TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

O8 - Real Options Assessment

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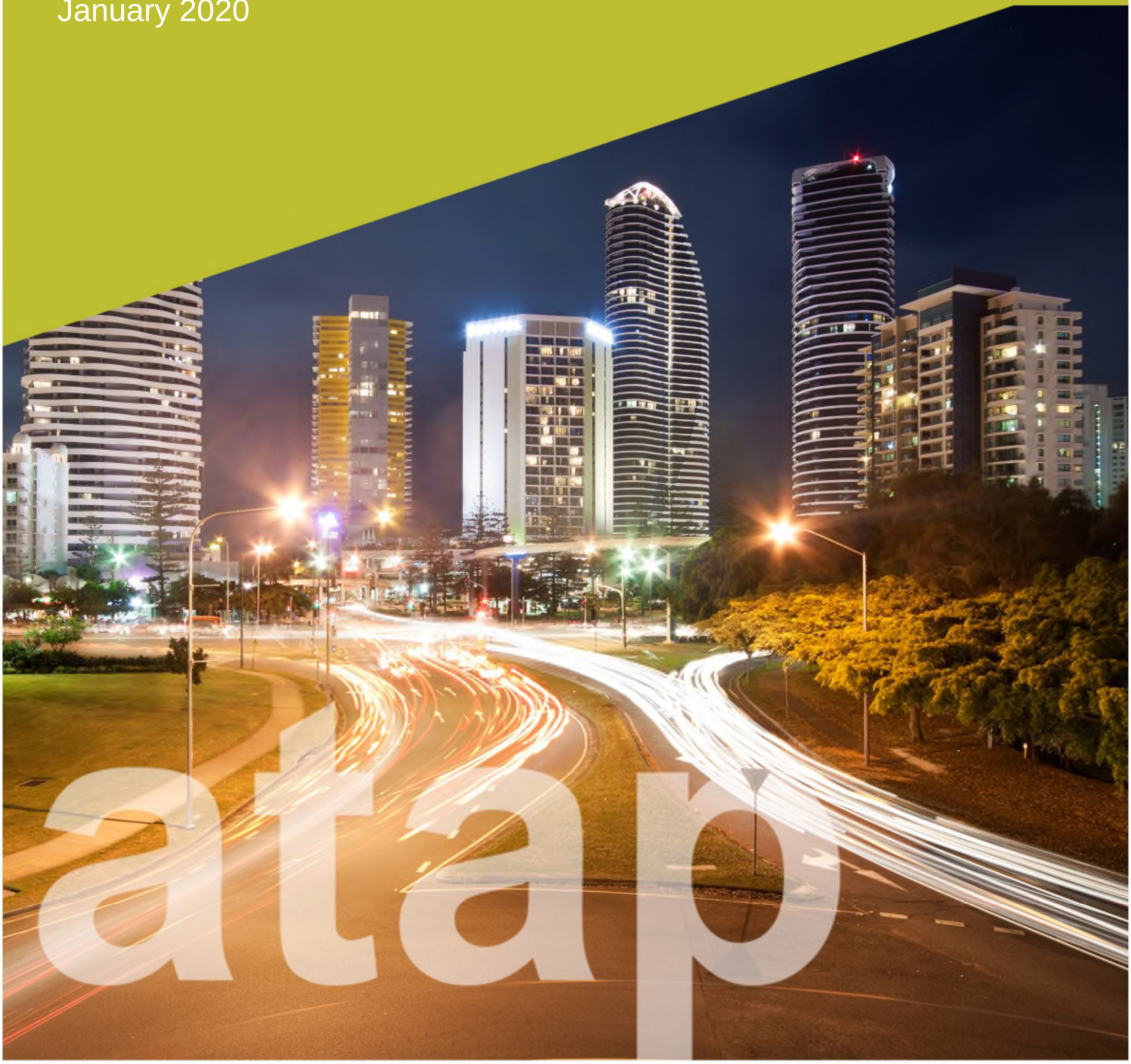

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For enquiries or feedback about this publication please contact:

ATAP Steering Committee Secretariat
Australian Transport Assessment and Planning Guidelines
Commonwealth Department of Infrastructure and Regional Development
GPO Box 594 CANBERRA ACT 2601
Email: atap@infrastructure.gov.au

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Contents

Figures

Tables

Real options assessment

At a glance

- This part of the Guidelines considers the assessment methodology called real options assessment. It provides a high-level overview of real options assessment, and illustrates its use in transport assessment
- Real options assessment can assist in finding solutions to a transport problem in the face of current and future uncertainty. A real option is a special type of option, containing a degree of flexibility in its design to allow changes in the nature or timing of investment as the future becomes more certain.
- As a result, real options provide the ability to identify a flexible investment strategy over future years that can adapt as the future unfolds
- Real options assessment is a form of appraisal that applies the discounted cash-flow methodology of cost-benefit analysis to real options. It provides a structure for minimising the costs of uncertainty by modifying the characteristics of the investment in response to changing circumstances
- For example, delaying an investment until better information about demand becomes available, or building flexibility in design to allow an investment to be expanded or modified, are two real options. Delaying an investment may reduce the probability that an initiative is over-designed relative to demand. Building flexibility into design may avoid expensive rework as user demands change
- Five types of real options actions are: timing, scale change, switching, abandon, and design
- After real options have been identified, a real options assessment then assesses those options to see if they create net benefits. Faced with a future uncertainty that can affect the value of the option implemented, 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 assessment will not be worthwhile for all investment initiatives. Real options assessment will be most useful for initiatives that:
  - Are large
  - Face significant uncertainties on the supply (delivery) or demand sides
  - Are divisible or stageable
  - Are subject to rapidly changing technology (see DTF 2018) for useful discussion)
- Like all analytical techniques, real options assessment has a number of elements that might restrict its applicability in the appraisal of public infrastructure investments. Two key ones are mentioned: administrative practicality; and reliance on subjective probability estimates
- Two case studies are summarised in Chapter 3

1. Introduction

This part of the Guidelines considers the assessment methodology called real options assessment. The primary purpose of the guidance is to provide a high-level overview of real options assessment, and illustrate its use in transport assessment.

Real options assessment can assist in finding and improving solutions to a transport problem, solutions that better manage future uncertainty. A real option is a special type of option, containing a degree of flexibility in its design to allow changes in the nature or timing of investment as the future becomes more certain. Real options assessment is a form of appraisal that applies the discounted cash-flow methodology of cost-benefit analysis to real options.

Real options assessment therefore complements CBA. Accordingly, it is recommended that this guidance be read alongside ATAP Part T2. Practitioners are also directed to ATAP Part T7 for a broader discussion of risk and uncertainty, where real options assessment is noted as one of a range of assessment techniques that can be used to account for risk and uncertainty.

Chapter 2 discusses the context for using real options assessment and provides an overview.

Chapter 3 then provides several case studies of applications of real options assessment.

Readers are directed to DTF (2018) for a more comprehensive discussion of how real options assessment can be used across the whole life cycle of a project.

2. Context and overview

2.1 Why undertake real options assessment?

Investment decisions are typically taken in the face of uncertainty about market demand, population growth, technology, changes in consumer preferences or changes in policy and legislation. Real options assessment provides a structure for improving the management of uncertainty faced by project, by facilitating modifications that allow the investment to respond better to changing circumstances.

For example, delaying an investment until better information about demand becomes available, or building flexibility in design to allow an investment to be expanded or modified, are two real options. Delaying an investment may reduce the probability that an initiative is over-designed or over-capitalised relative to demand. Building flexibility into design may avoid expensive rework as user demands change. Note that keeping open the option to invest later can involve additional short-term costs (an 'option premium') such as purchase or reservation of land. This point in outlined in more detail in BITRE (2014).

Overall, real options provide the ability to identify a flexible investment strategy (DTF 2018) over future years that can adapt as the future unfolds. As BITRE (2014) note, the real options approach involves consideration of options for waiting and staged flexibility.

2.2 The role of uncertainty

The use of real options analysis is a response to the existence of uncertainty about the future and present, and the need to account for that in decision making about infrastructure decisions. Uncertainty is therefore the driving force. DTF (2018) notes that, with uncertainties generally outside the control of the decision-maker, it is difficult to account for them in making robust investment decisions. Examples of such uncertainties in transport sector investment are shown in **Table 1**.

Table 1. Uncertainties in transport sector investment

Drivers of uncertainty	
Demographic	Population growth in aggregate and in particular areas
	Changing land-use and economic development patterns (including growth in regional centers and decline of rural towns)
	Changing workforce and human resource issues (e.g. Telecommuting and teleconference meetings).
	Increase in demand for services, both in quantity and nature (beyond that attributed to population growth and ageing)
	Changing community expectations, for example, a demand to extend traditional hours of service delivery
Economic	The consequences of Globalization resulting in increased protectionism, conflicts over trade, and departure from multinational common markets (e.g. Brexit, US-China Trade Wars,
	Changes in global economic conditions and financial markets (e.g. financial crises, term-of-trade shocks, asset bubbles, and boom-bust cycles in other markets)

Drivers of uncertainty	
	Fluctuations in Australian dollar worth and impact on competitiveness of Australian exports
	Structural changes in the domestic economy
	Industry sector and trends, such as continued rapid decline in manufacturing and heavy industry and increases in service sector industries
Environmental	Climate change and increased frequency of extreme weather events
Governmental, policy, legislative and legal	Changes to national and State policy agenda and priorities
	Changes to trade agreements etc.
	Asset failure risk
Technological	Rapid technological change, e.g. changing telecommunications; semi-autonomous and autonomous vehicles (e.g. driverless cars and driverless trains); electric vehicles
	Innovation, technological disruption
	Increased demand for online delivery of services (and faster delivery of services)

Source: Adapted from DTF (2018)

2.3 What is real options assessment?

2.3.1 Real options

BITRE (2014) defines a 'real option' as part of a 'good project appraisal' as a:

> *…decision taken today that makes it possible for policy makers to take a particular action in the future'*

In transport, the reservation of a future transport corridor is a classic case of a real option. If population and employment growth or changes in modal preferences change according to expectations, the corridor can be eventually developed, avoiding the costs associated with future disruptive resumptions. If expectations are not realised, the agency can recoup its investment by returning the corridor to the market.

What are real options?

A real option is the right, but not the obligation, for an investor to undertake certain actions in the future to alter a project pathway (scope) when uncertainty impacts current project scope.

Real options:

- Relate to tangible assets. They are called ‘real’ options because they generally relate to physical assets (differentiating them from traditional financial options that relate to the treatment of financial investments such as stocks)
- Provide an ability to undertake an action, 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 to enable action to be taken cost effectively, and pre-defining the action, that gives the option value.

Source: DTF (2018)

2.3.2 Real options assessment

After real options have been identified, a real options assessment then assesses those options to see if they improve the community’s overall welfare. 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.

2.4 Relationship to cost-benefit analysis

Real options assessment is essentially an extension of CBA. It applies the discounted cash flow methodology of CBA to a particular type of option — real options. The section below provides more detail on how real options can be incorporated into CBA thinking.

How do real options adjust traditional CBA thinking?

A key challenge for CBA of transport projects is that they rely on projections and forecasts that estimate the impact of changes decades into the future, often at least 30 years into the future, and in many cases beyond: up to 100 years to account for the full life of the assets and their use.

These very long time frames make forecasting challenging, if only because so much can happen in the future. For example, patronage demand forecasts may perform very well for sustained periods of time but then be impacted significantly by an unanticipated shock to oil prices or a financial crisis that impacts both employment and household income negatively. Even developments such as autonomous vehicles and ride-sharing create significant uncertainty about not only the level of patronage demand but also its pattern, with some predicting that autonomous vehicles will cause cities to be more spread out, while other claim that it will lead to higher density.

Further, where there are changes in important variables, it is not always clear whether these changes are a temporary response, or whether they represent more permanent changes. For example, sustained oil price rises and strong inflation, may cause private vehicle demand to slow or even reverse as commuters switch to other modes or cut back on trips to save money. Whether this represents a “new normal” or only a temporary shift is only clear in hindsight (or “ex-post”) and it poses a dilemma for decision makers. If less demand is considered to be “the new normal”, then we will not need to continue to build new roads and instead consolidate existing assets, and possibly even retire those surplus to need. However, if this is simply a temporary set of events that will be corrected through supply responses such as increased oil production and the use of more fuel-efficient vehicles, then demand can be expected to grow again, meaning the new road will need to be built.

These uncertainties are particularly challenging in infrastructure given that asset investment is very lumpy and can often not be reversed without great cost. The ‘sunk cost’ associated with such assets can also exaggerate the desirability of additional projects, hiding their true cost in previously completed BCAs.

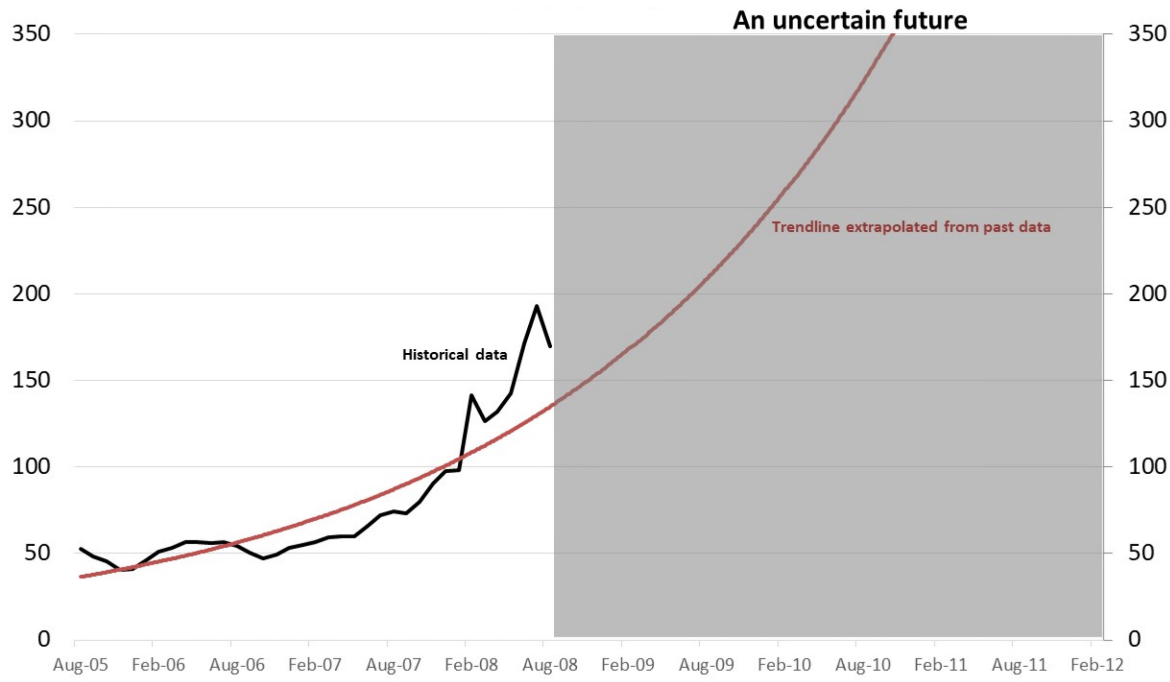
A key benefit of real options analysis is that it augments traditional CBA thinking to help decision makers incorporate these risks and uncertainties, rather than simply taking the most likely forecast/projection and hoping for the best. This distinction is demonstrated in the following hypothetical example.

A large city is experiencing strong demand in patronage growth, especially for use of trunk infrastructure which has been growing consistently for some time — in line with strong growth in: population, employment, and incomes — all associated with a long period of recession-free economic growth.

However, concerns about: persistently highly inflation, oil price rises, and the build-up of debt in the housing market are raising concerns about a future economic correction, reflected in macroeconomic forecasts showing a higher probability of a recession or financial crisis. Growing geopolitical tensions in the Middle East have also raised concerns over the availability of oil, evident in the price of oil futures and gold (a proxy for uncertainty) rising over several months.

The government is considering responding to the strong demand for travel by building a new major freeway and a new underground railway line. Both were identified as options in a strategic review which showed strong trend growth in demand, rising from 50,000 per day to almost 200,000 trips per day in a three-year period, as per Figure 1 below. The business case suggests that underlying trend of demand is strong, raising the possibility of it rising in an exponential fashion and representing a “new normal” (see Figure 1).

Figure 1. Historical Patronage Demand and Trendline Forecasts (trips per day)



However, at the same time there are growing concerns over the general state of the economy, and a sharp fall in patronage demand, which fell 15 per cent in two months prior to the business case being finalised. This dip cannot be explained by changes in variables that reliably forecast growth in the prior five years, suggesting that something outside the standard model may be changing behaviour, whether it is the confidence of travellers in the economy or some random variation.

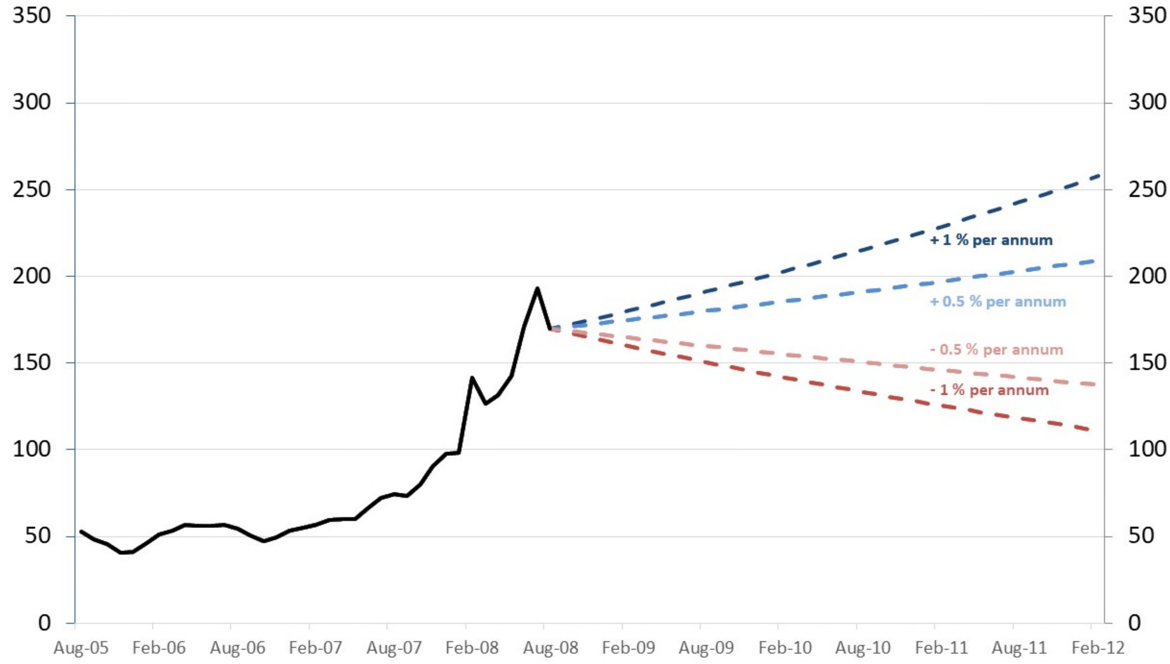
Among decision makers, opinion is divided as to the whether this sharp dip in demand will be permanent, representing a reversal of strong and continued growth due to a correction in the general economy, or whether the dip is temporary representing a mix of seasonal factors and responses to temporary oil price changes which will be offset by supply responses over the medium-term.

Depending on which view is taken on the “new normal”, there is either: a need to manage the risk of overcapitalisation — creating a drag on public finances and limiting the ability to respond to other policy priorities, or the risk of underproviding infrastructure — creating an infrastructure deficit that will impede economic activity, development and productivity growth along the affected corridor. Those who believe that the dip is temporary are advocating for the project to be funded while those who believe that lower demand represents a “new normal” are advocating for the project to be scrapped or at least postponed. Those who are unsure are concerned that the project will take on significant risk and uncertainty, leaving them hoping for the best.

To help resolve the uncertainty and manage conflict, a simple modelling exercise is undertaken showing how changes in patronage growth will impact total demand over the forward estimates period, highlighting how increase in demand growth of 0.5 per cent and 1 per cent per annum will impact total patronage demand, as well as decrease in demand of 0.5 per cent and 1 per cent per annum (See Figure 2).

While forecasters note that each scenario has equal probability of eventuating, they note that the macroeconomic events and the temporary dip in demand has increased uncertainty associated with patronage forecasts, noting that in addition to the events mentioned above there have been changes to autonomous vehicle technology and ‘social license’ associated with ride-sharing regulation that make the future of demand even more uncertain. As such, their confidence level of forecast is decreasing.

Figure 2. Historical Patronage demand and basic demand projections (trips per day)

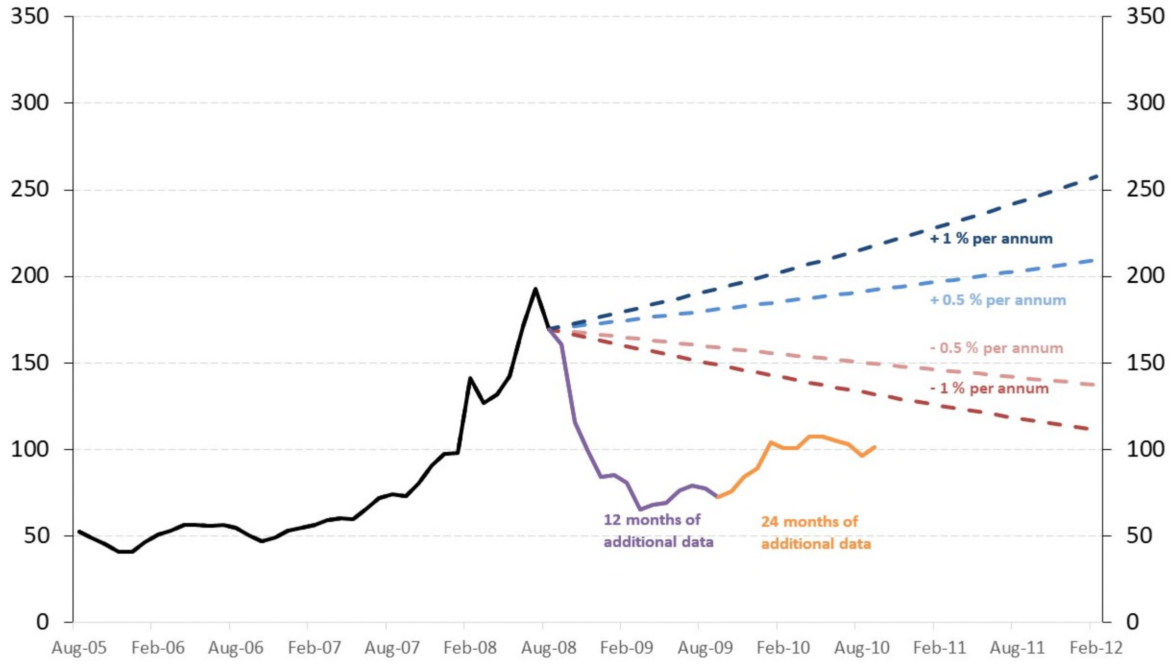


Examining the impact of the changes in assumptions around future patronage growth, and the growing uncertainty impacting at play, the project's proponents opt to postpone a decision on the project's funding; instead a small amount of funding is allocated to due diligence work that will identify risks to the project and re-scope to make it more deliverable in the future. That is to say that rather than simply proceeding, taking on massive risk, and then hoping for the best, the proponent opts to focus on better identification of risk and incorporating new information before making an irreversible decision.

The proponents opt to reappraise the project in 12 months, allowing decision makers to get a better picture of what the future path of demand may look like. This will be followed by a second assessment after an additional 2 years.

This pause yields the results found in Figure 3 suggesting strongly that the dip in demand was not a temporary change but instead indicative of a lower future demand scenario.

Figure 3. Historical Patronage Demand, Basic Demand Projections, and Observed Data (trips per day)

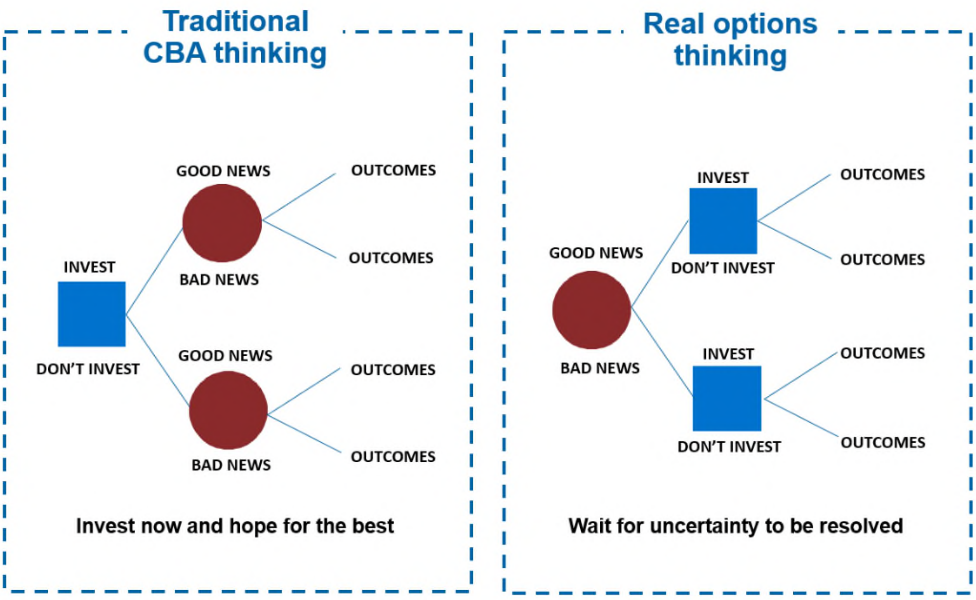


After evaluating these changes, it is decided that the project be postponed indefinitely, demonstrating the value of waiting for information. In his scenario, had the new projects been pursued without waiting, then it is almost certain that the infrastructure would be underutilised and resources wasted.

There are of course scenarios in which demand flatlined or increased, with the risk of under-provision of capacity. Nevertheless, in each of these scenarios, waiting to reduce the uncertainty over demand estimates provides flexibility for decision makers rather than just proceeding with a project hoping for the best.

This distinction is demonstrated schematically in the following slide (Figure 4) from DTF (2018). The first panel intends to show how CBA can be limited to simply making a decision, then living with the consequences, leaving decision makers hoping for the best. The second panel intends to show that real options analysis builds on CBA to allow it to incorporate new information — good or bad — before making an irreversible decision.

Figure 4. How Real Options Analysis improves traditional CBA



Source: DTF (2018)

2.5 Terminology

DTF (2018) provides the following relevant definitions:

- **Options costs**: costs associated with creating the flexibility to change the investment strategy and then maintaining access to the option
  - For example, a hospital may be built in a way that it is readily upgradeable if demand increases more quickly than expected
- **Exercise cost:** the cost to exercise the option
  - For example, the cost to upgrade the hospital
- **Life of an option**: the time until the option is no longer valid or available
  - For example, some time before the end of the life of the hospital
- **Exercise trigger** (or exercise signal): the conditions that define or signal when an option should be exercised.
  - For example, when the demand for services exceeds a particular threshold

2.6 Examples of real options

DTF (2018) identifies five types of real options actions:

- Timing
- Scale change
- Switching

- Abandon
- Design.

Definitions and examples of these actions are shown in Table 2.

Table 2 Examples of real options actions

Real options 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 or committing to the investment	An investment may be deferred for a period of time without relinquishing the right to invest in an initiative	Reservation of a transport corridor
Option to stage the implementation of 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 abandon the project depending on new information	Appraising a trial of increased public transport service frequency before making network-wide frequency changes
Scale changes	Expanding or reducing capacity in response to changes in demand	
Option to alter the scale of the investment (e.g. to expand, to reduce to shut down and to re-start)	An investment initiative can be expanded or reduced in scale depending on whether market conditions are more or less favourable	Design road or rail overpasses to accommodate additional lanes/tracks if and when needed (Note that, in the transport context, design can allow flexibility for expansion but once constructed are regarded as bygones – removal of any additional capacity would only be justified if scrap value and savings in maintenance costs were sufficient to justify the costs of removal
Switching options	Switching inputs/outputs to suit changes in demand and 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, or the same outputs can be produced using different types of inputs (input/process flexibility)	Incorporate capacity for tram in a dedicated bus corridor
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 if market conditions decline severely, impacting on the strategic need for an investment or the ability to deliver it cost effectively. 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 transport agencies to share data. The initial prototype does not meet requirements effectively. At this time, a new and more effective product becomes readily available.

Real options category	Description of real option	Example of real option
	Alternatively, government could undertake a feasibility study and then not proceed further.	An option to abandon allows Government to exit the project during delivery for a pre-determined price on the basis the poor results of the prototype indicate likely project failure. This leaves Government free to consider other emerging solutions. This example could arise in a range of situations, e.g. rail signaling, automatic ticketing in urban networks, lane control technology.
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 pre-requisite for follow-on investments opening up future growth opportunities (early investment, e.g. procuring 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 options	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.	The transport agency is considering delivery of a major new urban rail station below ground to be funded by the public sector. The station could be designed to accommodate a range of above ground options for private and town centre-like community facilities funded from a mix of public and private sources.

Source: Adapted from Department of Treasury and Finance (2018)

A further example, which would come under the ‘design’ heading, would be to build lower-cost infrastructure with a shorter lifespan initially, deferring a decision to build more expensive long-lived infrastructure until demand has increased to a viable level. This analysis would include the cost of replacing the asset at the end of its life, in particular, the disruption costs associated with additional construction, as per the case of the Tagus Bridge where additional foundation support allowed the construction of an underpass which allowed engineers to construct additional road lanes without disrupting traffic.

2.7 When should real options assessment be undertaken?

Real options assessment will not be worthwhile for all investment initiatives. Real options assessment will be most useful for initiatives that:

- Are large
- Face significant uncertainties on the supply (delivery) or demand sides
- Are divisible or stageable
- Are subject to rapidly changing technology (see DTF 2018) for useful discussion).

Table 3 When to apply real options assessment

Real options assessment would be useful	Real options assessment would not be useful
Large stageable motorway initiatives (new motorways or expansion/extension of existing motorways	Small scale initiatives
Large stageable rail corridor initiatives (new rail corridors or expansion/extension of existing rail corridors	Passing loops to relieve a local capacity constraint
Major rolling stock replacement programs	Expansion of existing rolling stock fleet to service enhanced frequency or a new route
ITS to support autonomous vehicle operation	Extension of an existing managed motorways initiative
Major public transport station upgrades	Low-cost amenity upgrades at stations and stops

Source: Broadly adapted from DTF (2018)

2.8 Limitations

Like all analytical techniques, real options assessment has a number of elements that might restrict its applicability in the appraisal of public infrastructure investments.

2.8.1 Administrative pragmatism

A key characteristic of real options assessment is its anticipation that decision makers might and sometimes should change their minds about the desirability of an investment when new information emerges or circumstances change. However, in practice the ability of governments to change direction on an investment, particularly when commitments of support have already been given publicly, may be more constrained than for a private sector investor. As BITRE (2014, P14) puts it:

> *"Real options approaches to infrastructure provision might not be very compatible with government budgetary and assessment processes. A decision to delay full implementation of a project might be seen as a failure on the government's part. Funds available in the short-term to implement a project in full, may be not available later if the project is initially implemented only in part."*

2.8.2 Reliance on subjective probability estimates

At the heart of each real options assessment is a set of subjective probabilities about contingent future events, proposed and applied by the analyst (as illustrated in the examples in the next chapter). A contingent event could, for example, be the rollout of affordable autonomous vehicles or a major demographic change in a region. The results of real options assessments are therefore fundamentally dependent of the underlying probability assumptions.

However, because the future cannot be known with certainty, and because historical information that informs risk analysis may not be relevant to future contingent events, subjective probabilities may be the best estimates that are achievable. Accordingly, it is good practice for analysts to:

- Draw their readers' attention to those subjective probabilities
- Explain their basis (and justification if possible)

- Set out the implications for the assessment results by varying the probability estimates in sensitivity testing.

Despite the limitation of using subjective probabilities, this is countered by the strength of the real options approach compared to traditional decision tools. Where traditional tools do not recognise the uncertainty and ability to stage/delay future choices, real options provide the ability to incorporate subjective assessment of uncertainty and more flexible decision making.

3. Applying real options assessment

This section illustrates the application of real options assessment by presenting several case studies.

As mentioned in section 2.3.2, faced with a future uncertainty that can affect the value of the option implemented, 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.

This can be ascertained by estimating and comparing expected net present values (NPVs) of the conventional option (all investment up-front) and the real option or options. The methodology here applies the probabilistic risk methodology in ATAP Part T2 Cost–benefit analysis. Chapter 11, Section 11.10 of T2 briefly addresses the real options approach under the heading of ‘risk management strategies’. ATAP Guidelines Part O1, ‘Cost estimation’, discusses probabilistic risk analysis on the cost side.

Use of decision tree analysis is recommended, as it can help with estimating expected NPVs. The decision tree performs two functions in the real options assessment:

- It assists in conceptualising the problem
- It provides the framework for scoping and estimating benefits and costs in each scenario.

The analytical effort required to estimate benefits and costs for each scenario in the decision tree will not always be justified by the size of the proposed investment. Nevertheless, even if used qualitatively, the decision tree can assist in the options analysis phase to ensure that proposed initiatives are not too narrowly scoped.

The use of decision trees is shown in the examples below at 3.1 and 3.2. In each of these examples, the analysis is dealing with the uncertainty attached to future demand scenarios, most notably patronage demand.

There may however be cases where providing complete and accurate numbers may not be possible. In these cases, it may be appropriate to use real options analysis in a more informal and qualitative manner. This approach is outlined in 3.4 and a qualitative case study at 3.4.1.

3.1 Widening and strengthening a sealed road

In anticipation to increases in demand for road trips in an agricultural and farming area, road engineers and transport planners are considering two options.

Option 1 entails widening a two-lane sealed road for 10 km at a cost of $50 million. The benefits of the initiative will depend strongly on whether (or not) a proposed feedlot to raise animals for slaughter will be built, increasing demand for heavy vehicle volumes as owners of the feedlot ship animals to market.

It is believed that there is a 70 per cent chance the feedlot will not proceed 8 years from now because of local objections and weakness in meat prices, and a 30 per cent chance that it will proceed. If the feedlot is not approved, no additional strengthening will be require with the widening being able to meet demand effectively.

Under this option, investing only in the widening — without the additional strengthening — yields and expected value payoff of: $75 million of net benefits (in present value (PV) terms) and an NPV of $25 million and a BCR of 1.94.

If the feedlot does proceed, the agency will need to return back to the road in 8 years and strengthen sections to accommodate increased heavy vehicle demand. This will necessitate some reconstruction of pavement already upgraded in the widening project at the additional cost of $20 million (in PV terms). However, this benefits would increase benefits to $100 million (PV), yielding an NPV would of $30 million and a BCR of 1.43.

The calculation of the expected NPV for option 1 is shown in Table 4 and represented in a decision tree at Figure 5.

Table 4 Economic performance of Option 1 (present values) – road-widening initiative [1]

	Scenario 1	**Scenario 2**
	Feedlot not approved (70% probability)	**Feedlot approved (30% probability)**
Investment costs	$50 m	$70 m
Benefits	$75 m	$100 m
NPV	$25 m	$30 m
BCR	1.5	1.42
Expected NPV of Option 1	$26.5m = ($25 m × 0.7) + ($30 m × 0.3)	
Expected BCR of Option 1	1.48 = (1.5 × 0.7) + (1.42 × 0.3)	

[1] These costings and relativities of BCRs and NPVs are purely for illustrative purposes and do not represent actual project costs and benefits.

In **Option 2** the road is widened as in Option 1 but in addition to this pavement road strengthening works are carried out at the same time. This increases the upfront capex costs to $60 million irrespective of whether the proposed feedlot proceeds (i.e. in both scenarios 1 and 2). This bringing forth of the capex is assumed to reduce the cost of the strengthening works — from $20 million to $10 million — because in Option 1 there are additional costs associated: with disruption to traffic during the rework, and reconstruction on parts of the existing road itself.

Option 2 generates benefits of $75 million if the feedlot does not proceed and $100 million if it does proceed. The expected NPV for option 2 is $22.5 million as shown in Table 5

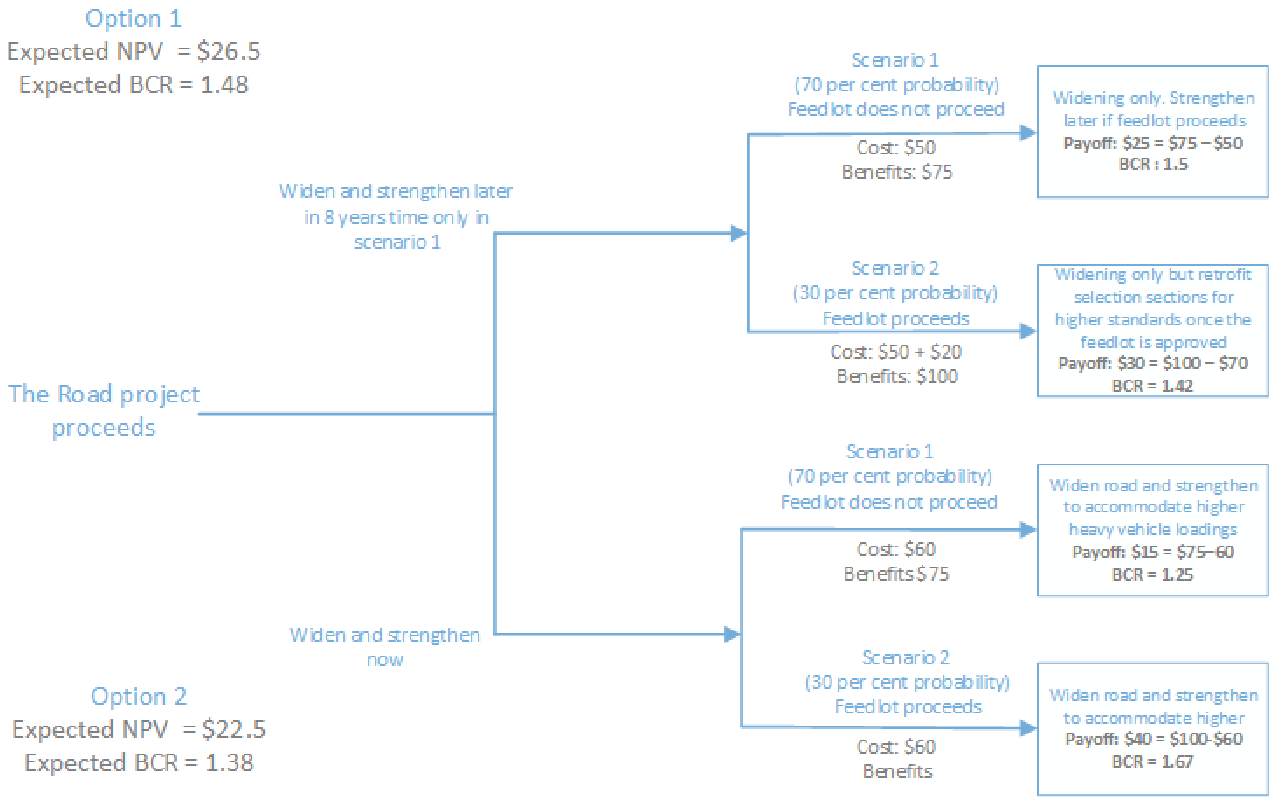
Table 5. Economic performance of option 2 (present values) – road-widening and strengthening initiative [2]

	Scenario 1	Scenario 2
	Feedlot not approved (70% probability)	Feedlot approved (30% probability)
Investment costs	$60 m	$60 m
Benefits	$75 m	$100 m
NPV	$15 m	$40 m
BCR	1.25	1.67
Expected NPV of Option 1	$22.5m = ($15 m × 0.7) + ($40 m × 0.3)	
Expected BCR of Option 1	1.38 = (1.25 × 0.7) + (1.67 × 0.3)	

Comparing bother option's NPVs and BCRs shows that Option 1 would be the preferred option. In other words, it would be economically advantageous for the agency to widen the road now and then, if subsequently the feedlot development proceeds, to go back and strengthen selected sections of pavement on the widened road.

[2] These costings and relativities of BCRs and NPVs are purely for illustrative purposes and do not represent actual project costs and benefits.

Figure 5. Decision tree – Widening and strengthening a sealed road [3]



Note: All values in $ million
Source: Adapted from Department of Treasury and Finance (2018)

3.2 Busway and tramway corridor

Faced with the challenge of growing patronage demand to a developing CBD a public transport agency is considering two options. Under Option A they will build a dedicated busway, costing $500 million. Under Option B they will build a busway but add capability to accommodate trams in the future through additional construction that add $250 million dollars to the immediate construction costs, and then an additional $100 million (in PV terms) after 8 years if and when the busway is converted into a tramway.

These options are considered against two forecast scenarios for patronage growth. Under Scenario A, patronage growth is high while under Scenario B patronage growth is expected to be moderate. Demand forecasters estimate that there is a 70 per cent probability of Scenario A (high-growth) emerging and a 30 per cent probability of Scenario B (moderate growth) emerging.

[3] *ibid*

To provide for expansion to the tram corridor required under Option B, the busway would need to be lowered under a rail bridge. This is needed to accommodate the electric power lines and the power collection equipment on the roof of each tram rail set. This feature would need to be constructed at the beginning of the project, and not later as a retrofitted feature, increasing the upfront Capex costs by $250 million initially and then additional works 8 years later that cost and addition $100 million (in PV terms) bringing the total cost for Option B to $850 million under the high-growth scenario, and $750 million under the low-growth scenario (in which the project remains a busway).

The bulk of the cost for Option B is upfront to allow conversion to a tramway without lengthy construction that causes lengthy delays or disruptions. In addition to avoiding the costs associated with renovating an asset that provides critical services, it also allows a significant amount of money ($100 million) to be put to alternative uses where it can meet other needs, or at the very least delays a significant expenditure indefinitely.

Expansion to tram would be only be triggered when patronage growth in the corridor is high. (Scenario B). Options A and B are described in more detail at Table 6 and Table 7.

The benefits of each project under each scenario include: time and vehicle operating cost savings for private vehicles in the general traffic stream as commuters switch modes to the busway or the tram. For the purposes of simplification, it is assumed that the tram will come at greater cost but also yield higher benefits through: higher capacity in both public transport and active travel, lower and more reliable journey times, higher street-side amenity — through reduced noise, vibration and pollution, and increased health benefits through increased active travel and lower pollution. Other benefits include higher in-vehicle amenity for tram passengers — relative to the bus alternative[4] — in the form of comfort and convenience.

Table 6 shows the projected outcome for **Option A** under each scenario. When patronage growth is only moderate the NPV will be $150 million but, with Scenario B the NPV will be $300 million, with the growth in patronage offsetting the additional bus operating costs to meet higher demand. Based on the assumed probabilities, the expected NPV for Option A is $255 million and the Expected BCR is 1.51.

Table 6. Economic performance of Option A (present values) – Dedicated busway only[5]

	Scenario A	Scenario B
	Patronage growth high (70% probability)	Patronage growth moderate (30% probability)
Investment costs	$500 m	$500 m
Benefits less additional opex	$800 m	$650 m
NPV	$300 m	$150 m
BCR	1.60	1.30
Expected NPV	$255 m = ($150 m × 0.3) + ($300 m × 0.7)	
Expected BCR	1.51 = (1.3 × 0.3) + (1.6 × 0.7)	

[4] The estimation of user comfort and convenience benefits is discussed in ATAP Part M1 and the supporting M1 Technical Supporting Technical Report which provides parameter values for estimation of this category of benefit. ATAP Part O6 provides an example of the estimation of these benefits.

[5] These costings and relativities of BCRs and NPVs are purely for illustrative purposes and are not intended to serve as realistic representations of project costs and benefits.

In Option B, the busway will be built with tram-enabling works that include: enough height clearance under the rail bridge to eventually allow tram operation. If patronage growth is moderate (Scenario A), the NPV reduces to $250 million (from $255 million in Option A) due the additional investment costs of lowering the busway under the rail bridge.

If the high-growth scenario eventuates, the conversion to the tramway will occur in 8 years. This creates an addition $100 million in cost (PV) but also yields significantly higher benefits, boosting the NPV to $565 million and a BCR of 1.82 (after allowance for additional operating costs of tram operation) because the local market finds tram to be more attractive and comfortable than the bus service.

The expected NPV for Option B (after allowing for additional operating costs to accommodate patronage growth) is $565 million and the expected BCR is 1.68. Both are higher than in Option A, suggesting that Option B is preferable given the balance of probabilities. That is to say that the additional upfront expenditure to allow the busway to be converted to a tramway is worthwhile.

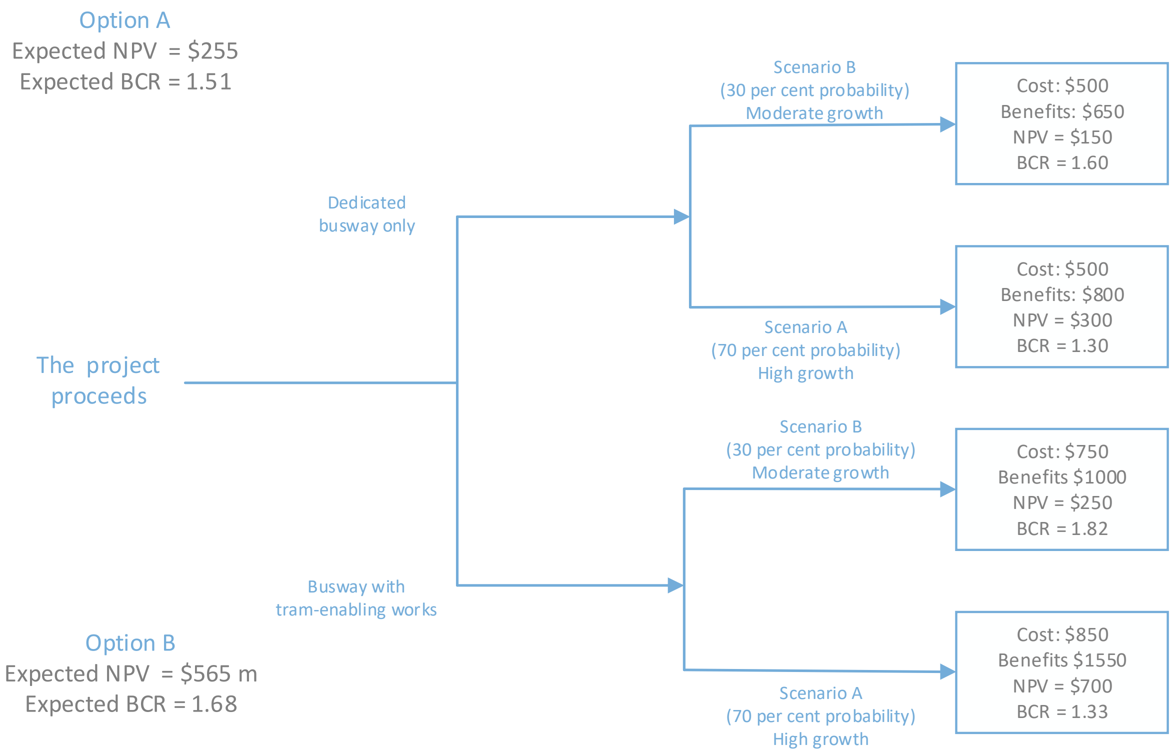
Table 7 Economic performance of Option B (present values) – Busway with tram-enabling works [6]

	Scenario A	**Scenario B**
	Patronage growth high (70% probability)	**Patronage growth moderate (30% probability)**
Investment costs	$850m	$750 m
Benefits less additional opex	$1550 m	$1000 m
NPV	$700 m	$250 m
BCR	1.82	1.33
Expected NPV	$565m = ($250m × 0.3) + ($700m × 0.7)	
Expected BCR	1.68 = (1.33 × 0.3) + (1.82 × 0.7)	

Option 2 would be preferred because it has the higher expected NPV: that is, it would be preferable when delivering the busway to provide enough clearance under the rail bridge to accommodate future tram provision should high patronage growth eventuate.

[6] These costings and relativities of BCRs and NPVs are purely for illustrative purposes and are not indicated to acts as realistic representations of each project's costs and benefits

Figure 6. Decision tree – busway and tram-way corridor [7]



Note: All values in $ million
Source: Adapted from Department of Treasury and Finance (2018)

3.3 The '25 de Abril Bridge' on the Tagus River

A real-life and intuitive example of the use of real options analysis is the construction of the '25 de Abril Bridge' over the Tagus River in Portugal. The bridge was constructed in 1966 with a single-deck four-lane road. However, the addition of deeper and stronger foundations created — at significant cost — the real option to add: an additional two road lanes, and a railroad deck underneath the bridge.

This real option was executed 33 years after initial construction ended in 1999 through additional construction.

The real option was executed once the government had better information about the demand for additional private vehicle travel and new commuter rail services from one side of the Tagus river to the other.

The section provides an outline of how the real options approach was used on the bridge based on range of sources.

[7] These costings and relativities of BCRs and NPVs are purely for illustrative purposes and are not indicated to acts as realistic representations of each project's costs and benefits

3.3.1 How were the problems and opportunities identified?

The city of Lisbon is large but divided by the Tagus River that is over one kilometre wide at some points, meaning that building of river-crossing bridges is expensive and presents significant engineering challenges because of the required bridge's length. The challenge is accentuated by Lisbon's vulnerability to earthquakes and high-speed winds. Without the bridge, the Setúbal Peninsula would be isolated from key transport links preventing economic and land-use development taking place and limiting the north side from realising economic opportunities associated with this development.

The opportunity for development on the Setúbal Peninsula and the need for a river crossing was identified by a number of sources, with the need for a north-south connection across the Tagus identified as an opportunity to close gaps in the transport network and facilitate economic and land-use development.

3.3.2 How were options, and the 'real option' developed?

The Portuguese Government conducted studies examining the feasibility of providing river-crossing bridges as early as 1876 before creating commissions in 1933 and 1953 and then a special department to examine the project proposals in 1953.

These entities examined options to develop a river crossing, ultimately recommending a bridge that would carry both private vehicle traffic and rail bridge.

Once a decision was made to build a bridge, the government sent out invitations for bidders. Four bids were received before it was awarded to the US Consortium, using a bid that they had developed in 1935. The long lead times appears to have allowed time for bidders to work out design solutions to the engineering and cost challenges discussed, most notably cable suspension designs similar to that made famous by San Francisco's Golden Gate Bridge to manage high speed winds and seismic activity.

Construction was completed in 1966 producing a four-lane road bridge, with two lanes running either side. The bridge was the longest in Europe at the time, with a span of 1,013 metres and measuring 2,278 metres from the south to the north anchorage. This include the world's longest continuous truss.

However the design of the bridge, which included a caisson foundation at the south main tower, embedded in rock 79 metres below water — making it the world's deepest bridge foundation, allowed for future expansion; providing the real option of adding additional loads to the bridge.

While not entirely clear, the reason that the future expansion was postponed appears to be a combination of budget constraints and uncertainty surrounding patronage demand, much of which appears to have been contingent on the Setúbal Peninsula's economic development, and the long timeframes over which development would occur. The latter creates a risk that, while the bridge could cater to demand that would occur decades into the future, it would also result in large overcapacity in the intervening period, especially if tolls were set too high.

These deeper foundations appear to have had a large immediate upfront cost, but also a significant opportunity cost. This includes projects that could have been funded with the additional money and resources used to make the caisson foundations stronger — projects that could have developed infrastructure or social expenditure in other areas of Lisbon, or more specifically the Setúbal Peninsula.

3.3.3 How was the ‘real option’ executed?

After the construction of the bridge, the relatively inaccessible Setúbal Peninsula developed rapidly, connecting the country’s longest steel mill to the north, developing residential centres and a tourism sector built around the areas’ natural assets (beaches, forests, harbours). Over this time, the population of Lisbon also increased and by 1993 every day 120,000 trips were made using the bridge.

To cater to this growing demand for cross-river trips in the short-term, ferries were used to connect commuters to the rail system in the south, and a second bridge was built in on the eastern side of the river, almost 20 kilometres away.

However, the deep foundations laid when the ‘25 de Abril Bridge’ was built allowed a clever retrofit of the bridge to increase capacity rapidly. In response to growing demand, it included:

- the addition of two new lanes, one of which could be reversed in direction, to better manage the asymmetrical flows during peak hours; and
- the creation of a rail deck underneath the bridge to create a line for commuter rail and long-distance freight.

It is obvious that this retrofit prevented the need to construct an additional bridge at much greater cost, but what is less obvious is that — whether intended or not — the creation of the real option allowed engineers the time to find innovative ways of doing the construction. This included the use of new and improved cables to manage the vibrations that arise from the additional traffic and heavy commuter and freight rail. These challenges are very significant given the area’s vulnerability to earthquakes and high-speed winds.

This highlights another important advantage of a real options approach: the ability to manage ‘technological risk’ — most notably the risks that arise from technologies failing, and the risk of using obsolete or uncompetitive technologies which ‘lock in’ and prevent the adoption of superior technologies. The timing of the bridge’s retrofit meant that technology not available in 1962 (when the bridge began construction) could be utilised: not only new technologies invented by others but also technologies and designs that were created and tested specifically for the project. In the case of the ‘25 de Abril Bridge’, the new cables required significant testing to ensure that they could create stability for the bridge for it to withstand wind speeds of 72 metres per second.

Also less obvious, but very important, is that the creation of a real option allowed construction to occur without closing the bridge — meaning the cost and risk associated with disruption from construction was almost eliminated completely. 140,000 trips per day did not need to be redirected, postponed of cancelled. Instead, the strong foundations and underpass allowed construction to occur with almost no traffic disruption. This is a particularly important point as it is uncommon for transport business cases to include construction disruption externalities such as cancelled or delayed trips in project costs.

More generally, these issues highlight how real options create ways to meet immediate needs while also providing time to do further ‘due diligence’ relating to areas as varied as the choice and development of technological and design solutions, construction techniques, and financing and procurement.

While not included in this assessment, there are two important counterfactuals. The first is where the '25 de Abril' Bridge was overbuilt in 1966 to meet demand that would only materialise after 30 years. The second counterfactual is where a new bridge crossing would need to be built from scratch after some 30 years. In each case, a thorough formal assessment would require high-quality estimates of the costs and the creation of a base case against which the project case can be compared. For example, Fogel (1964) examined the economic impact of America's great railway expansion by creating a base case (or counterfactual) in which demand for trips and land development was met through canal transport rather than the construction of new railroads. Similarly, ex-post economic evaluation of projects in Australia by BITRE (2018) considered multiple base case scenarios for some case studies, noting that the ex-post CBA result for a project can differ significantly depending on the particular base case assumed.

It would not be controversial to suggest that the real option created in case of the '25 de Abril' Bridge made the community better off compared with a number of possible base cases or counterfactuals. This is because it seems most counterfactuals would have provided similar benefits, but with much higher construction costs. In some counterfactuals, there would be major negative impacts on public finances and development of the Setúbal Penisular.

3.4 Using real options qualitatively

While real options can be used in a formal and quantitative way — as outlined above at 3.1 and 3.2 — they can also be used when making qualitative assessments.

A qualitative use of real options can be particularly valuable during strategic reviews when detailed quantitative information is not available. The qualitative uses of real options is particularly useful in the first phases of strategic reviews when attempting to assess whether (or not) certain options are appropriate to respond to a problem or opportunity identified by a review or audit.

When these options are being developed and assessed, detailed costings and/or cost-benefit analysis is often not available to make a definitive comparison between options. Real options can explore, and then graphically represent, uncertainty faced by certain options, and the conditions/events/triggers that could alter the view of a problem and/or opportunity. For example, similar to the case study at 3.2, whether growing transport demand be met by busway or tram.

There are several approaches which allow a qualitative assessment in lieu of detailed quantitative information. These includes: 'scenario analysis'[8] and 'decision analysis'[9] – both of which use decision trees to facilitate qualitative real options analysis. Tools that use these approaches — such as the Investment Management Standard (IMS) (outlined in Figure 7), or a 'real options triage' (outlined in Figure 8) — can be used to identify likely scenarios (or future states of the World) and then create a corresponding decision tree.

The IMS is a series of four workshops that bring together the informed contributors seeking to deliver the project and help shape an investment proposal early in its development (illustrated in Figure 7 below).

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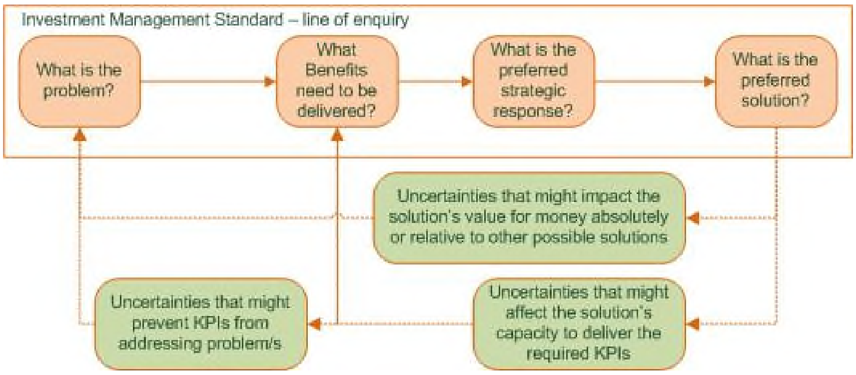
[8] 'Scenario analysis' is a process of analysing the possible outcomes of a strategy or an investment by considering the strategy's outcomes in a range of alternative possible future states, or scenarios, of the world.

[9] 'Decision analysis' is the examination of contingent decisions and the implications of uncertainty for the design and valuation of project options. For more detailed guidance see Appendix 3 of DTF (2018).

Figure 7: Outline of the Investment Management Standard



Source: DTF (2018)

The 'real options triage' (Figure 8) is a strategic exercise that requires agencies to think about the uncertainties that could impact their investment, the vulnerability of the investment to those uncertainties, and the level of flexibility within the investment to adapt its strategy to mitigate those impacts. More detailed guidance and question examples can be found in DTF (2018).

Figure 8: Outline of the Real Options Triage

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 the 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; and/or – 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; and – increasing design flexibility to add greater resilience.
Identify 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; and • new market participant.

Source: DTF (2018)

Strategic foresight documents, which include modelling of likely future states can inform these processes and ensure the identified problems and opportunities remain significant under changing conditions. Examples include: Queensland Department of Transport and Main Roads (2019a & 2019b), Infrastructure Victoria (2018), Infrastructure Australia (2018a & 2018b).

Using the modelling of likely future states, decision analysis can then graphically represent the potential alternative trajectories or pathways the investment could potentially take. These pathways may lead to secondary trigger points, and a series of further management decisions and potential investment trajectories.

Thinking in such a way provides Government with a more comprehensive and intuitive view of the likely future outcomes, resulting from decisions taken now rather than considering a single forecast or projection regardless of what decisions are taken. This can facilitate more detailed consideration of project options in later stages of the investment lifecycle, such as business case development and assessment. This process can allow Government to better anticipate future changes, and then plan how they will respond if certain events or trigger conditions occur.

A hypothetical example outlining this approach and its benefits is included below.

3.4.1 Case study: Decision tree – qualitative real options analysis of a hospital upgrade

'Ralesville' is a (hypothetical) new outer suburb and growth area, averaging population growth of 15 per cent per annum over the past five years. The nearest hospital is another service area, requiring residents to travel up to 90 minutes by car and longer by public transport, so the State Government's review has flagged the need to construct a new hospital within the area.

There is significant uncertainty about whether population growth in 'Ralesville' will: continue at the levels experienced in recent years, slow, or even stagnate. This uncertainty arises from, among others: changes in household demographics, immigration policy, structural and cyclical adjustments in the economy — including the housing market cycles and asset booms.

This uncertainty means that there is uncertainty about the size of the hospital required to meet service obligations in the future. In response, a strategic review considered the following options to respond to the problem of growing demand for hospital services.

- Option 1 — involves building a base, non-upgradable, hospital. This hospital will take 5 years to complete and has capacity to service the existing population plus an additional 10 per cent population growth which is in line with medium-term growth expectations for the state.
- Option 2 — involves building a hospital that meets the same capacity requirements as Option 1 but invests in a stronger foundation and structure. The stronger foundation and structure creates the 'real option' to expand the hospital by 3 floors when (and if) population growth exceeds the medium-term forecasts considered in the strategic assessment.

Option 2 is considered to be more costly that Option 1 but it is not possible at this stage to obtain accurate estimates of the cost given the highly specialised nature of hospital construction and changes to legislative requirements relating to occupational health and safety.

This information can be set out in a decision tree to help Government visualise the impacts of its decisions.

Figure 9. Qualitative Real Options Decision Tree

A key advantage of using the real options approach, whether quantitative or qualitative, is that it can prevent governments from being 'painted into a corner' to face a scenario in which only very expensive or prohibitively expensive options can be considered. In the example above, it is possible to avoid a scenario in which a government facing higher-than-expected population growth is forced to build a second hospital from scratch and at much greater cost. In addition to avoiding the direct financial cost, it avoids or postpones the costs associated with the administrative burden of creating the new hospital, including: identifying new land for hospital construction, engaging with affected residents, making unexpected adjustments to government budgets, drawing down debt, and/or raising new taxes.

In some cases, the real options approach may avoid the expenditure completely while in others they may simply defer the expenditure by several years or event decades. This offers significant benefits to government budgets not just in savings but also the flexibility to meet other budget pressure resulting from revenue or expenditure shocks, especially if this approach is applied over several projects with significant value. It also suits large infrastructure projects as capital expenditure is often lumpy, with some investments taking years to build, risking the cost of excess capacity. In the example, it avoids a scenario in which a large new hospital is built to meet demand but only a small proportion of capacity is used, leaving large underutilised capital.

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