Australian Government | Infrastructure Australia

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Guide to risk and uncertainty analysis

Technical guide of the **Assessment Framework**

The Assessment Framework comprises an overview, stages 1 to 4 and technical guides:

- Overview
- 1 Defining problems and opportunities
- 2 Identifying and analysing options
- 3 Developing a business case
- 4 Post completion review
- **Technical guides**

The Assessment Framework (including this document) and the Infrastructure Priority List are changing in line with amendments to the Infrastructure Australia Act 2008.

While this transition process is underway, IA will continue to receive and evaluate proposals according to the current process and assessment framework.

For further information contact engagement@infrastructureaustralia.gov.au

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It leads reform on key issues including means of financing, delivering and operating infrastructure and how to better plan and utilise infrastructure networks.

Infrastructure Australia has responsibility to strategically audit Australia's nationally significant infrastructure, and develop 15-year rolling infrastructure plans that specify national and state level priorities.

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Introduction

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At a glance

- Risk and uncertainty both impact infrastructure projects throughout delivery and operation. It is important to test the robustness of proposed projects by understanding how they will perform under different conditions.
- Risks are events that have probabilities of occurrence that are predictable, and outcomes that can be estimated with some confidence. In this document, we have described tools that can help you understand and manage risks, including qualitative risk assessment, probability-based analysis and sensitivity analysis.
- Uncertainties are events where probabilities of occurrence are difficult to predict and outcomes are challenging to quantify. In this document, we have described tools that can help you understand and manage uncertainties, including scenario analysis and real options analysis.
- A changing climate presents clear and potentially intensifying risks and uncertainties that are likely to impact infrastructure decision-making. Climate risks and uncertainties should be considered throughout the Assessment Framework stages using the tools described for both risk and uncertainty.

1.1 How to navigate this document

This document is designed for proponents (you) wishing to analyse risk and uncertainty to support a proposal for submission to Infrastructure Australia (us) in accordance with the Infrastructure Australia Assessment Framework (the Assessment Framework). If you are unfamiliar with the Assessment Framework, we recommend that you review our **Overview** and relevant **stage volumes** before reviewing this document.

- **Section 1** explains the context of risk and uncertainty, including how they are considered within our broader assessment process.
- **Section 2** provides our definitions of risk and uncertainty and describes how to identify and distinguish them. It then explains how to analyse them using the approaches described in the subsequent sections.
- **Section 3** provides detailed guidance on how to account for risk throughout project development and outlines how to apply relevant tools such as sensitivity analysis.
- **Section 4** provides detailed guidance on how to account for uncertainty throughout project development and outlines how to apply relevant tools such as scenario analysis and real options analysis.
- **Section 5** provides detailed guidance on how to account for climate-related risks and uncertainties.

Box 1: **Key terms**

Business case: a document that brings together the results of all the assessments of an infrastructure proposal. It is the formal means of presenting information about a proposal to aid decision-making. It includes all information needed to support a decision to proceed, or not, with the proposal and to secure necessary approvals from the relevant government agency. Unless otherwise defined, we are referring to a final or detailed business case, rather than an early (for example, strategic or preliminary) business case, which is developed in accordance with state or territory requirements. A business case is prepared as part of Stage 3 of the Assessment Framework.

Option: a possible solution to address identified problems and opportunities. A wide range of options should be considered and analysed to determine the preferred option, which will be recommended in the business case.

Program: a proposal involving a package of projects that are clearly interlinked by a common problem or opportunity. The package presents a robust and holistic approach to prioritise and address the projects, and there is a material opportunity to collaborate and share lessons across states, territories or agencies. The projects can be delivered in a coordinated manner to obtain benefits that may not be achieved by delivering the interventions individually.

Project: an infrastructure intervention. A project will move through the stages of project initiation, planning, delivery and completion. A suite of related projects to address a common problem or opportunity will create a program.

Proponent: an organisation or individual who prepares and submits infrastructure proposals to us for assessment. To be a proponent of a business case (a Stage 3 submission), the organisation must be capable of delivering that proposal.

Proposal: the general term we use for successful submissions to the *Infrastructure Priority List*, across the key stages of project development, specifically – early-stage (Stage 1), potential investment options (Stage 2) and investment-ready proposals (Stage 3). Proposals that have been delivered would be assessed in Stage 4.

1.2 Purpose of this technical guide

A key part of the infrastructure development process is accounting for risk and uncertainty. All infrastructure projects have risks and uncertainties, even after applying mitigation measures.

This technical guide describes how risk and uncertainty impact infrastructure projects and explains the tools required to analyse and respond to them when developing a proposal for submission to us. The technical guide:

- describes what risks and uncertainties are
- sets out the tools and methodologies that should be considered at each stage of the Assessment Framework to respond to risk and uncertainty
- provides detailed guidance for considering climate change risks and uncertainties.

This approach acknowledges that risk and uncertainty need to be considered throughout the assessment process to ensure successful project outcomes.

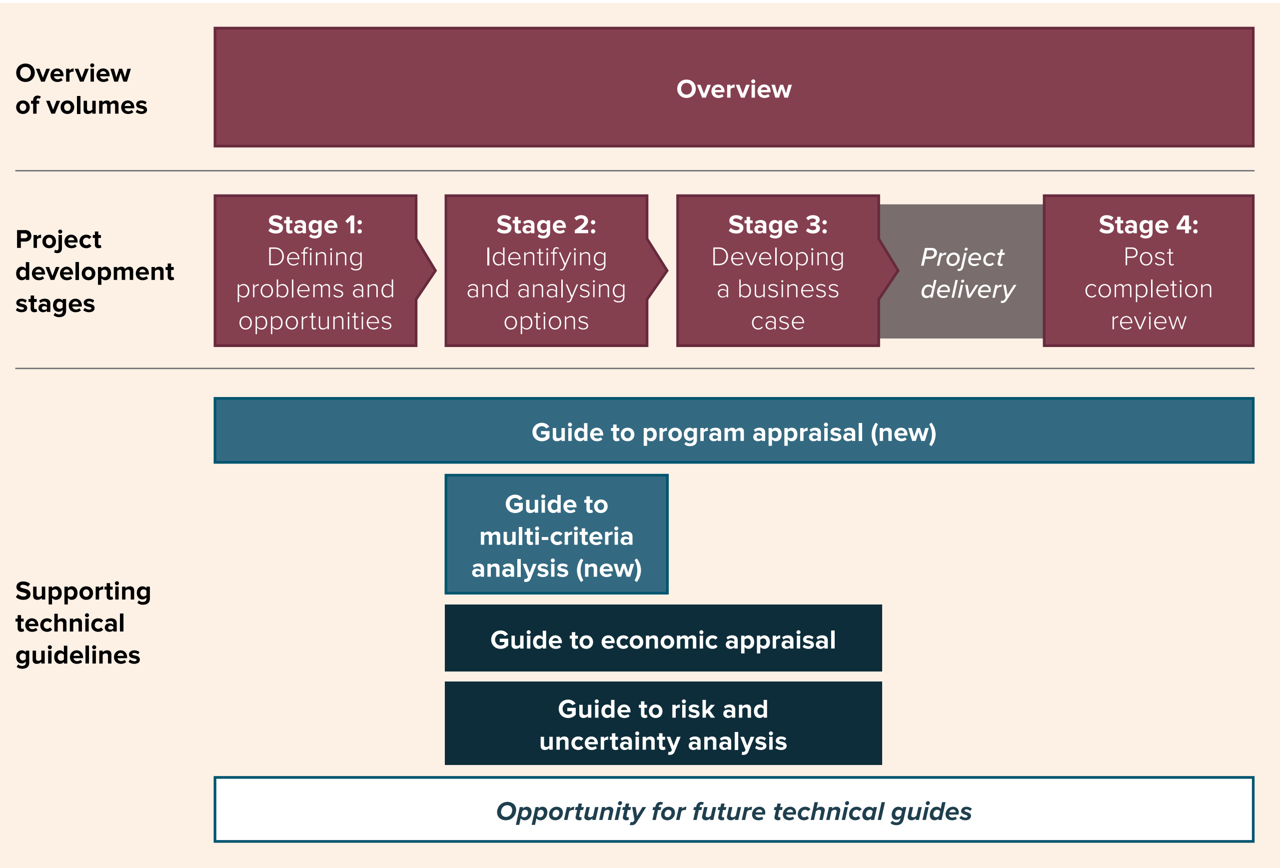
1.3 Structure of the Assessment Framework

The Assessment Framework consists of a series of volumes and technical guides. Together, they describe the activities in a typical project development process and how we assess proposals that are submitted to us.

For practicality and ease of use, each submission stage is described in a separate document and supported by the technical guides. This allows you to focus on the guidance most relevant to you at the stage you are up to in project development.

The structure of the Assessment Framework is shown in **Figure 1**. The suite of Assessment Framework volumes is available at **www.infrastructureaustralia.gov.au/publications/assessment-framework**.

Figure 1: Structure of the Assessment Framework



1.4 Risk and uncertainty in the Assessment Framework

This document provides guidance on risk and uncertainty in the context of planning and forecasting expected demand and achieving defined outcomes. The approaches defined in this document complement existing methods of analysis described in the Assessment Framework to make the analysis more robust, most notably:

- **Stage 1:** Identify risks and uncertainties that are a key driver for the proposal. This may be particularly relevant where resilience is a driver for change.
- **Stage 2:** Review the proposal at a high level to identify exposure to risk and uncertainty, then develop options that consider and/or respond to it:
  - identify and respond to risk exposure
  - identify potential shocks and stresses (see the **Overview** volume)
  - review option performance under shocks and stresses
  - develop flexible investment strategies to respond to uncertainty.
- **Stage 3:** Apply the same principles as Stage 2 in further detail, to validate the approach and analyse the shortlisted options in detail.
- **Guide to program appraisal:** Programs allow the sequencing of projects with regard to impact, cost, continuity of service and deliverability. The examples of using real options analysis described in this document can be supported by a program approach. This would be achieved by defining a desired program outcome, but committing on a project-by-project basis to allow changes in the nature or timing of subsequent investment as the future becomes more certain.
- **Guide to economic appraisal:** Our recommended approach to cost–benefit analysis (CBA) considers the effects of risk and uncertainty and applies the tools outlined in this document in **Step 6: Analyse risks and test sensitivities**. If you identify significant risks and uncertainties (for example, where major shocks and stresses are identified or where resilience is a driver of the proposal), you should consider and integrate them throughout the CBA.

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Risk and uncertainty in infrastructure analysis

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2.1 Risk and uncertainty overview

Infrastructure projects are vulnerable to a spectrum of risks and uncertainties over which there are varied levels of control. These can impact intended investment outcomes, so should be considered in decisions about how best to achieve investment objectives.

Box 2 explains our definitions for risk and uncertainty. This explains their differences, while addressing potential overlaps and contradictions, to help you to apply the techniques described later in this guide in an informed way.

Future outcomes and events all involve risk and uncertainty. When realised, risks and uncertainties can have profound impacts on project outcomes, for example, a preferred option may become undeliverable if circumstances change. To avoid this situation, risks and uncertainties need to be effectively analysed and managed, with their expected impacts and mitigation strategies included in the advice to decision-makers.

This advice is relevant throughout the project development process. It should be **comprehensive and rigorous, describing both risks and uncertainties, to inform**:

- the identification, development and shortlisting of options (in Stage 2 of the Assessment Framework)
- the selection of a preferred option (in Stage 3 of the Assessment Framework)
- an understanding of the potential impacts on scope, cost, schedule, and benefit realisation
- investment inclusions or flexible investment strategies that can future-proof infrastructure (for example, designing a proposal to allow capacity flexibility without excessive additional costs)
- an understanding of where an investment decision is irreversible (for example, where cancelling or abandoning a project during delivery may be almost as costly as finishing it).

As such, the consideration of risks and uncertainties allows for their identification, review and management by developing strategies to avoid or mitigate risks and uncertainties. Importantly, it provides material that is essential for making fully-informed decisions.

This guide provides separate advice about the treatment of risks (in **Section 3**) and uncertainty (in **Section 4**) because it is generally appropriate to use different techniques. You should decide how to classify and treat potential events based on your understanding about how well their probabilities and consequences can be forecast.

Box 2: **Defining risk and uncertainty**

We define **risk** as:

> **events that have probabilities of occurrence that are predictable and outcomes that can be estimated with some confidence.**

Risk is often expressed as a combination of the consequences of an event (including changes in circumstances or knowledge) and the associated likelihood of occurrence.[1]

We define **uncertainty** as:

> **events where probabilities of occurrence are difficult to predict and outcomes are challenging to quantify.**

Uncertainty is not clearly defined in relevant standards, although a range of definitions to support your understanding are available in Saunders' *Differentiating between Risk and Uncertainty in the Project Management Literature.*[2]

In practice, there is a spectrum between risk and uncertainty, based on the level of confidence of information. In many cases, further investigation can define additional information on the outcomes and likelihood of uncertainties to allow them to be treated more like risks. Where the effect of the uncertainty on project outcomes is significant, it is usually worthwhile to do so.

Table 1 compares the attributes of risk and uncertainty.

Table 1: The attributes of risk and uncertainty

Risk	Uncertainty
• Risks are occurrence or event based	• Uncertainty is a state of unknowing and a lack of information
• Risks are quantifiable; often with estimatable probabilities of occurrence and consequences that can be estimated should the event occur	• Uncertainty is less susceptible to analysis, involving variability and ambiguity
• Risks, if they occur, impact the proposal	• Uncertainty has the potential to impact the proposal

Our definitions of risk and uncertainty are based on your ability to estimate the probability and expected outcomes of events.

This approach provides a useful way of thinking about events at either end of the risk-uncertainty spectrum. As the knowledge of these events and our ability to forecast their incidence and impacts grows, uncertainties may warrant being treated as risks. See **Section 2.2** for examples demonstrating the differences between risk and uncertainty.

1. The definition of risk used in key Australian Government and state and territory guides is the one defined in Standards Australia 2018, Risk management: Guidelines (AS/NZS ISO 31000:2018).
2. Saunders F. 2016, *Differentiating between risk and uncertainty in the project management literature*, University of Manchester, available at fionasaunders.co.uk/wp-content/uploads/2016/07/Differentiating-between-Risk-and-Uncertainty-in-the-Project-Management-Literature.pdf.

2.2 Identifying and distinguishing risks and uncertainty

To identify risks and uncertainties and determine those requiring more detailed analysis, you should:

- comprehensively and systematically consider all the events that may impact the outcomes for the investment being considered
- be clear about the evidential basis for excluding events that are considered insignificant for the investment under consideration
- identify events that require more detailed analysis, determine whether these should be treated as risks or uncertainties, then apply appropriate tools to work out how best to mitigate their potential impacts.

You can complete this type of analysis by:

- **Drawing on the lessons from similar investments (ideally in similar circumstances).** The risks and uncertainties included for these investments together with the lessons learned from the realised outcomes of completed and operational investments provide a good starting point for identifying these events.
- **Conducting research and investigations relevant to the investment drawing on specialist inputs as required.** This will help contextualise the investment and understand how applicable the risks and uncertainties are for similar proposals. This research can also identify risks and uncertainties related to any unique investment attributes and also complete an updated scan of the environment for any emerging risks or sources of uncertainty. Specialists may be able to draw on their experience managing risks and uncertainties in similar situations.
- **Engaging with stakeholders.** This knowledge and perspectives of relevant stakeholders is likely to be invaluable in identifying and understanding the importance of risks and uncertainties. You need to think about how to most effectively engage these groups with potential methods including focus groups and workshops, interviews or questionnaires and written submissions.
- **Using comprehensive checklists describing the potential risks and uncertainties** likely to affect infrastructure proposals. Standard checklists for relevant sectors and asset types should be used, where available, to improve the consistency of the analysis.

The experience with the COVID-19 pandemic has shown that it is challenging to identify all significant risks and uncertainties. However, completing these activities will provide assurance to decision-makers that you have made reasonable efforts to do this.

Sources of risk and uncertainty

Risks and uncertainties can arise from many sources. Within each category there are likely to be both risks and uncertainties that are distinguished by how quantifiable their probabilities and outcomes are. **Table 2** provides four examples that highlight the differences and help you distinguish risks and uncertainties in your proposals.

Table 2: Examples comparing risks and uncertainties

Category	Risks	Uncertainties
Forecasting	Changes in inputs and modelling parameters within expected ranges based on past performance and endorsed forecasts including: • Realised demand being less or more than forecast because of margins of error in modelled parameters (e.g. use of public transport with a service improvement). • Population and employment growth in the study area exceeding or falling short of endorsed forecasts.	Significant potential changes in the factors driving demand from events that are very difficult to predict and to quantify the consequences: • The COVID-19 pandemic is a good example of an area of uncertainty. • Infrastructure investments across Australia did not foresee this type of change nor understand the scale of the potential short- and long-term behavioural and demand responses. • Predicting if and when similar events are likely to occur is very difficult.
Climate-related events	Impacts from an expected rise in sea levels on a proposal may be treated as a risk if: • You are confident that research and modelling have provided clarity about the likely magnitude of future changes and their consequences. • For example, if there is a 95% confidence that global warming is likely to result in a sea level rise of 30cms (+/- 10%) and you now understand where and how this is likely to impact the land and infrastructure in the area.	Impacts from more frequent and intensive extreme weather events may still need to be treated as an uncertainty if you: • Know these will increase but the research and modelling has not progressed to providing a narrowed range on event frequency/intensity. • Are not able to adequately quantify and narrow the range of impacts when these events occur.
Environmental impacts	A wide range of impacts can be treated as risks because their likely occurrence and consequences are well understood, such as: • Water corporations forecast emissions levels from wastewater treatment plants based on population forecasts, hydraulic modelling and the technologies applied. • Road design teams analyse and mitigate the impacts of a new road on adjacent water courses and can analyse the risks.	Uncertainties that might impact environmental outcomes and are difficult to predict include: • Changes in regulatory requirements over a 30-year appraisal period, e.g. if research finds a substance is more toxic than expected the change in regulatory requirements may significantly impact the assessment outcomes. • Where the likely impacts of climate change are not well understood.

Table 2: *Continued*

Category	Risks	Uncertainties
Technological risk	Many technology developments can be treated as risks as they have a moderate level of predictability: • Improvements in technology at an expected rate (e.g. Moore's law – the number of transistors in a silicon chip doubles every two years). • For electric buses the price of batteries has fallen over time. Risks could be evaluated if you had expectations about the likelihood of this trend continuing into the future or changing.	Unforeseen technological advancements or market disruptions. Technology changes can make existing products and assets obsolete or less competitive; creating 'lock-in' effects. Continuing with the theme of zero emission buses: • Hydrogen as a fuel is expected to be more expensive to use than diesel or electricity for some considerable time depending on the development of large-scale production. • However, a technological advance that enabled small-scale and much cheaper hydrogen production would impact the preferred transition pathways. • This type of change is very difficult to predict.

2.3 Analysing risks and uncertainties

We suggest that you account for risk and uncertainty when developing a shortlist of options in **Stage 2**, and then when analysing these options in detail in **Stage 3**.

This section provides a high-level overview of the tools that can be used to analyse the impacts of risks and uncertainties on infrastructure proposals. **Section 3** and **Section 4** provide detailed guidance on these tools and how to apply them for:

- risks, using qualitative (see **Section 3.2**) and quantitative (see **Section 3.3**) techniques
- uncertainties, using scenario analysis (see **Section 4.2**) and real options analysis (see **Section 4.3**).

A qualitative analysis is simpler and less costly. The initial, qualitative analysis described in **Section 3.2** should be used to assess the nature and expected significance of all events relevant to the investment and to decide if and how to incorporate these events in the overall analysis.

For risks, this means using the available information to provide and then refine ratings of probability and consequence. This qualitative analysis is likely to identify events where it is very difficult to assign probabilities and estimate consequences, which should instead be considered in your analysis of uncertainties.

Qualitative analysis may be sufficient to guide decision-making about a proposal, but you should be conscious of inherent bias and embedded views. While this analysis is qualitative, it should be supported by quantitative evidence, tested and, if the implications are significant, validated using detailed quantitative analysis.

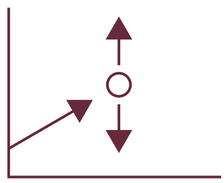
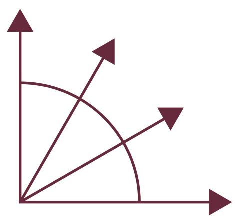
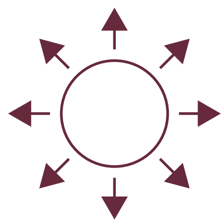
Different analysis and tools are appropriate for risk and uncertainty

Different types of analysis, mitigations and tools are suited to considering and responding to risk and uncertainty. **Table 3** illustrates the spectrum from risks, with clearly predictable probabilities and consequences, through to uncertainties that in the most extreme cases, have many possible futures. The table describes the most appropriate types of analysis, mitigations and tools.

These tools should be applied in an appropriate manner to respond to the risks and uncertainties identified. They range from qualitative and sensitivity analyses to understand and inform risk mitigations, to scenario and real options analyses to inform the management of uncertainties.

Box 3 provides an example of applying risk and uncertainty tools in the context of a transport proposal.

Table 3: Overview of project risk and uncertainty in a planning context

	Risk ←			→ Uncertainty
View of the future	A clear enough future 	Alternative futures (with probabilities) 	A limited, bounded set of plausible futures 	Many/unlimited set of possible futures 
Analysis type to use	Static analysis	Static analysis	Static analysis	Dynamic analysis
Specific analysis and mitigations to apply	Forecast the future and choose a suitable option.	Risk-based analysis: Use probabilities to analyse proposals in accordance with the risk attitude of the decision-maker.	Static robust analysis: Identify plausible futures and find a solution that works across most of them.	Adaptive policy: Options adapt over time as conditions change and learning takes place.
Tools and where to find them	• Qualitative risk assessment (**Section 3.2**) • Sensitivity testing (**Section 3.3**)	• Probability-based analysis (**Section 3.3**)	• Scenario analysis (**Section 4.2**)	• Real options analysis (**Section 4.3**)

Source: Adapted from Walker, Marchau, & Swanson 2010, *Addressing deep uncertainty using adaptive policies: Introduction to section 2*, Technological Forecasting and Social Change, Vol. 77, Issue 6, doi.org/10.1016/j.techfore.2010.04.004

Box 3: **Examples of defining and mitigating risk and uncertainty for a transport proposal**

Table 4: Examples of risks and uncertainties for a tunnelling project

Risk or Uncertainty	Description	Mitigations
Risk	• The project encounters geotechnical conditions that will make tunnelling more difficult than expected, delaying the project and increasing its costs above those budgeted.	• This risk should be the subject of extensive analysis of local ground conditions and the pooled experience of tunnelling in these conditions from past projects. This should provide a good basis for estimating risk probability and consequence. • The team would propose a range of mitigations that include: – Extensive testing to better understand the nature and prevalence of the risk. – Taking account of this risk when designing the tunnels and choosing a design to appropriately balance the risks and costs. – Employing skilled contractors (those with a proven record of delivering projects in a similar environment). • In terms of the analysis, the identified risks can be accounted for in the CBA through sensitivity testing or through the use of probabilistic cost estimates to inform the assessment.
Uncertainty	• Parts of the tunnelling alignment are through land used for heavy industry and manufacturing. In the planning phase, contamination was raised as both a risk and uncertainty. • Identification and removal of contaminated soil was classified as a risk, as there is sufficient experience and information to manage it, and analysed accordingly (by including in the risk register, and informing the cost estimate). • The possibility of responsible authorities changing the classification and assumed toxicity of one or more contaminants, was classified as an uncertainty.	• Changes in legislation and regulation would be considered an uncertainty as it is difficult to predict and may involve a significant change in practices and costs. • A reasonable approach to managing this uncertainty might involve: – Doing desk-based research and a literature review to detect any emerging signs of a change in the perception, toxicity and treatment of key contaminants for this site. – If this shows some susceptibility, the impacts of changed classifications could be analysed by assessing alternative scenarios with changed requirements.

3

Tools to analyse risk

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3.1 Decision-making under risk

This section describes the tools to understand and manage risks, as summarised in **Table 5**.

Table 5: Tools to understand and manage risks

Tool	Description
Qualitative risk assessment	Typically involves identifying the full range of relevant risks, estimating their expected probability and consequence developing mitigations (especially to key risks), then reassessing risks once mitigations have been applied. The basis for this analysis should include quantitative and qualitative analysis, as well as inputs from specialists and stakeholders.
Quantified risk analysis	
Probability-based analysis	The use of probability distributions to represent the risky variables of interest, and computer simulations to produce probability distributions of analysis output results. For example, probabilistic CBA and probabilistic cost estimation.
Sensitivity analysis	Test how the costs and benefits of each option change if there is a change in a particular input or assumption, set of inputs and assumptions or set of assumed changes in the outcomes (e.g. costs and benefits are assumed to vary by X%). The sophistication and detail of this analysis may vary from relatively simple 'what if?' analyses, conducted alongside more complicated modelling, to the re-specification and re-running of complex models.

Note that risk assessment will often identify events that should be classified as uncertainties and require application of the tools described in **Section 4**.

3.2 Qualitative risk assessment

A qualitative risk assessment involves the following steps:

- Identify and describe the full range of events that are likely to have relevance to the investment decision (for example, the occurrence of an event with cause(s) and consequence(s) detailed).
- Identify any uncertainties that, if significant, should be managed using the tools in **Section 4**.
- Determine the probability and consequence ratings for each risk where:
  - Ratings are drawn from the standards or, if different, from relevant jurisdictional guidelines.
  - You can connect these ratings to the underpinning evidence (quantitative data, specialist inputs or stakeholder perceptions).
  - These ratings will set the overall, combined probability and consequence rating for each risk.
- Eliminate any risks that you are confident are irrelevant or insignificant to the investment.
- For the remaining risks, determine the actions required to mitigate them, based on past experience and specialist/stakeholder input. This includes describing the action(s), who is responsible for these actions and the proposed implementation timelines.
- Re-rate the probability, consequence and overall risk rating for the situation where the mitigation actions are successfully applied.
- Document this process and gather the essential information to describe the risks in a register (in accordance with jurisdictional guidelines if they exist).

You should refer to Standards Australia,[3] the Victorian Managed Insurance Authority[4] and Australian Transport Assessment and Planning (ATAP) Guidelines *T7 Risk and Uncertainty Assessment*[5] tables on rating likelihood, consequence and risk for further guidance.

Risk rating tables can be used as a means of developing consistency in rating likelihood, consequence and risk, as well as encouraging transparency. Qualitative rating tables can be tailored for particular contexts. Again, the Victorian Managed Insurance Authority[4] is a source of guidance here.

Guidelines vary between states and territories as to when and how these processes are applied across options. However, in all cases, the level of detail increases as the number of options decreases, with the most detailed risk register reserved for the preferred option.

Through the Assessment Framework, we recommend that you:

- at Stage 1:
  - develop an initial understanding of key risks relevant to the problems and opportunities
- at Stage 2:
  - develop a comprehensive listing and description of all risks thought to be relevant to the investment while identifying and analysing options
  - focus on the highest rated risks and rate these using probability and consequence to reduce a longlist of options to a shortlist for detailed analysis
- at Stage 3:
  - validate the qualitative risk assessment for the shortlist of options considered in the business case, focusing on the more significant risks
  - develop a detailed risk register and mitigations for all included risks for the preferred option in the delivery strategy and operations strategy
  - document the risk assessment within the business case or supporting documentation to adequately explain the application of this process.

3.3 Quantified risk analysis

We recommend two broad types of quantitative analysis:

1. Probabilistic methods to estimate the impact of risks on the investment cost. This method can be enhanced by applying a probabilistic approach to the CBA.
2. Sensitivity analysis, including common and more tailored sensitivity testing.

Probability-based analysis

This applies probability distributions, rather than most likely or point estimates, to the variables of interest. This typically requires input from experienced specialists to define the form and shape of the distributions used within the probabilistic analysis. While this type of analysis applies statistical observations on the outcomes of risks, it is underpinned by a series of subjective decisions, which may introduce other sources of bias into the analysis. Results should be considered and tested accordingly.

Probabilistic cost estimation

We prefer expected costs to be calculated using probabilistic cost estimates, based on the risk analysis for the proposal. However, this process may be more common practice in some sectors over others.

Probabilistic cost estimates are calculated by developing an overall cost probability distribution by inputting probabilities, mean values and sub-distributions for all the risks included in the analysis. This approach may provide a more realistic cost estimate and avoids the inclusion of large generic contingencies, depending on the level of design. Typically, statistical techniques such as Monte Carlo analysis are used to generate an overall cost distribution based on data provided on the costs and probabilities of a range of cost inputs and their inter-dependencies.

3. Standards Australia 2018, *Risk management: Guidelines* (AS/NZS ISO 31000:2018)
4. Victorian Managed Insurance Authority, *Risk management tools*, VMIA, available at https://www.vmia.vic.gov.au/tools-and-insights/tools-guides-and-kits/risk-management-tools.
5. Transport and Infrastructure Senior Officials' Committee 2016, *ATAP Guidelines T7 Risk and Uncertainty Assessment*, Transport and Infrastructure Council, Canberra, available at: www.atap.gov.au/tools-techniques/risk-uncertainty-assessment/index.

You should detail full year-by-year costs for the lifetime of the proposal and present these as 'expected costs'. Cost estimates are drawn from the distribution of risk-incorporating costs and may be presented as:

- **Expected value** – the mean value of the cost distribution, or 'best estimate'.
- **P50** – a P50 cost estimate is the project cost with sufficient contingency to provide 50 per cent likelihood that this cost would not be exceeded. The P50 is the median value, and will be equal to the expected value when the cost distribution is symmetric.
- **P90** – a P90 cost estimate is the project cost with sufficient contingency to provide 90 per cent likelihood that this cost would not be exceeded. Therefore, a P90 cost is higher than the P50 cost.

There are a range of techniques for calculating cost distributions, for example, using @RISK software as an add-on to Microsoft Excel.

Probabilistic cost estimation is a key element of the analysis process and **we prefer that**:

- **Stage 2 submissions include, where sufficient option definition and design has been completed, probabilistic cost estimates of each shortlisted option, based on a strategic level of design**
- **Stage 3 submissions include probabilistic cost estimates of each shortlisted option, based on a preliminary level of design.**

For more information, see the cost guidance in our **Guide to economic appraisal**, The Department of Infrastructure, Transport, Regional Development and Communications *Cost Estimation Guidance*[6] and ATAP *O1 Cost Estimation*.[7]

Probabilistic cost–benefit analysis

Probabilistic modelling approaches can be useful for high-risk and large-scale infrastructure proposals, where significant variances in cost and benefit estimates are expected. This involves applying probabilistic distributions to the key variables likely to determine proposal costs and benefits, within the CBA model itself.

These are then used to generate the probabilistic distribution outputs – for net present value (NPV), benefit cost ratio (BCR) and other decision criteria. **This raises the complexity of the analysis and is not an approach we expect to be routinely applied** but may be relevant for proposals where there is significant risk or uncertainty. If you are not sure whether you should adopt this approach, please consult with us to discuss whether it is appropriate.

If appropriate, probabilistic CBA would be applied at Stage 3 of the Assessment Framework.

ATAP *T7 Risk and uncertainty assessment*[8] provides more detail on applying probabilistic CBA.

Sensitivity analysis

The purpose of sensitivity analysis is to determine the potential impacts of risks on project outcomes by varying key inputs and assumptions to determine how much they change the expected outcomes. Sensitivity analysis allows you to:

- understand the key factors and variables that impact on project outcomes
- prioritise, analyse and select options, including the preferred option, based on different assumptions and outcomes.

Sensitivity testing of options is a key element of the analysis process and **we expect that**:

- **Stage 2 submissions demonstrate the key sensitivities of the shortlisted options, including high-level sensitivity analysis as part of the options filtering process**
- **Stage 3 submissions include proposal-specific sensitivities, plus our standard sensitivity tests as appropriate, as part of the CBA of shortlisted options.**

Standard sensitivity tests

Table 6 identifies the standard sensitivity tests and ranges that we recommend you conduct (in the absence of proposal-specific sensitivities) in analysing shortlisted options within the business case.

6. The Department of Infrastructure, Transport, Regional Development and Communications 2018, *Cost Estimation Guidance*, Australian Government, available at: investment.infrastructure.gov.au/about/funding_and_finance/cost_estimation_guidance.aspx
7. Transport and Infrastructure Senior Officials' Committee 2016, *ATAP Guidelines: O1 Cost Estimation*, Transport and Infrastructure Council, Canberra, available at www.atap.gov.au/other-guidance/cost-estimation/index,
8. Transport and Infrastructure Senior Officials' Committee 2020, *ATAP Guidelines: T7 Risk and uncertainty assessment*, Transport and Infrastructure Council, Canberra, available at www.atap.gov.au/tools-techniques/risk-uncertainty-assessment/index.

Table 6: Our recommended sensitivity tests applied at the business case stage

Test	Ranges used
Discount rate	4% and 10% (around a central value of 7%)
Under/over estimation of capital costs	±20% of value used (expected value, P50 or P90). If P50 used, then test P90 as a sensitivity
Under/over estimation of maintenance and operating costs	±20% around central estimate
Under/over estimation of benefits	±20% around central estimate
Best case sensitivity tests	Simple: Assume -20% total costs and +20% benefits Complex: Assume upside adjustments for 4–5 key variables
Worst case sensitivity tests	Simple: Assume +20% total costs and -20% benefits Complex: Assume downside adjustments for 4–5 key variables
Deferral test	*If the proposal presents marginal value for money and first-year rate of return (FYRR) is less than the discount rate:* defer cost and benefit cash flows by five years to test whether the CBA results (net benefits) improve because of the deferral of the project

Sensitivity testing of costs is additional to the probabilistic determination of costs.

Any land use impacts or wider economic benefits (WEBs) should be presented separately to the overall CBA results with metrics calculated with and without these benefits. They are not included within the standard sensitivity testing.

Our Assessment Framework provides guidance on expected cost variances at different stages for the level of project definition and design completed at each stage. This is designed to cover a broad range of infrastructure sectors including transport, water, energy, telecommunications and social infrastructure. In each **Stage volume** of the Assessment Framework and summarised in the **Guide to economic appraisal**, you will find suggested cost ranges based on the level of project definition that may be appropriate for sensitivity testing.

Test project deferral where the proposal does not present value-for-money

This test can be applied to any project, but **we recommended a deferral test if the proposal is marginal** (as a guide, this may be where the BCR is less than 1.2) **and the first-year rate of return (FYRR) is less than the discount rate**. This tests whether deferring the project by five years improves the net benefits of the proposal. However, we encourage you to contact us for assistance in determining the appropriate deferral period to use.

As an alternative to a deferral test, the FYRR also helps to identify the most economically efficient time to construct the project. If a project has a FYRR below the discount rate (that is, 7%) then you should defer the project until the FYRR either equals or exceeds the discount rate.

The purpose of the deferral test is to provide insight about the appropriateness of the investment's timing. For example, if a major capacity expansion is completed well in advance of the levels of demand that require this added capacity, deferring the project will generally increase the returns because:

- the present value of costs is likely to fall as capital expenditure is delayed and discounted
- the present value of benefits will not fall by as much because the early years of the investment will provide few benefits as the existing capacity is sufficient, but the major benefits will still occur over the same time period as the non-deferred option
- the likely outcome is that the net benefits will increase.

Analysing the impact of deferral is important to ensure that a project proceeds when it will deliver the greatest net benefits. If the costs of the problem the proposal is addressing are immediately material and will persist in the longer term, the deferral sensitivity test can provide confidence that the greatest net benefits can be achieved by implementing the proposal now.

The deferral involves shifting the cost and benefit streams forward by the number of years selected for deferral. These streams are in current year prices and are not escalated so it is a relatively simple exercise to shift the cost and benefit profiles. These revised profiles are then discounted to form inputs for updating the key economic metrics.

The benefits over the appraisal period are generated through interpolating and extrapolating results from specific, modelled years. You need to shorten the start of the benefit stream and extend it for the same number of years at the end of the appraisal period.[9]

Test proposal-specific sensitivities

We recommend that you apply proposal-specific sensitivity tests when preparing your business case.

You should consider the risk profile and key risk drivers for the project in setting proposal-specific sensitivity tests. These tests will focus on changing specific inputs and assumptions and should focus on those inputs where the combination of probability and consequence could impact the choice of preferred option. This is particularly relevant for analysing the effect of shocks and stresses where resilience is the driver of a proposal.

For example, if the choice of preferred option depends on the demand response to an enhanced public transport service and there is a significant range around forecasts, then testing alternative demand responses will provide important insight into this risk.

More sophisticated and specific sensitivity testing is more likely to be required for larger and more complex projects. However, this should be considered for all proposals where the realisation of a risk is likely to be material and is not adequately covered by the standard sensitivity tests.

Specific sensitivity tests may include varying:

- population
- prices for competing products (for example, mobile broadband when testing fixed broadband solutions)
- prices of inputs (contributing to the cost) including those dependent on local and global trends (for example, for global – oil prices)
- changes in demand (for example, high, medium and low demand sensitivities)
- changes in modal competition or pricing in transport
- flooding probability sensitivities (if flooding was flagged as a key risk).

Table 7 provides examples of variables and ranges that may be relevant for transport proposals as specified by Austroads. **Table 8** provides similar variables and ranges that may be relevant for water infrastructure proposals.

In summary, you should consider whether standard sensitivity tests will be sufficient to inform the decision about a preferred option and whether additional, specific tests are required.

9. For details, see see the Australian Transport Council's 2006 *National Guidelines for Transport System Management in Australia*, Vol. 2 and Volume 5, pp 92 and 107.

Table 7: Example variables for sensitivity analysis of transport infrastructure

Test	Ranges used
Total traffic volume (AADT)	±5 percentage points
Proportion of heavy vehicles	±0.3 from estimate
Traffic growth rate	± 2% pa (absolute) from the forecast rate
Traffic generated by specific (uncertain) developments	Zero or as forecast
Traffic diverted or generated by the proposal	± 50% of estimate
Traffic speed changes	± 25% of estimate
Changes in crash rates	± 25% of estimate

Source: Austroads 2018, as published in *ATAP Step 11: Assess risk and uncertainty Table 3, Sensitivity variables and ranges recommended by Austroads*, available at: http://atap.gov.au/tools-techniques/cost-benefit-analysis/12-step-11-assess-risk-and-uncertainty

Table 8: Example variables for sensitivity analysis of water infrastructure

Test	Ranges used
Agricultural demand	± 20% of estimate
Consumer demand	± 20% of estimate
Long-run marginal cost of water	± 20% of estimate
Growth rate in demand for water	± 2% pa (absolute) from the forecast rate
Population growth	± 20% of estimate

Source: WSP and previous Infrastructure Australia reviews of water business cases, see www.infrastructureaustralia.gov.au/project-evaluations/past-evaluations?f%5B0%5D=sector_tab_pa%3A32.

4

Tools to analyse uncertainty

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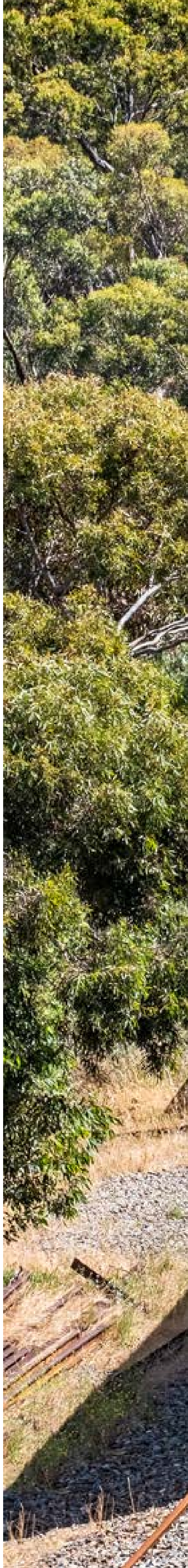


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4.1 Decision-making under uncertainty

Accounting for uncertainty requires a different approach from that used for project risks due to the greater challenges in quantifying the likelihood and consequences of events.

These events, if they materialise, have the potential to alter investigations and significantly impact the outcomes of infrastructure proposals, so should inform the selection of the preferred option. You need to methodically identify and test sources of uncertainty.

Where significant uncertainty exists, you should build in more flexibility and resilience to accommodate uncertainties and deliver intended outcomes.

Accounting for uncertainty may lead to options that:

- perform well under a wide range of alternative futures and are not just designed for one future
- involve deferring or staging the investment so that the design can accommodate emerging information to better define uncertainties
- incorporate greater flexibility into the design, for example, building at smaller scale in a way that allows for much easier and less costly expansion and adaptation.

Table 9 shows tools that are appropriate to understand and manage uncertainties.

Table 9: Tools to understand and manage uncertainties

Tool	Description
Scenario analysis	Assessing outcomes for different but plausible futures. Depending on the investment, these alternative futures might be modelled in detail or the expected outcomes assessed in a more qualitative way.
Real options analysis	Analysis of future scenarios which could occur and how alternative strategies or proposals perform under these scenarios. Based on this analysis, the proposal can incorporate flexibility into the investment in response to uncertain future outcomes and value how this flexibility impacts the costs and benefits.

Important steps to account for uncertainty

We expect that to account for uncertainty you complete the following actions:

- **Stage 1: Consider the likely role and significance of uncertainty for the proposal adopting a structured and transparent approach to identifying significant sources of uncertainty.** Identify events that cannot be adequately managed through risk analysis and are considered significant for the options analysis and incorporate their assessment in the project planning. It may be appropriate to identify and quantify scenarios for key uncertainties where resilience is identified as a driver for the proposal. For example, where the proposal is being developed to mitigate against flooding or improve access during critical incidents such as bushfire.
- **Stage 2: Develop and apply scenarios to incorporate the expected impacts of uncertainty in the analysis appropriate to the significance of uncertainty.**
- **Stage 3: Further refine and apply scenario analysis and, if uncertainties are considered significant for the assessment, apply real options analysis to inform the choice of preferred option.**

4.2 Scenario analysis

Scenario analysis is a process of analysing the possible outcomes of a strategy or an investment by considering a range of alternative, possible future states, called 'scenarios'. It is based on the premise that investing in infrastructure is a complex process, which must consider uncertainty and understand that assets may have to perform under many plausible futures.

Scenario analysis presents several alternative future states for an investment, rather than developing one assumed future, as is often the case in traditional investment decision-making. The scenarios combine to provide a set of distinctive, internally consistent views of a future world that can be constructed in the way that the probable range of results will be covered.

Scenario analysis helps to ensure that preferred options are robust to the range of possible futures that may play out.

Applying scenario analysis involves:

- identifying and describing a number of different plausible future scenarios based on uncertainties relevant to the proposal
- reviewing how options performs under each of those futures.

This allows you to:

- test how robust options are in the face of uncertainty about the future
- assist decision-makers in choosing robust options.

For example, an expanded transport corridor, including additional road capacity, is required to establish a new residential suburb. The transport infrastructure is designed to provide the capacity needed once this suburb is fully developed and to withstand the impacts of a 1 in 100-year storm event. There are several sources of uncertainty that might significantly impact the intended outcomes of this investment over a 30-year appraisal period. For example, disruption due to technology or behavioural change might affect the scale of population growth and nature of travel demand, while climate change may lead to a much higher likelihood or severity of flooding or other service disruptions.

Where appropriate, scenarios should capture consistent overarching external influences on proposal outcomes. For example, when considering climate impacts, the specific impacts on individual proposals may differ, but the overarching climate scenario should remain the same for every proposal. Similarly, standardised land use and population scenarios should be considered for all proposals within a region.

We recommend that scenario analysis at an appropriate level is included when developing proposals for review by us. The range of scenarios tested will depend on your analysis of the level of uncertainty applying to the proposal. More extensive scenario testing should be applied where you have identified significant uncertainty in assumptions or future states (such as shocks or stresses).

Scenario analysis can be a useful precursor to real options analysis in that it provides a good practice methodology for thinking about 'future states' and their impacts.

Describing future scenarios

You should consider the relevant uncertainties to determine alternative future states that would impact the proposal outcomes. The scenarios identified should describe the possible future outcomes and their impact on inputs, assumptions and proposal outcomes. As part of this work, you should develop a set of scenarios that are optimistic, pessimistic, and more or less probable developments, based on the identified uncertainties. Consequently, an individual scenario should:

- describe a coherent, internally consistent, set of assumptions describing the key characteristics of a 'possible future' such as population levels and distribution, growth rates and assumptions about climate and technological changes
- be evidence-based
- reflect expected variations in key drivers, how these affect people and businesses and their behavioural responses to these changes
- where possible, have a probability weighting assigned to it, based on perceptions about the likelihood of these alternative assumptions eventuating.

In the simplest form of scenario analysis, the likelihood of scenarios can be qualitative in nature, due to the difficulty in estimating the likelihood of uncertain events. However, estimating probabilities of a future scenario or the frequency of events is necessary for probability-weighting scenarios to monetise the impacts of these events and for real options analysis.

As for other types of analysis in this guide, you should note that this is underpinned by a series of subjective decisions, which may introduce other sources of bias into the analysis.

Box 4 provides guidance on how to develop future scenarios.

Box 4: **Developing coherent scenarios**

In most cases, the goal with scenario analysis is to consider 3–4 coherent pictures of the future that enable key areas of uncertainty to be explored.[1] For example, scenarios that could be compared might represent:

- high population and economic growth coupled with higher levels of climate change and a low level of technology disruption
- lower population and economic growth, lower levels of climate change, but significant technology disruption (for example, a high incidence of working from home, more rapid transition to travel electrification and automation).

Scenarios can be developed through a combination of formal projections for population (for example, Australian Bureau of Statistics projections[2]), a climate narrative and, for the more uncertain aspects, statements of changes in technology and consumer behaviour.

While the impacts of scenarios will differ between proposals, they should capture consistent overarching external influences for every project, where relevant, such as standardised climate or population growth scenarios for a city, region or the nation.

When using scenario analysis to frame alternative options, you should consider the least, medium and greatest plausible levels of change, to help identify options that provide robust outcomes across all three scenarios.

It is also important to consider the lifetime of the asset (and possible path dependencies):

- if assets have short lives (e.g. 5–10 years), it may be sufficient to consider one scenario
- if assets are longer lived (e.g. over 10 years), then multiple and more divergent future scenarios become more important.

1. For very large or contentious investments, more comprehensive, quantitative scenario analysis may be warranted: e.g. using Robust Decision Making (RDM). See: Groves, DG, Lempert, RJ 2007, 'A new analytic method for finding policy relevant scenarios', *Global Environmental Change*, Vol. 17, pp 73–85.
2. Australian Government Australian Bureau of Statistics (2018), *Population Projections, Australia, 2017 (base) to 2066*, www.abs.gov.au/ausstats/abs@.nsf/mf/3222.0.

Applying scenario analysis through the Assessment Framework

To assist you with determining when and how to consider uncertainty in project development, we have developed guidance around our preferred approach.

Table 10 details how to consider uncertainties at each stage of the Assessment Framework. **While this process is not a requirement, you should consider which of these actions are appropriate for the investment being considered.**

Table 10: Key steps to incorporate and consider future scenarios

Relevant Stages	Actions to consider future scenarios	Examples
Stage 1	Where resilience is identified as a driver for the proposal, it may be appropriate to identify scenarios for key uncertainties to help quantify the problems and opportunities.	Does an event, such as a shock or stress, have a significant cost associated with it? For example, a one in 100-year storm event may cause significant flooding and/or dam failure. Does this scenario affect projected demands for, or the reliability and affordability of, the supply of the targeted critical services (transport, communications, etc.)? Is the need for access/evacuation routes in fires likely to intensify in future?
Stage 2	Use plausible least and greatest future scenarios to: • help identify options that are robust across scenarios within the timeframe of the options and their consequences • include consideration of robustness in the shortlisting process.	Do some scenarios of inundation (sea level rise or flooding) suggest an alternative location or greater levels of protection that appears unaffected under current forecasts? If changes in temperature and rainfall affect future water demand, can the design of proposed water storage and transfer infrastructure be flexibly staged and cost-effectively expanded should demand significantly exceed forecasts? How are potential variations in climate likely to affect agricultural production and the volumes and patterns of freight demand? How well does the design and timing of transport infrastructure to improve road freight performance match these potential changes? How do different transport options perform if there is a behavioural shift to working from home and digital services, or a shift to driverless cars? How do different energy infrastructure options perform if there is a shift to policies that reduce carbon emissions?

Table 10: *Continued*

Relevant Stages	Actions to consider future scenarios	Examples
Stage 3	Based on the significance of the impacts of the identified uncertainties, determine the appropriate tools for analysing and responding to them: • for a 'Low' level of impact, sensitivity analysis may be sufficient • for a 'Moderate' level of impact, a combination of sensitivity and scenario analyses are usually appropriate • for a 'High' level of impact, you should apply a combination of sensitivity, scenario and real options analyses.	Returning to the earlier example of an upgraded transport corridor connecting a new suburb: • A 'Low' level of impact would entail a level of change somewhat beyond the variability in outcomes captured in a risk analysis. For example, by stretching the range of variables included in a sensitivity analysis – varying the timing and scale of population changes while considering smaller changes to flood incidence. • A 'Moderate' level of impact would take this further, considering shocks including more significant changes in population and growth and adopting a medium climate change scenario. • A 'High' level of impact might incorporate high end but plausible changes in key parameters including significant disruptions, population changes and sudden shocks and worst-case climate change outcomes. Where there is high uncertainty, it is also appropriate to apply real options analysis, described in **Section 4.3** and in more detail for climate impacts in **Section 5.3**.

Applying scenario analysis in Stage 1

Where resilience is identified as a driver for the proposal, it may be appropriate to identify scenarios for key uncertainties to help quantify the problem or opportunity.

This would be achieved by identifying the relevant shocks or stresses to the problem or opportunity that has been identified. The monetised value of a problem or opportunity can be determined by the probability-weighted cost of the event.

Applying scenario analysis in Stage 2

Most large infrastructure projects have a long operating life, enable other developments and create even greater impacts across society when an expected future varies significantly from the one assumed. For example, where residential, commercial or industrial development depends on investments in transport, water, electricity and telecommunications providing services of a certain standard over several decades. There is uncertainty about the performance of planned infrastructure, and this is likely to increase over time, especially beyond one or two decades.

Failure to consider these possibilities may lead to underperforming and potentially stranded assets and poor outcomes that might include danger to human wellbeing. **Scenario analysis should be used in these instances to help identify and refine options so that the recommended option performs better in responding to significant uncertainties**.

Undertaking scenario analysis usually involves identifying and applying drivers of change to establish three or four alternative scenarios of the future. Using data-rich information about forecasts, these drivers are clustered and ranked to identify those that are most important for the goals and objectives defined during Stage 1. A range of 'shocks' (scenario attributes) are then set to test the scenarios through quantitative and qualitative approaches that look for 'tipping points', which can then be compared with the defined goals and objectives.

Scenario analysis should also help identify and design response options to ensure an appropriately diverse range of options is considered and that shortlisted options are 'robust' in being able to respond to the diversity of possible future scenarios that may play out.

In the context of uncertainty, the robustness of an option is described in stricter terms. **An option is said to deliver 'robust' outcomes in the face of future uncertainty if it performs satisfactorily in most plausible, future scenarios** (that is, the option will be lower risk), compared to an option which performs well under one scenario but fails in several others. An option is said to dominate[10] another option if it performs better than the other option in all plausible, future scenarios.

Applying scenario analysis in Stage 3

For CBA, 'scenarios' mean coherent futures driven by plausible sets of exogenous trends in factors such as population, economic growth and climate. While it is often conventional to assume a fixed scenario in the base case for many proposals (particularly transport proposals), **it is good practice to model at least one future alternative scenario in the base case. For large, long-lived investments, the base case should explore a diversity of future scenarios in the same way that the options do**. This will ensure a more accurate estimation of expected cost and benefit flows in the CBA.

The time horizon for analysis should reflect the nature of the problems and challenges likely to prevent the achievement of the defined goals and objectives. For example, some challenges, such as those associated with climate change and the availability and cost of various energy sources, have long-term implications that extend beyond 25 years. Transport networks also tend to have long lives. For these reasons, scenario analysis frequently involves an analysis of the future beyond the next 20, 30 or 40 years. However, medium-term horizons (of five to 10 years) are generally considered more plausible and certain than longer-term horizons.

To assist you in determining when and how to consider risk and uncertainty in a CBA, we have developed guidance around our preferred approach.

Table 11 details how to consider risks and uncertainties at each step of a CBA (as set out in the **Guide to economic appraisal**). **Box 5** provides examples of scenarios to capture the short- to medium-term effects of COVID-19, while **Box 6** provides more detailed guidance on how scenario analysis could be applied to test these scenarios for a proposal.

10. Specifically, first order stochastic dominance.

Table 11: Key steps to incorporate and consider future scenarios in a CBA

CBA steps	Actions to consider uncertainty and risks
Step 1: **Articulate the problems and opportunities being addressed**	Keep the problem focus from Stage 1 in mind – how is this affected in the least and greatest plausible future change scenarios? The problem analysis should examine and quantify current problems where performance falls short of expectations and also forecast how these problems will change over time.
Step 2: **Identify the base case and project case options**	Consider the performance of options at coping with the changed circumstances resulting from the least and greatest plausible scenarios. Consider at least one future, alternative scenario as an alternative base case. Identify the options that cannot adequately cope with this wider level of variability and expand and adapt the options to include those that better cope with the wider set of future states. Consider the full range of approaches for responding to the possible future scenarios.
Step 3: **Identify costs and benefits and how they are measured**	This step in the CBA involves identifying all sources of costs and any impacts that might enhance or detract from the intended outcomes (benefits and disbenefits). For future scenarios, this will primarily involve determining how the identified costs and benefits are affected. However, alternative scenarios may bring in to play impacts that were not thought significant under the assumed scenario (e.g. climate change may make flooding a possibility where it was previously considered as insignificant). Generally, it is more relevant to focus on downside risks and uncertainties, as there is limited value to decision-makers from analysing risks and uncertainties that will positively affect the project to offset the additional effort that these scenarios will require over the core analysis.
Step 4: **Forecast the demand and impacts over the life of the investment**	Quantify the expected impacts for the base case and options under alternative scenarios over the assumed life of the investment. This involves forecasting the scale and nature of the impacts that underpin the costs and benefits estimated in the CBA, including: • The scale and nature of demand (e.g. traffic movements or demand for social infrastructure facilities, such as schools, hospital consultations). • The changes in performance that underpin the benefits including the efficiency and effectiveness of services and their connection to the factors driving this change. This will include the timeliness, quantity and quality of services delivered (e.g. for a road transport project, performance will be measured in terms of travel times, journey lengths and speeds and the reliability of travel. For a health project, performance might encompass the number of people treated and changes in the length and quality of life).

Table 11: *Continued*

CBA steps	Actions to consider uncertainty and risks
Step 5: **Monetise the costs and benefits**	Monetise the expected capital, operating and maintenance costs for options based on the level of expected resources needed to build, operate and maintain each option. Monetise the benefits by applying valuation parameters to the quantified difference in impacts between options and the base case. Include the costs and benefits of risk mitigation options.
Step 6: **Identify non-monetised impacts**	Complete a qualitative analysis of the key risks and uncertainties not quantified or monetised.
Step 7: **Discount costs and benefits to determine the net benefit**	Calculate the difference in costs and benefits between each option and the base case for each future scenario. Consider the relative performance of each option over the range of scenarios. Determine value of additional features added to some options to better manage uncertainty potentially using real options analysis.
Step 8: **Analyse risks and test sensitivities**	Test the performance (net benefit) of each option under the range of scenarios as a process of 'stress-testing' and analysing robustness. Use a break-even analysis to see whether additional risk mitigation is affordable. If the preferred option is sensitive to the choice of assumptions, it is necessary to consider ways to mitigate risks, including potentially re-designing infrastructure projects. In this case, loop back to Step 2.
Step 9: **Report on CBA results**	Describe the results of the analysis. Explain how the proposal is resilient to shocks and stresses.

Box 5: **Using scenarios to consider the uncertainty surrounding COVID-19**

Major infrastructure decisions are made on the basis of expected future need, often spanning a 20- to 50-year planning horizon and based on where people are expected to live and work. The COVID-19 pandemic has had a significant impact on the use of infrastructure and there is uncertainty about the longer-term trends resulting from these behavioural changes.

However, a number of emerging trends have been identified including digitisation (e.g. virtual interaction), decentralisation (e.g. net migration to regional areas, working from home), localism (e.g. increased use of green space and national parks), service innovation (e.g. telehealth) and adaptability (e.g. repurposing infrastructure).

Scenarios may be used to represent COVID-19 impacts over the short- to medium-term in proposal development, including adjustments to reflect reduced travel during traditional commuter peaks (e.g. lower peak-to-day expansion factors), increased use of cars over public transport (i.e. lower public transport demand and/or increased congestion costs), higher regional population growth and/or higher domestic and lower international tourism demand. Where possible, the magnitude of changes should be informed by the available evidence (for example, most recent traffic counts) but it is also possible to use a range of indicative values (for example, 5%, 10%, 20%).

A range of studies exist that you can use to support your consideration and analysis of the impacts of COVID-19, such as Infrastructure Australia's *Infrastructure beyond COVID-19: A national study on the impacts of the pandemic on Australia*[11] and the UK National Infrastructure Commission's *Behaviour change and infrastructure beyond COVID-19*.[12]

4.3 Real options analysis

Real options analysis is an investment evaluation and decision-making process used to embed flexibility into an investment strategy to better structure and manage proposals impacted by uncertainty.

Real options analysis can be used as a way of thinking or as a quantitative technique to place values on options and different investment strategies. In both cases, it represents a process of understanding the value of investments under different future states of the world and developing more nuanced investment strategies to reflect this.

Faced with a future uncertainty that can affect the value of the option, the real option alternative incurs additional costs or forgoes benefits in exchange for flexibility to adapt in the future after the uncertain outcome is resolved. The appraisal question is whether the expected net gain from the additional flexibility exceeds the additional costs of the real option alternative.

Real options analysis should be completed for investigations where project risk analysis has highlighted significant uncertainty in proposal assumptions or future states (such as shocks or stresses). Where this is the case:

- **Stage 2 submissions may consider real options at a high level** (for example, applying scenarios to inform options filtering and estimating the broad impacts of these alternative scenarios. This might be included through an expanded multi-criteria analysis and/or the estimation of these impacts through the rapid CBA)**.**
- **Stage 3 submissions may include more detailed real options analysis** to inform the choice of a preferred option, including estimating the changes in costs and benefits from including greater flexibility**.**

11. Infrastructure Australia 2020, *Infrastructure beyond COVID-19: A national study on the impacts of the pandemic on Australia*, Australian Government, available at: www.infrastructureaustralia.gov.au/publications/Infrastructure-beyond-COVID.
12. National infrastructure Commission 2021, *Behaviour change and infrastructure beyond COVID-19*, UK Government, available at: nic.org.uk/studies-reports/behaviour-change-and-infrastructure-beyond-covid-19/.

Box 6: **COVID-19 scenarios in detail – changes in population growth**

The closure of international borders as a result of Covid-19 has created uncertainty for future population growth. This example demonstrates how you could use a scenario to consider the impact of COVID-19 on population growth and how it may affect a proposal.

The Australian population grew by 321,300 people (1.3%) in 2019–20 to 25.7 million.[13] Despite the COVID-19 pandemic commencing in December 2019, and international travel restrictions commencing between February and March 2021, net overseas migration still accounted for 57% of this growth.

However, this growth was less than the 1.5% increase that was originally forecast by the ABS in its 2018 medium series.[14] As a result, in 2020–21 there are 2.3% fewer people in Australia than was originally forecast in 2018 by the ABS (accounting for real population growth between 2017–18 and 2020–21).

Possible futures

The rate of Australia's population growth in the short term will be highly contingent on the reopening of international borders and return of overseas net migration.

Assuming international borders are reopened by the end of 2021–22, you could expect a progressive return in net overseas migration and increases in the population growth rate over the short-term. For example:

- Assuming net zero migration through 2021–22 would result in a population growth forecast of 0.6% (which is 1.1% lower than the medium series).
- With low rates of net overseas migration following the reopening of the international borders, you could expect population growth of 1.4% in 2022–23 and 1.3% in 2023–24 (-0.1% and -0.2% lower than the medium series).
- As a result, population is forecast to be 3.8% lower than the medium series by 2023–24. A return to normal (medium series) could then be assumed from 2024–25, so this 3.8% differential will persist for remaining forecasts.

How to account for possible futures

The low net international migration scenario as a result of COVID-19 could either be implemented by adjusting land use forecasts before they are incorporated in to demand models, or by directly adjusting economic appraisal benefit cashflows to account for the reduction in population growth (i.e. -2.3% in 2020–21, -3.4% in 2021–22, -3.6% in 2022–23 and -3.8% from 2024–25).

Geographical location will be important, and so this approach should be tailored for the specific state/territory and urban or regional context for the proposal. In this instance, the impacts of reduced net international migration are expected to be more pronounced in an urban environment based on historic settlement patterns concentrated in capital cities. In a regional environment, these impacts may be less pronounced (or even reversed) as a result of net migration from capital cities as a result of increased remote working and increased domestic tourism in regional areas.

Presenting results

To present the results of this scenario, you would present your CBA outputs using population scenario inputs (including benefits, costs, BCR, NPV) alongside the central case and any other project scenarios to allow decision-makers to consider the impacts of these possible futures

13. Australian Bureau of Statistics (ABS) December 2020, *National, state and territory population*, available at: www.abs.gov.au/statistics/people/population/national-state-and-territory-population/jun-2020
14. ABS November 2018, *Projected Populations, Australia*, available at: www.abs.gov.au/statistics/people/population/population-projections-australia/latest-release

Defining real options

A real option provides the ability to undertake a different action in the future to alter a project pathway (scope) when uncertainty impacts project scope and performance. Real options:

- Relate to tangible assets. They are called 'real' options because they generally involve changes to physical assets (differentiating them from traditional financial options that relate to the treatment of financial investments such as stocks).
- Provide an ability to act, but no obligation to do so. A real option provides the investor with the capability to take a specific action in the future. However, there is no obligation to take the action if it would be unsuitable to do so given the prevailing conditions at the time.
- Are defined in advance, which gives them value. Real options are distinguished from 'choices' or 'alternatives' by being defined in advance (often via a contract). It is the flexibility that is derived from investing now to enable a valuable change in the future.

Box 7: **Understanding the value of a real option**

The value of a real option is dependent on:

- Different future states of the world and how likely these are – for example, if the likelihood of a high demand scenario is small, then the value of having an option to flexibly expand capacity in the future is likely to be small.
- How different the returns from investments are under different states of the world – if a particular option is preferred under all states of the world, then there is no need to consider option value. If one option is preferred in some circumstances but not others, then a more flexible investment strategy may be worth pursuing.
- Whether or not the uncertainty about the future is resolved and it is clear which scenario is occurring. For example, if it will not be possible to tell in ten years' time if climate change is leading to more frequent flooding or not, then there is no value in building in an option to adjust in ten years. This is because the information set will not yet have improved, and the uncertainty will not be resolved.

At its most basic, option value exists because a particular action has value in some circumstances, but not in all circumstances. There is therefore value in retaining the ability to undertake that action, in case the favourable circumstances occur.

For example, a rail proposal may be viable in 20 years for a new development area in some circumstances, such as rapid population growth, but not in others. To allow for the option of a rail service in future requires that a corridor is preserved now.

Note that option value often exists where an investment is delayed because deferral means a wider range of options for intervening are kept open and you can shape the investment as more information on the most likely future state emerges.

When to apply real options analysis

Real options analysis will not be worthwhile for all investment proposals. Real options analysis will be most useful for proposals that:

- are large and are subject to significant uncertainties
- are capable of staging or being designed to build in flexibility
- are likely to be affected by rapidly changing technologies.

Table 12 describes the factors that are likely to promote or constrain the use of this analysis.

Table 12: Factors that enhance or limit the value of real options analysis

Real options is potentially valuable if…	Real options probably adds little value if…
Decisions affect long timeframes	The project has a short timeframe
Assets have long lifecycles and are costly to adapt once delivered	Assets have short lifecycles or a high degree of obsolescence
Uncertainty is large enough that it may be sensible to wait for more information, or to invest in better information earlier, prior to proceeding	Project information is largely complete and uncertainties do not make a major difference to the preferred option
There are critical dependencies or contingent investment decisions	The investment is standalone
Project costs and benefits may change significantly because of unexpected changes in demand, technologies, population, economic conditions or policy, regulation or legislation. There is a risk that a preferred proposal is no longer feasible or does not offer the best value in addressing the need	Project costs and benefits are unlikely to change significantly because of these sources of uncertainty
Project costs and benefits are susceptible to market supply limitations (e.g. market capacity, capability and competition, evolving technologies and proprietary solutions)	Project costs and benefits are not susceptible to these areas of uncertainty
There are likely to be opportunities for enhanced benefits or cost reductions (e.g. through technology advances)	There are no foreseeable opportunities to reduce costs and increase benefits
There is scope to incorporate flexibility within the investment to deal with uncertainty	There is little or no scope to introduce flexibility into the investment
Significantly better information affecting costs and benefits will be available during the project life	Current information is robust and is unlikely to be significantly improved over time

Source: Adapted from Department of Treasury and Finance 2018, *Investing under uncertainty: real options analysis technical supplement – investment lifecycle and high value high risk guidelines*, Victorian Government, Table 4.

Quantitative real options analysis is particularly useful in considering water investments, as there is considerable uncertainty about future dam levels and inflows from rainfall, and this substantially impacts on the value of new investments. The ability to stage new water supply capacity and deliver this in such a way that it can be extended provides decision-makers with flexibility to respond as dam storage levels change.

This type of analysis is also valuable for managing uncertainty in the transport sector. Coming up with flexible and easily scalable solutions for major transport investments is likely to be important because of the potential impacts of shocks (such as a pandemic), changing technologies (for example, automated vehicles) and population and economic growth on transport demand.

Applying real options analysis

Overall approach

Figure 2 summarises a framework for analysing uncertainty in proposals and developing real options and the trigger points that might activate their deployment.

Once you have determined the scope of real options and how they might be deployed, you can measure the relative performance of real and traditional options by:

- Defining alternative scenarios based on the identified uncertainties (usually a small number, for example, one to two scenarios in addition to the central case), as described in **Section 4.2**
- Assigning likelihoods for the scenarios reflecting your understanding of the likelihood of a particular future occurring
- Measure the costs and benefits of the options selected under each of these scenarios, including estimating present values of costs and benefits and key economic metrics
- Analysing the relative performance of more rigid and more flexible, real options across the range of scenarios and summarising the consolidated performance in terms of weighted benefit cost ratios. This will inform the choice of preferred option while incorporating the impact of uncertainty and the relative merits of a more flexible approach.

Figure 2: Real options analysis framework

Identify the primary sources of uncertainty that could impact your investment

- What factors could impact the investment need or demand for a service, the preferred response, solution implementation or benefits realisation?
- Could any of the uncertainties materially impact the business case assumptions and assumed future state?

Identify how these uncertainties are likely to impact preferred investment strategy

- What would your 'preferred investment strategy' look like under different conditions and future states?
- Under what circumstances would the preferred investment strategy:
  - no longer offer the best value for money
  - no longer achieve the intended benefits
  - be less effective than a different approach
  - be regretted?

Identify how you increase your investment strategy's flexibility to better deal with uncertainty

- If conditions or assumptions do not turn out as you expect, what actions would you take to adapt your project to suit prevailing conditions? Examples include:
  - delaying or staging investment until there is greater certainty
  - expanding or reducing capacity to suit changes in demand
  - switching inputs/outputs to suit changes in demand or supply
  - abandoning the investment
  - increasing design flexibility to add greater resilience.

Indentify trigger points that would prompt a decision to take a different course of action

An event(s) or change of conditions (beyond expected).

Examples include:

- population increase or decrease
- change to demographic makeup
- economic downturn/upturn
- failure of project interdependency
- globalisation/isolationism
- climate change
- switch in technology platform
- new market participant.

Source: Department of Treasury and Finance 2018, *Investing under uncertainty: real options analysis technical supplement – investment lifecycle and high value high risk guidelines*, Victorian Government, Figure 9.

Developing flexible investment strategies

Using real options analysis allows you to develop a flexible investment strategy over future years that can adapt as the future unfolds. Flexibility has value because of this enhanced ability to respond to uncertainty, but this needs to be weighed against any increased costs in providing this flexibility.

The value of flexibility is likely to be greater where:

- uncertainties are expected to become greater over time
- an investment involves some degree of irreversibility – many infrastructure projects are largely irreversible, including most road and rail projects
- committing to an investment narrows the options for further change, such as where widening a road rules out the possibility of a future rail extension.

The inclusion of flexibility should be considered at the early stage of developing options (refer to **Stage 2**) and also during the sensitivity analysis. This may require an iterative approach, refining and analysing options in response to uncertainties and the results of real options analysis.

There are some indictors that show whether flexibility is likely to be valuable:

- if different options are preferred in different scenarios, then this signals that a flexible investment design may be of value.
- if benefits of an option change markedly over time, then this signals that options around staging and deferral should be examined.

Table 13 summarises options that can create flexibility and provides examples for each of these – it has been adapted from the Victorian Government guidelines.

Table 13: Approaches to creating flexibility or reducing decision risk in the face of uncertainty

Category	Description of real option	Example of real option
Timing options – Delaying or staging investment until there is greater certainty		
Option to defer or delay before commencing an investment	An investment may be deferred for a period of time without relinquishing the right to invest in the project. This option is often used to wait and see if input/output prices justify developing and/or operating a capital project. Deferral is not always costless – the investor may need to make a smaller investment to maintain this flexibility. However, the value of greater flexibility may outweigh this cost.	Government procures land within a growth area subdivision to cater for future service demand. Government buys the land prior to property value increases driven by development. It therefore procures the right to construct a facility at some time in the future when there is a service demand, e.g. for schools, police stations, health services, road and rail corridors, and train stations.
Option to invest in information before committing to the investment	An investment may be made to obtain better information before deciding on an investment. This may reduce the costs associated with delay referred to above. Information options include research and development, resource exploration, education and training.	The Government has decided to transition its bus fleet to be zero emissions. However, it invests in a two-year research and piloting program to reduce some of the uncertainty it currently has about the best technical options and the likely evolution of technology over the next decade.
Option to stage the investment (time to build option)	Project implementation can be staged to introduce a series of decision points into the process. At each decision point, Government has the option and flexibility to continue, wait or even abandon the project depending on new information.	This is the most often used option for Government as it allows further work to be undertaken to reduce uncertainties. Funding a project in stages or as a pilot may reduce uncertainty and cost through project evaluation prior to delivering future stages. Government requires a new ICT system. It appoints a contractor to deliver the system, with the project comprising three stages: i) develop a system specification; ii) develop a prototype; and iii) deliver the end product.

Table 13: *Continued*

Category	Description of real option	Example of real option
Scale change options – Expanding or reducing capacity to suit changes in demand		
Option to alter the scale of the investment (e.g. to expand, reduce, shut down and restart)	A capital project can be expanded or reduced in scale depending on whether market conditions are more or less favourable than expected. A reduction option provides the flexibility to reduce service delivery or production output if conditions become unfavourable. An expansion option provides the flexibility to expand the current state to increase service delivery or production. The flexibility to shut down means that once an investment is in operation, the Government has the option to shut down the facility. The shutdown may be temporary, such as during periods when it cannot recover enough revenue to meet its operating costs, or permanent.	A port operator invests in a new port facility as existing infrastructure is operating close to capacity as a result of a recent, rapid increase in trade. A real option may be incorporated as international trade can be dependent on a range of uncertainties. For example, demand can fluctuate depending on changes to global or domestic economic conditions and increasing/decreasing barriers to trade. Changes to ship sizes can also influence port capacity requirements. An expansion option: purchasing additional land to allow for expansion if demand is high. A reduction option: facilities are designed in a modular way to allow for the efficient scaling down of operations if demand falls. Shut down and restart option: for the port operator this might mean closing one of its portfolio of ports until demand picks up. Most public infrastructure can be designed in a way that facilitates subsequent expansion more cost effectively.
Switching options – Switching inputs/outputs to suit changes in demand or supply		
Option to switch outputs or inputs during delivery	If prices or demand change, agencies can change the output mix of the facility (output/product flexibility). Alternatively, the same outputs can be produced using different types of inputs (input/process flexibility).	Output shifts: When building a new rail line, Government may include the functionality to allow for future changes to rolling stock (e.g. double deck carriages or longer train station platforms). Input shifts: A coal fired power station may plan for increased financial penalties for sulphur emissions by using low rather than high sulphur coal sources.

Table 13: *Continued*

Category	Description of real option	Example of real option
Abandon options – Abandoning the investment		
Option to abandon the investment proposal or exit the project during delivery	Some projects have a high degree of uncertainty regarding their potential success or failure. In these instances, an option to abandon can enable government to permanently dispose of an investment. Agencies can realise the resale value of capital equipment, land and other assets in a declining market.	After fully considering other technology options and determining no suitable off the shelf solutions are available, as a last resort, the Government commits to develop a bespoke technology portal to allow schools and kindergartens to share information. The Government committed to a staged approach that allowed for cancellation of the project at defined milestones. The initial prototype does not meet requirements effectively. At this time, a new and more effective product became available and Government cancelled the project.
Design options – Increasing design flexibility to add greater resilience		
Growth options	Options that invest early in the flexibility to upgrade in the future at a much lower cost. An early investment is a prerequisite for follow-on investments opening up future growth opportunities (early investment, e.g. land for future development).	Government constructs a new bridge to a growing suburb and provides the capacity to add extra lanes. There is no current demand for a wider crossing, but Government is planning for increased service demand in the future.
Multiple interacting option	Opportunities to add value and flexibility to a project through multiple real options, usually of different types, but often interacting in complementary or mutually beneficial ways to add value.	A state government delivers a new hospital in a regional city to meet growing demand. There is a possibility the Commonwealth Government will partially fund the project. The state government stages project delivery: • Stage 1 starts immediately, funded internally and is designed so it can operate in its own right • Stage 1 incorporates flexibility to enable additional floors to be added at a later date if additional (Commonwealth) funding becomes available.

Source: Adapted from Department of Treasury and Finance 2018, *Investing under uncertainty: real options analysis technical supplement – investment lifecycle and high value high risk guidelines*, Victorian Government, Table 3.

Example of applying real options analysis

Applying real options analysis requires you to:

- map out a decision tree of alternative options that respond to the key uncertainties identified through the analysis
- set probabilities and expected changes in costs and benefits or each of these pathways
- calculate the expected impact on the net economic returns to inform decision-making.

Box 8 provides a simple worked example of a decision tree for real options analysis, drawing on an example presented in the Victorian Department of Treasury and Finance guide *Investing Under Uncertainty*.[15]

Box 8: **Worked example – decision tree for real options analysis**

This worked example demonstrates how a proponent may use real options analysis to respond to uncertain hospital demand growth. **Figure 3** shows the decision tree for two options for meeting hospital demand growth by either building a new fixed capacity hospital based on demand forecasts or building a more flexible hospital capable of being upgraded in response to actual demand changes, if they occur. All prices presented are in $m.

A traditional approach would focus on alternative options to deliver a hospital with fixed capacity limit. As an alternative approach, given the level of uncertainty around demand, the proponent has considered the value of a real options approach to flexibly respond to demand.

The proponent has also:

- estimated the cost of the two options of a fixed capacity (Option 1) or an upgradable hospital (Option 2)
- estimated probabilities of whether demand conforms to (50%) or exceeds (50%) expectations, these are independent of which option is chosen
- estimated additional costs and realised benefits for these scenarios and options and used these to calculate the 'payoff' or the total benefits minus total costs
- calculated the probability-weighted returns for each option.

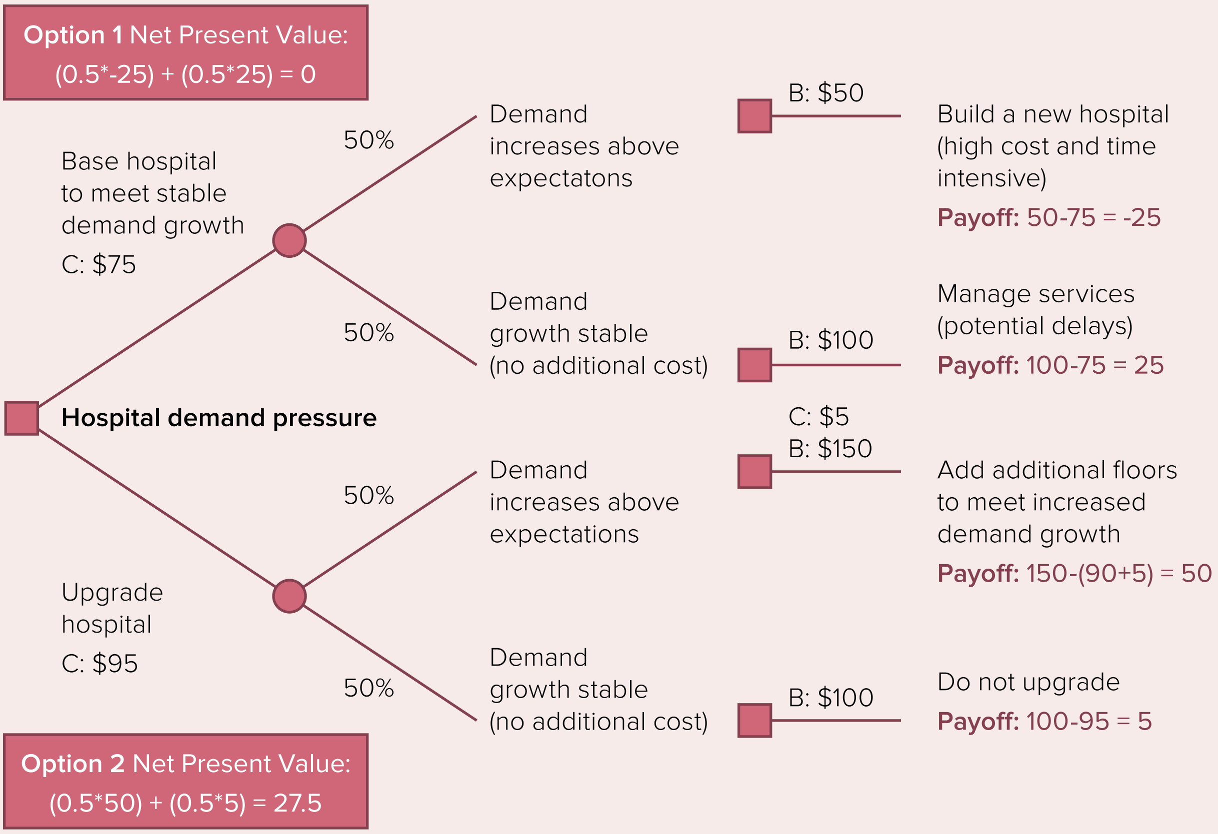
The results suggest that the flexible approach (Option 2) delivers an overall weighted NPV of $27.5, compared to an NPV of $0 for the inflexible approach (Option 1):

- the initial $95 investment in a flexible design costs more than the $75 cost of building to a specific level of demand
- however, there is a significant erosion of benefits where demand exceeds supply (benefit (B) = $50) and a significant benefit enhancement under the flexible option because of the relative ease of expanding services (B = $150 with an additional cost C of $5 to fit out additional floors)
- the relative probabilities of the demand outcomes and the calculated payoffs provide overall NPV (payoff) estimates that suggest the proponent should recommend the more flexible option.

15. Department of Treasury and Finance 2018, *Investing under uncertainty: real options analysis technical supplement – investment lifecycle and high value high risk guidelines*, Victorian Government, pp 50–54

Box 8: **Worked example – decision tree for real options analysis** *continued*

Figure 3: Decision tree for real options analysis



Source: Adapted from Department of Treasury and Finance 2018, *Investing under uncertainty: real options analysis technical supplement – investment lifecycle and high value high risk guidelines*, Victorian Government, pp 50–54.

The Victorian Department of Treasury and Finance's *Investing under uncertainty*[16] provides detailed technical guidance on real options analysis, while ATAP's *O8 Real Options Assessment*[17] provides similar case studies for transport applications.

16. Department of Treasury and Finance 2018, *Investing under uncertainty: real options analysis technical supplement – investment lifecycle and high value high risk guidelines*, Victorian Government, available at: www.dtf.vic.gov.au/sites/default/files/2018-06/Investing%20under%20uncertainty%20-%20real%20options%20ILG%20technical%20supplement%20-%20Version%201%20June%202018.docx
17. Transport and Infrastructure Senior Officials' Committee 2020, ATAP Guidelines *T8 Real Options Assessment*, Transport and Infrastructure Council, Canberra, available at: www.atap.gov.au/tools-techniques/real-options-assessment/index

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Climate risks and uncertainties

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5.1 Considering climate risks and uncertainties

A changing climate presents clear and potentially intensifying risks and uncertainties that are likely to impact infrastructure decision-making. This section describes how the approaches to analysing risks and uncertainties may be applied to climate impacts, and provides examples of relevant impacts.

The impacts of climate change are clearly established and the prospect of these impacts increasing over time is very likely.

Planning for these changes may mean building infrastructure to different standards (e.g. building a bridge to a higher flood specification) and considering different, more flexible options for achieving intended service outcomes (e.g. moving a road corridor away from areas of possible future coastal inundation or changing transport mode to become more flexible).

There is growing evidence that early action on these risks can result in rapid payback times – for example, the Queensland Reconstruction Authority's DARMSys[18] monitoring is showing that improving infrastructure resilience can pay for itself within 2–4 years.

In this section we examine how climate change may impact infrastructure projects, when to consider alternative climate change scenarios for infrastructure investments and when and how to apply risk and uncertainty tools.

We recommend that climate risks and uncertainties are considered and documented in Stage 1, Stage 2 and Stage 3 submissions made to us.

5.2 How climate change impacts infrastructure projects

There are three ways in which climate may affect the value of an infrastructure project:

- **Direct effects** that alter its ability to deliver the intended services or its costs; these may be acute (for example, increasing disaster impacts from natural hazards such as flooding) or chronic (e.g. trends towards higher average temperatures promoting faster corrosion).
- **Indirect effects** that alter benefit flows even if the infrastructure itself is working as intended (for example, changing temperatures and rainfall altering agriculture production and this affecting demand for freight transport and water).
- **Transition risks** where changes in technology, policy or behaviour occur in response to climate change, altering the relevance of the services delivered by the infrastructure whether or not climate change itself eventuates (for example, changing fuel markets that reduce the demand for coal transport to export ports, driverless truck technology that increases movement of goods via trucks, or increased remote working that reduce the demand for transport).

Table 14 provides examples of potential climate risks and uncertainties that might affect infrastructure projects. You should consider these when analysing options.

18. Queensland Government Reconstruction Authority 2017, *Damage Assessment and Reconstruction Monitoring*, DARMsys™, www.qra.qld.gov.au/darm.

Table 14: Examples of climate impacts on infrastructure projects

Phase and effect	Examples
Disrupting the construction phase	Higher frequency of flooding during construction, or heatwaves inhibiting outdoor work.
Interrupting the flow of services from the asset once operating	High temperatures causing a transformer to shut down or a flood event closing down a road.
Increasing maintenance and repair, or other running costs like cooling	Damage from storms, fires or high winds or increased corrosion. Increased cooling demands due to poor design for high temperatures.
Reducing the asset's life	Inability to cope as long as intended with coastal flooding as sea levels rise – i.e. expected benefit flows are not able to be maintained due to direct effects.
Altering the expected demand for the asset during its lifetime	Changes in need for agricultural transport because of climate change affecting what crops can be grown, or global policy changes reduce the viability of coal exports – i.e. expected benefit flows change due to indirect effects.
Affecting the residual value of the asset, potentially creating public liabilities beyond an evaluation period	A flood mitigation dam that cannot cope with increased scale of flooding later in the century; sea walls that become prohibitively expensive to maintain with sea level rises.
Altering cross-dependencies, where assets depend on other infrastructure, which may also be affected by climate	Water supplies may be dependent on electricity for pumping and power supplies and are subject to more outages due to storm and bushfire damage.

5.3 When to consider climate risk and uncertainty

Many proposals may not need to consider future climate risks in detail. This section provides a simple decision tree to determine whether such consideration is needed. Determining whether to incorporate climate change risks in shortlisting options (during Stage 2 of the Assessment Framework) depends on an analysis of the expected impacts of these risks on the costs and benefits of the options.

Conventional CBA may not adequately incorporate climate change risks and uncertainties because it assumes that decisions are concerned with:

- actions of limited irreversibility
- limited path dependency
- short lifetime
- small value changes
- limited interdependencies
- low levels of uncertainty
- small option values associated with delay or other sources of flexibility.

Whether climate change needs explicit consideration depends on expectations about how well these assumptions are likely to be met.

You can determine how climate change should be treated in proposals by answering the following questions:

- How significant are the impacts of climate change likely to be in shaping the outcomes of the investment?
  - If there is no connection, then general climate change trends can be incorporated in the central case but no further consideration of specific uncertainties is required.
  - If climate change is likely to be significant, then its impacts need to be incorporated in the options identification and analysis process, including through the analysis of risk and uncertainty and the detailed CBA (in Stages 2 and 3).
- What is your level of understanding and confidence about forecasting climate change events that are likely to affect the investment and forecasting the impact of those events?
  - If the events are predictable, they will be incorporated in the risk analysis, sensitivity testing and, where relevant, scenario testing.
  - For some aspects of climate change that are more uncertain, this will likely require more extensive scenario testing. Where the level of uncertainty is very large, you should use real options analysis.
- Is the proposal specifically aimed at climate adaptation?
  - If so, you will need to use detailed analysis of climate impacts using scenario analysis and, where relevant, real options.

5.4 Applying tools for climate risk and uncertainty

When preparing a submission to us, we suggest that you briefly describe:

- the impacts of climate change risks and uncertainty on your proposal
- the outcomes of your analysis and how options have been refined or new options developed as part of this process.

To assist you in determining how to consider climate adaptation in project development, we have developed guidance around our preferred approach.

Table 15 details how to consider risks and uncertainties in the first three stages of the Assessment Framework. **While this process is not a requirement, it provides an example of how climate change can be considered at each stage**.

Table 15: Planning for climate risks and uncertainties in the Assessment Framework stages

Relevant Stages	Actions to consider future scenarios	Examples
Stage 1	Analyse expected climate risks and uncertainties, then identify any key impacts relevant to the proposal. Where resilience is identified as a driver for the proposal, it may be appropriate to identify scenarios for key uncertainties to help quantify the problem or opportunity.	Will agricultural demand for water significantly increase due to changes in temperature and rainfall? Are access/escape routes in response to fire or flooding sufficient if the severity of these events is expected to intensify in future? Is an intervention required to respond to increased inundation of populated areas (sea level rise or flooding)? Would a climate event have a significant cost associated with it? For example, a one in 100-year storm event may cause significant flooding and/or dam failure.
Stage 2	Confirm all relevant climate risks and uncertainties, in addition to those that may be key drivers for the proposal. Identify options that are resilient to the identified climate risks and uncertainties. Consider performance against the key climate risks and uncertainties when analysing options to develop your shortlist. It may be appropriate to apply qualitative risk analysis, sensitivity and/or scenario analyses. Apply a qualitative risk analysis to understand the expected significance of risks and identify events that need to be managed as uncertainties. For uncertainties, develop scenarios for the least, highest and medium climate impacts. Test the impact of these scenarios on the shortlist of options.	How do changes in temperature and rainfall affect regional agricultural production and consequent freight demand? Is increased damage or disruption anticipated due to storms, fires, high winds or corrosion? Include measures for mitigating climate change risks, such as consideration of additional costs for cooling such as tree-planting for an urban warming scenario. Do some scenarios of inundation (sea level rise or flooding) suggest an alternative location for the proposal that is unaffected? Can options be staged? For example, if changes in temperature and rainfall affect future water demand, can water storage options respond? Determine how the base case and options are expected to change over time with respect to climate change. Consider the effect on anticipated benefits if demand changes due to climate impacts. For example, additional likelihood of extreme weather events impacting infrastructure (flooding, bushfires). Consider sensitivity tests for parameters related to climate change. For example, this could include parameters such as price of carbon or willingness-to-pay values for emissions or environmental parameters.

Table 15: *Continued*

Relevant Stages	Actions to consider future scenarios	Examples
Stage 3	Analyse the shortlisted options in detail, considering the performance against the key climate risks and uncertainties. It may be appropriate to apply qualitative risk analysis, sensitivity and/or scenario analyses. For risks, revisit the qualitative analysis for the shortlisted options and complete sensitivity tests to understand the impact of risks. For uncertainties, refine and complete further scenario testing. Where uncertainties are likely to have a significant impact, apply real options analysis to develop flexible investment strategies that will respond as more information becomes available.	Provide a qualitative description of how climate risks and uncertainties impact the proposal. For example, the potential impacts of more extreme weather events on the reliability or availability of infrastructure. Test additional sensitivities on proposal variables impacted by climate change. For example, this could include parameters such as price of carbon or willingness-to-pay values for emissions or environmental parameters. Test additional scenarios based on future states of climate change to analyse how they would impact the costs and benefits over the evaluation period. Use the information to determine if there is still a net benefit once the costs of responding to a climate risk are considered. For example, by considering if the costs to build a bridge to cope with larger floods are outweighed by the benefit of community access during flood events. Invest in flexibility by committing to time-critical elements but delaying major investments. Build in a more flexible form. For example, a dam wall could be built with larger foundations so that, if needed, the wall height could be increased in future more cheaply than by re-building. Define and agree triggers for proposal approval or additional staged development that are condition-dependent rather than time-dependent. For example, linking decisions to particular levels of demand or climate effects, such as rainfall, dam levels, coastal erosion or the incidence of bushfires.

Glossary

Term	Definition
Appraisal	The process of determining the impacts and overall merit of a proposal, including gathering and presenting relevant information for consideration by the decision-maker.
Appraisal period	The number of years over which the benefits and costs of an infrastructure proposal are assessed in a **cost–benefit analysis**. A default value of 30 operational years plus construction time is generally used for infrastructure proposals. Refer to the **Guide to economic appraisal** for more information.
Assessment	For the purposes of the **Assessment Framework**, this refers to Infrastructure Australia's evaluation of proposals submitted to us for inclusion on the ***Infrastructure Priority List*** or for a funded proposal review.
Assessment Criteria	The three criteria Infrastructure Australia assesses proposals against: **Strategic Fit, Societal Impact** and **Deliverability**.
Assessment Framework	A publicly available document that details how Infrastructure Australia assesses infrastructure proposals. It provides structure to the identification, analysis, appraisal, and selection of proposals and advises proponents how to progress through the following four stages: • Stage 1: Defining problems and opportunities • Stage 2: Identifying and analysing options • Stage 3: Developing a business case • Stage 4: Post completion review
Australian Infrastructure Audit	Published in August 2019, the Audit was developed by Infrastructure Australia to provide a strategic assessment of Australia's infrastructure needs over the next 15 years. It examined the drivers of future infrastructure demand, particularly population and economic growth. Data from the Audit is used as an evidence base for assessments of proposals for inclusion on the ***Infrastructure Priority List***.
Australian Infrastructure Plan	The 2021 Plan was developed by Infrastructure Australia as a positive reform roadmap for Australia. Building off the evidence base of the Audit (see ***Australian Infrastructure Audit***), the Plan sets out solutions to the infrastructure challenges and opportunities Australia faces over the next 15 years, to drive productivity growth, maintain and enhance our standard of living, and ensure our cities remain world class. The 2021 Plan supersedes the February 2016 Plan.
Base case	A project **appraisal** compares the costs and benefits of doing something (a 'project case') with not doing it (the 'base case'). The base case should identify the expected outcomes of a '**do-minimum**' situation, assuming the continued operation of the network or service under good management practices. We recommend the committed and funded expenditure approach to defining the base case, but recognise that some states and territories use the planning reference case approach.
Benefit–cost ratio (BCR)	This is the ratio of the present value of economic benefits to the present value of economic costs. It is an indicator of the economic merit of a proposal presented at the completion of a cost-benefit analysis. (See **cost–benefit analysis**).
Business case	A document that brings together the results of all the assessments of an infrastructure proposal. It is the formal means of presenting information about a proposal to aid decision-making. It includes all information needed to support a decision to proceed, or not, with the proposal and to secure necessary approvals from the relevant government agency. Unless otherwise defined, we are referring to a final or detailed business case, rather than an early (for example, strategic or preliminary) business case, which is developed in accordance with state or territory requirements. A business case is prepared as part of Stage 3 of the Assessment Framework.
Capital cost	The initial fixed costs required to create or upgrade an economic asset and bring it into operation. This includes expenses such as the procurement of land, buildings, construction, labour and equipment.

Term	Definition
Cost–benefit analysis (CBA)	An economic analysis technique for assessing the economic merit of an infrastructure proposal. It involves assessing the benefits, costs, and net benefits to society the proposal would deliver. It aims to attach a monetary value to the benefits and costs wherever possible and provide a summary indication of the net benefit. (See **benefit–cost ratio**).
Cost distribution	**Probabilistic project cost estimates** identify cost components, determine the probability distribution for each cost component and then undertake a simulation (often a 'Monte Carlo' simulation) to generate a probabilistic distribution of project costs.
Demand forecasting	The activity of estimating future demand (such as public transport patronage, vehicle volumes or water usage) in a particular year or over a particular period.
Discount rate	The interest rate at which future dollar values are adjusted to represent their present value (that is, in today's dollars). This adjustment is made to account for the fact that money today is more valuable than money in the future. **Cost–benefit analysis** should use real social discount rates.
Do-minimum	A base case reflecting the continued operation of the network or service under good management practices. It should assume that general operating, routine and periodic maintenance costs will continue to occur, plus a minimum level of capital expenditure to maintain services at their current level (e.g. maintaining access or reliability) without significant deterioration. This may include asset renewals and replacement of life-ending components on a like-for-like basis, as well as committed and funded projects and smaller scale changes required to sustain viable operations under the base case. (See **base case**).
Expected Value	The mean value of the **cost distribution**. If the cost distribution is symmetrical, the Expected Value will be equal to the P50 value. Where the cost distribution is positively skewed, the mean will be above the P50 value and may lie closer to the P90 value. (See **P50 cost** and **P90 cost**)
First-year rate of return (FYRR)	Benefits minus operating costs in the first full year of operation of a proposal discounted to the start of the evaluation period, divided by the present value of the investment costs, expressed as a percentage. The first-year rate of return is used to determine the optimum timing of proposals.
Impact	A generic term to describe any specific effect of a proposal. Impacts can be positive (a benefit) or negative (a cost).
Infrastructure	Physical assets and facilities that enables organisations to provide goods and services to the community and improves quality of life, efficiency, accessibility and liveability of our cities and regions. This includes, but is not necessarily limited to, transport, energy, telecommunications, water and social (such as health, education, social housing and community facilities) infrastructure.
Infrastructure Priority List	The Priority List is a credible pipeline of nationally significant infrastructure proposals that are seeking investment. Every proposal on the Priority List is expected to contribute to national productivity or to be otherwise socially beneficial. It is a statement of where governments, the community and the private sector can best focus their infrastructure efforts.
Investment costs	The costs of providing the infrastructure before operations commence (e.g. costs for planning and design, site surveying, site preparation, investigation, data collection and analysis, legal costs, administrative costs, land acquisition, construction costs, consequential works, construction externalities). In some cases, investment costs can recur throughout the **appraisal period** (e.g. asset replacement or renewal costs). For **cost–benefit analysis**, these should all be expressed in economic cost terms (also known as resource costs).
Longlist of options	A comprehensive list of potential options to address the problems and realise the opportunities identified in Stage 1. The longlist includes all options that are identified for a proposal and should represent a range of reasonable alternatives, including capital and non-capital options, as well as demand-side and supply-side options.
Maintenance	Incremental work to repair or restore infrastructure to an earlier condition or to slow the rate of deterioration. This is distinct from construction and upgrading, which seeks to extend infrastructure beyond its original condition.

Term	Definition
Monetised	Where a quantified impact has a corresponding dollar value attached to it. (See **impact**).
Net present value (NPV)	The monetary value of benefits minus the monetary value of costs over the appraisal period, with discount rates applied (See **discount rates** and **appraisal period**).
Network	Infrastructure networks are the physical assets that enable the provision of services such as transport connectivity, power, water and internet.
Non-infrastructure options/ solutions	Proposals that avoid the need for significant expenditure on new or upgraded infrastructure. For example, changes to pricing or reforms to regulations.
Operating costs	The costs of providing the infrastructure after it has commenced operation (e.g. maintenance and administration costs of a facility).
Opportunity	An evidence-based reason for action that results from a gap between an actual and a desired outcome. In the context of the Assessment Framework, an opportunity is informed by the ***Australian Infrastructure Audit*** and by our collaboration with proponents to identify jurisdictional and national opportunities.
Option	A possible solution to a problem, including base case options such as 'do nothing' or 'do minimum'. (See **base case**).
Options analysis	The analysis of alternative options for solving an identified problem or realising an identified opportunity. (See **option**).
Path dependencies	The continued use of an asset or service based on historical preference or use. For example, railway track guages are a prominent historical example of path dependence. Decision-making, where there may be path dependencies, should be more rigourously tested due to the disproportionate long term implications of decisions.
Probabilistic project cost estimates	These estimates identify cost components, determine the probability distribution for each cost component and then undertake a simulation (often a 'Monte Carlo' simulation) to generate a probabilistic distribution of project costs. (See **cost distribution**, **expected value**, **P50 value** and **P90 value**).
Problem	An evidence-based reason for action that results from a gap between an actual and a desired outcome. In the context of the Assessment Framework, problems are informed by the ***Australian Infrastructure Audit*** and by our collaboration with proponents to identify jurisdictional problems and national problems.
Producer surplus	The difference between the price at which a producer is willing to supply a particular good or service and the price the producer actually receives.
Productivity	The efficiency with which the economy as a whole convert inputs (labour, capital and raw materials) into outputs. Productivity grows when outputs grow faster than inputs, which makes the existing inputs more productively efficient.
Project	An infrastructure intervention. A project will move through the stages of project initiation, planning, delivery and completion. A suite of related projects to address a common problem or opportunity will create a **program**.
Program	A proposal involving a package of projects that are clearly interlinked by a common **problem** or **opportunity.** The package presents a robust and holistic approach to prioritise and address the projects, and there is a material opportunity to collaborate and share lessons across states, territories or agencies. The projects can be delivered in a coordinated manner to obtain benefits that may not be achieved by delivering the interventions individually. (See **project**).
Proponent	An organisation or individual who prepares and submits infrastructure proposals to us for assessment. To be a proponent of a business case (a Stage 3 submission), the organisation must be capable of delivering that proposal. (See **business case**).
Proposal	The general term we use for successful submissions to the ***Infrastructure Priority List***, across the key stages of project development, specifically – early-stage (Stage 1), potential investment options (Stage 2) and investment-ready proposals (Stage 3). Proposals that have been delivered would be assessed in Stage 4.

Term	Definition
P50 cost	An estimate of project costs based on a 50% probability that the cost estimate will not be exceeded.
P90 cost	An estimate of project costs based on a 90% probability that the cost estimate will not be exceeded.
Qualitative	A description of an impact that does not rely on quantitative or monetised information.
Quantitative / quantified	A description of an impact that utilises, presents or references values, numbers or statistics.
Real prices	Prices that have been adjusted to remove the effects of inflation. They must be stated for a specific base year, for example '2016 prices'. (See **base year**).
Real options analysis	An investment evaluation and decision-making framework used to embed flexibility into an investment strategy to better structure and manage projects impacted by uncertainty. Real options analysis can be used as a way of thinking or as a quantitative technique to place values on options and different investment strategies. In both cases, it represents a process of understanding the value of investments under different future states of the world and developing more nuanced investment strategies to reflect this.
Residual value	The value of an asset at the end of the appraisal period. Residual values are used in cost–benefit analysis calculations involving long-lived assets whose life extends beyond the end of the appraisal period. (See **appraisal period** and **cost–benefit analysis**).
Resilience	The ability of the community to anticipate, resist, absorb, recover, transform and thrive in response to shocks and stresses to realise positive social, economic and environmental outcomes.
Risk	Events that have probabilities of occurrence that are predictable and outcomes that can be estimated with some confidence.
Scenario analysis	Scenario analysis provides a framework for exploring the uncertainty about future consequences of a decision, by establishing a small set of internally consistent future scenarios and assessing options against each of them. This form of analysis is especially useful for decision-makers faced with forms of uncertainty that are uncontrollable or irreducible (e.g. future technology change or increased climate variability).
Sensitivity analysis	Changing a variable, or a number of variables, in a model or analysis to test how the changes affect the output or results.
Shortlist of options	The set of options determined as most likely to benefit the Australian community using a structured, quantitative and unbiased analysis (in Stage 2). The shortlist of options is taken to Stage 3 for detailed analysis. We recommend the shortlist includes at least two viable options.
Social, economic and environmental impact	The positive and negative effects of a proposal, with regards to: • social: quality-of-life effects, such as social exclusion and access to services, employment and safety. • economic: productivity effects, such as productive capacity, economic capability, global competitiveness. • environmental: effects such as greenhouse gas emissions, waste treatment, noise pollution, visual intrusion, heritage impacts.
Themes	Themes are outcome areas within our Assessment Criteria. Each criterion comprises five themes. (See **Assessment Criteria, Strategic Fit, Societal Impact** and **Deliverability**).
Sustainability	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Uncertainty	Events where probabilities of occurrence are difficult to predict and outcomes are challenging to quantify.

Infrastructure Australia is an independent statutory body that is the key source of research and advice for governments, industry and the community on nationally significant infrastructure needs.

It leads reform on key issues including means of financing, delivering and operating infrastructure and how to better plan and utilise infrastructure networks.

Infrastructure Australia has responsibility to strategically audit Australia's nationally significant infrastructure, and develop 15-year rolling infrastructure plans that specify national and state level priorities.

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