreme values. The total cost is calculated for each simulation, giving a distribution of values for the total cost. The precise weighting depends on the probability distributions specified for each variable.

Using triangular distributions, it can be concluded that the most likely total cost is $334,000; and that the chance of total cost exceeding $350,000 is less than 1%.

Monte Carlo simulation diagrams can be represented visually, as seen in Figure 1.

Figure 1: Monte Carlo simulation diagrams

The figure is a stylistic representation of a Monte Carlo Simulation.
In a Monte Carlo simulation, input variables, which have uncertain conditions, are combined with parameters, which have certain conditions. Both the input variables and parameters are taken through reiterations to produce the output.
Input variables and parameters can take a variety of probability distributions.
The output of a Monte Carlo simulation gives a range of possible outcomes with their corresponding likelihood.


Source: Adapted from HM Treasury (2013) [The Green Book: Appraisal and Evaluation in Central Government](https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent). and DTF (2013) [Economic Evaluation for Business Cases Technical Guidelines](http://www.dtf.vic.gov.au/sites/default/files/2018-03/Economic%20Evaluation%20-%20Technical%20Guide.doc).

Probabilistic approach to estimating costs (P10/P50/P90 approach)

Probabilistic approaches to estimating costs recognise that there are risks around the costs of investment proposals. Cost estimates can be reported at ‘P10’, ‘P50’ and ‘P90’ levels. P90 represents the estimate of costs such that there is a 90 per cent probability of the project being delivered within that cost estimate. P50 represents the estimate of costs such that there is a 50 per cent probability of the project being delivered within that cost estimate.

This method can be used to address the optimism bias discussed earlier.

How to address uncertainty – the real options approach

Real options analysis is a methodology that can complement a traditional CBA analysis by taking into account the value of uncertainty and flexibility in decision making. The methodology draws on the tools used to value financial options and applies it to real or tangible assets, providing decision makers with ‘real options’. Real options analysis is most useful when the proposal involves:

* uncertainty about the investment and its ability to best deliver the desired outcomes
* significant sunk costs that cannot be reversed
* decision-makers are able to incorporate new information as uncertainties become more certain.

Deciding whether to use real options analysis

While a real options analysis can be powerful, the analyst needs to assess whether it’s suitable for a particular initiative, ideally before the development of feasible options. Table 2 presents some questions to help assess whether real options will be valuable or a traditional CBA method will suffice.

Table 2: Questions to assess whether real options may be valuable

| Question to answer | Real Options may be valuable if… | CBA may be enough if… |
| --- | --- | --- |
| What are the project **timeframes**? | * the project will be implemented or completed over a number of years | * the project has a short timeframe |
| What is the **degree of** **uncertainty** or range of outcomes? | * volatility or uncertainty of the costs or revenues is large | * there is a small range of possible outcomes |
| Will new, **additional information** be available during the project life? | * information that affects the project’s expected benefits or costs, or allows these to be estimated with greater accuracy, becomes available during the project’s lifetime | * no new information is likely to become available during the project life |
| Are **external influences** likely to change the conditions of the project? | * project benefits or costs are susceptible to external trends and developments | * project benefits or costs are subject to minimal external influences |
| Is there **flexibility** in decision-making during the project? | * decisions can be phased or undertaken in stages to respond to new information | * there is little or no flexibility |

Adapted from van Rhee et al, *Real Options applied to infrastructure projects: a new approach to valuing and managing risk and flexibility*, paper presented at the International conference on infrastructure systems 2008

DTF recommends a [triage approach](http://www.dtf.vic.gov.au/sites/default/files/2018-02/Investment%20Lifecycle%20and%20High%20Value%20High%20Risk%20Guidelines%20-%20Conceptualise%20.docx) to determining whether real options is appropriate. This ensures the cost of a real options analysis is balanced against the potential benefits, and therefore focuses efforts on investments where the gains are likely to be the greatest.

Once a real options analysis has been approved, a further set of questions can help to explore the full range of options that could be included to ensure the best application of the method.

Real Options – next steps

Should a real options approach be an appropriate approach for an investment, the analyst undertaking an economic evaluation will need to value the real options in the investment. There are a number of techniques available to value real options. These include:

* Decision tree analysis – tree diagrams outline where decisions can be made, what risk / uncertainties exist and possible outcomes of decisions. This information can be used to value the real options
* Black-Scholes valuation – advanced modelling technique to value financial options and may be used to also value real options.

Other approaches to addressing risk and uncertainty

Portfolio analysis

Portfolio analysis is the consideration of a number of different options and scenarios for an investment that is assessed against the costs, benefits and contribution to strategic objectives. Undertaking such an assessment produces a ‘preferred portfolio’ based on its performance against objectives and robustness in the face of uncertainty.

Where proposals will interact to bring about benefits, it is preferred that they are analysed as a portfolio, rather than in isolation. This is especially so for infrastructure investments. A portfolio of interventions and investments will be more effective when planned and considered together rather than separately.

Scenario analysis

Scenario analysis is a process used for developing robust strategies in the face of uncertainty. It involves the analysis of possible future events by considering alternative possible outcomes or ‘scenarios’. Scenarios are designed to bring up issues that otherwise might not be considered and should be chosen to draw attention to the major uncertainties – technical, demographic, social, economic, environmental and/or political – upon which the success of a proposal depends. While this method recognises that uncertainty exists in a proposal, it does not necessarily capture the value of flexibility inherent in a situation.

A scenario analysis consists of multiple sensitivity tests that are performed simultaneously. It evaluates the changes to outcomes as a result of changes to multiple variables under different likely scenarios. The changes to the variables in a scenario analysis should be realistic and based on optimistic and pessimistic scenarios that have a reasonable likelihood of occurring, rather than extreme cases.

The consideration of scenarios needs to be proportionate. It may take the form of asking simple ‘what if’ questions for small and medium sized projects, but extend to creating detailed models of future states of the world for major policies and large programs. The expected NPV can be calculated for each scenario. It may also be helpful to undertake some sensitivity analysis within a scenario.

BOX 2: EXAMPLE OF SCENARIO ANALYSIS

A department is deciding whether to implement an IT project that allows its clients to undertake self-service activities. However, it is unsure of the likelihood that clients will adopt the online service (the success rate). The department believes that the likely success rate of the project ranges between 40 and 60 per cent.

In the pessimistic scenario, the project has a 40 per cent chance of success, which will generate up to $12 million of net benefits, but it also has a 60 per cent chance of failing, which will incur a net cost of up to $9 million. Taking into account this risk, under the pessimistic scenario, the project is expected to have a net cost of $0.6 million. However, if the department rejects the project and does nothing then the net impact is a cost of $2 million with certainty.

Under the optimistic scenario, where the project has a 60 per cent chance of success, the expected net benefit after risk has been taken into account is $3.6 million. Again, if the department rejects the project and does nothing then the net impact is a cost of $2 million with certainty.

Ultimately, once this additional information on the likely outcomes of different scenarios has been provided for each of the options, it is up to the decision-maker to decide whether or not to proceed with the project given his or her risk appetite.

Figure 2: Scenario analysis to implement an IT project

The figure shows the impact of different risk scenarios on expected outcomes. There are two possible scenarios, a pessimistic scenario and an optimistic scenario.
Under both scenarios, the decision maker can either accept or reject risk 1.
If risk 1 is accepted, there are two possible outcomes 12 or -9 each occurring with different probabilities, and if risk 1 is rejected, there is one possible outcome. Expected outcomes are calculated by multiplying the outcomes by their expected probabilities. The probabilities are different under each scenario. 
In the pessimistic scenario, the expected outcomes are both negative. In the optimistic scenario, one of the expected outcomes is positive whereas the other is negative.
The main idea is that under different scenarios, the expected outcomes can be different even if the outcomes at each branch are the same.


Source: DTF (2013) [Economic Evaluation for Business Cases Technical Guidelines](http://www.dtf.vic.gov.au/sites/default/files/2018-03/Economic%20Evaluation%20-%20Technical%20Guide.doc).

How should I communicate information about risk and uncertainty in the results of my assessment?

A risk and uncertainty dashboard is a useful way to summarise the results of your risk and uncertainty analyses and to communicate to decision makers the risks and uncertainties that influence the proposed investment and the economic assessment. Appendix A presents and illustration of such a dashboard.

Appendix A: Example dashboard to communicate risk and uncertainty



Glossary

***Benefit-cost ratio (BCR)*** One of the three main decision rules commonly used to help assess and rank different options in a cost-benefit analysis. The BCR measures the ratio of the present value of benefits to the present value of costs The ratio must exceed one for the proposal to be assessed as generating a net benefit.

***Cost-benefit analysis (CBA)*** The primary economic assessment tool used to inform many major public expenditure and regulatory decisions. Cost-benefit analysis quantifies in monetary terms as many of the costs and benefits of a particular policy proposal as feasible, including private and social costs and benefits, and items for which the market does not provide a satisfactory measure of economic value.

***Economic assessment*** The process of identifying, calculating and comparing the costs and benefits of a proposal in order to evaluate its merit, either absolutely or in comparison with alternatives. The term, ‘economic assessment’ is also used in this guidance to describe analysis of the economic impact of an intervention or proposal. These types of analysis are known as ‘economic impact assessment’.

***Internal rate of return (IRR)*** One of the three main decision rules used to help assess and rank different options in a cost-benefit analysis. The IRR is the discount rate at which the NPV of a new investment’s expected costs and benefits equals zero. In general, the IRR is compared with a benchmark figure to determine whether a project should proceed. IRRs are also compared across projects to determine their relative performance. In some cases, the higher the proposed investment's IRR, the more preferable it is to undertake.

***Monte Carlo analysis*** A computer simulation methodology that undertakes repeated random sampling to obtain numerical results. For a given project or policy proposal, the simulation repeatedly replaces uncertain variables and recalculates the NPV of a proposal. Monte Carlo simulation provides a probability distribution of results or outcomes from the repetition. That is, rather than a single-point estimate of probabilities of occurrence it will provide a probability distribution of the expected NPV outcome.

**N*et present value (NPV)*** One of the three main decision rules commonly used to help assess and rank different options in a cost-benefit analysis. The NPV of an option equals the present value of benefits minus the present value of costs. If the NPV is positive, the investment improves efficiency because it involves benefits that, over time, more than outweigh the costs. If the NPV is negative, the proposal is inefficient (the costs outweigh the benefits). Policy options can then be compared by the size of their NPV.

***P50 and P90 method*** A probabilistic approach to estimating costs recognising that the costs of investment proposals are uncertain. Cost estimates can be reported at P50 and P90 levels, which communicate the project costs with a 50 per cent and 90 per cent likelihood, respectively, that these costs will not be exceeded.

***Portfolio analysis*** The consideration of a number of different options and scenarios for an investment that is assessed against the costs, benefits and contribution to strategic objectives. The outcome from assessment would yield a preferred portfolio given its performance against the objectives and robustness to uncertainty.

***Risk*** When a potential event or outcome can be identified and estimated with a certain degree of confidence, i.e. can be given a probability. Risk is expressed as the ‘expected outcome given the probability and impact of the event based on data and expert judgment’. Examples of common risks are economic, environmental, political, construction and technology risks.

***Scenario analysis*** A process for developing robust strategies in the face of uncertainty. It involves the analysis of possible future events by considering alternative possible outcomes or ‘scenarios’. Scenarios are designed to bring up issues that otherwise would not be considered and should be chosen to draw attention to the major technical, economic and political uncertainties upon which the success of a proposal depends.

***Sensitivity analysis*** The process of analysing how different values or outcomes affect the value of a proposal. Sensitivity analysis allows the decision maker to examine the plausibility of assumptions made in the analysis. Specifically, the decision maker can observe the effect of changing discount rates, prices, and other assumptions on the estimates of benefits and costs and the associated effect on the net present value of a proposal.

***Real options analysis*** Real options analysis is a methodology which expands on a traditional net-present-value analysis by taking into account the value of uncertainty and flexibility in decision making. The methodology draws on the tools used to value financial options and applies it to real or tangible assets, providing decision makers with ‘real options’. A real options approach recognises that not all elements of a project are fully known and that there are decisions available in the future. These factors can affect the value of a project.

***Uncertainty*** When the event cannot be reasonably identified or the probability of an event occurring is unknown. Forecasts (e.g. of population, economic growth, and transport demand), assumptions, judgements and conditional outcomes in investment projects often involve uncertainty.