CRC for
Water Sensitive Cities

INFFEWS Benefit: Cost Analysis Tool: Guidelines

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INFFEWS Benefit: Cost Analysis Tool: Guidelines

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Contents

Introduction

These guidelines provide advice on the INFFEWS Benefit: Cost Analysis (BCA) Tool for projects related to urban water and green infrastructure. They are not a comprehensive guide to BCA. For that, we recommend several text books and practical guidelines prepared by various governments (see 'Learning more' at the end of this document).

These guidelines provide practical advice that will assist users to prepare BCAs of water related projects using the INFFEWS BCA Tool. Guidance is provided on exactly what information is needed, options for obtaining the required information, and standard values to use for particular parameters (e.g. the discount rate). The guidelines also explain the various types of sensitivity analysis that are built into the BCA Tool, pitfalls and errors to avoid, and the structure of the BCA Tool spreadsheet.

I recommend you read these guidelines in conjunction with the other two main documents that make up the INFFEWS BCA Tool*: INFFEWS BCA Tool: Benefit: Cost Analysis and Strategic Decision Making for Water Sensitive Cities* and the *INFFEWS BCA Tool: User Guide* (see Box 1).

Box 1. Resources included in the INFFEWS BCA Tool

The BCA Tool is a package consisting of the following components. This is the recommended order for accessing the components (apart from the training resources).

INFFEWS BCA Tool: Benefit: Cost Analysis and Strategic Decision Making. Provides guidance on: BCA basics; strategic issues related to BCAs; whether to conduct a BCA; use of economic information, including BCAs, in strategic decision making.

INFFEWS BCA Tool: Rough BCA Tool. Provides guidelines and a spreadsheet for a "rough" BCA, useful as a first step towards a full BCA, and a test of whether a BCA is feasible.

INFFEWS BCA Tool: Guidelines. Explain key concepts behind BCA, and pitfalls to avoid when doing a BCA.

INFFEWS BCA Tool: User Guide. Provides detailed step-by-step instructions and advice for completing a BCA in the spreadsheet tool.

INFFEWS BCA Tool Spreadsheet. Captures the qualitative and quantitative information, calculates BCA results and conducts a sensitivity analysis to test the robustness of results.

INFFEWS BCA Tool: Comparison Tool. Makes it easy to compare the results from BCAs for multiple projects, or different versions of the same project.

INFFEWS BCA Tool Training Resources. Contains videos and slide sets used in training courses.

Project definition

Works and actions

A water sensitive city project must bring about a set of works and actions. These are the works and actions that will directly deliver the benefits. Examples could include installing water conserving technologies in the home, switching from centralised to decentralised water supply, or converting a concrete drain to a more natural vegetated stream.

It is helpful to distinguish between three groups who may be responsible for delivering the works and actions that are relevant to the project:

(a) the project itself
(b) private citizens or businesses
(c) other organisations.

The relevance of distinguishing between these three entities or groups is that the activities to be undertaken by the project are different in the three cases. In case (a), the project is in direct control of the actions that need to be undertaken. In case (b), the role of the project is to encourage or incentivise other people or businesses to undertake the necessary actions and works. In case (c), the role is to encourage, reach agreement with, or contract other organisations (e.g. government departments or non-government organisations) to make specific contributions to the project.

The INFFEWS BCA Tool, in parts 1.6, 1.7 and 1.8, asks the user to specify the required works and actions for each of these three entities or groups.

Project activities

Having identified the necessary works and actions, the next step is to identify what the project will do to generate benefits by getting the three groups or entities mentioned above (or as many of them as are relevant to the project) to implement the required works or actions. Identifying the project activities – what precisely the project will do – is necessary to estimate the project's costs, risks and, ultimately, its benefits.

For entity (a), the answer is obvious. What the project will do to deliver the actions or works is implement them itself.

For group (b), the project needs to select mechanisms to encourage or incentivise the private citizens or businesses to adopt the works or actions desired by the project leaders. There are many options available, including the following:

- Regulatory constraints, backed up by penalties for non-compliance. These are available to only certain types of project organisations with the necessary legal powers.
- Incentive payments, to reward the desired behaviours. These are often effective, but expensive.
- Provision of information, education, training, etc. These are probably cheaper per person than incentive payments, but likely to be less effective, unless the action being advocated is beneficial to the private citizen or business.

If mechanisms like these are being used, they need to be defined in some detail, so that the analyst can cost them and judge their likely effectiveness.

For group (c), the two main types of mechanism used are agreements and contracts. The costs of these approaches include the cost of staff time for negotiation.

All three cases are likely to incur administrative costs and maybe also legal costs, both of which should be included in the project costings.

In the INFFEWS BCA Tool, project activities are specified in sections 1.10 (activities related to investigation and management), 1.11 (activities related to project management), 1.12 (activities targeting private citizens or businesses) and 1.13 (activities targeting other organisations). These activities need to be described clearly and in enough detail to cost them accurately.

Specific, measurable, time-bound target(s)

Good practice in developing a project is to specify a SMART goal for the project. The A (for “achievable”) and R (for “relevant”) parts of the acronym will be satisfied as a result of doing the BCA and using it to guide decisions about the project. The other three letters correspond to:

- “Specific”, which means the target is described in a precise and unambiguous way
- “Measurable”, which means the target definition is based on a variable that can be monitored and recorded reliably and economically, and
- “Time-bound”, which means a particular date is provided by which time the target should have been achieved. The time frame for the target can be of any relevant duration.

The targets should focus as much as possible on achieving outcomes and benefits, not just activities or outputs.

The target may include a probability of success.

The target should anticipate the risks of project failure (which will be higher for more ambitious targets), and the adoption by others of the works and actions required to achieve the target. You may need to return and revise the target later after considering issues like project risk and adoption.

Setting the right target is a balancing act. If you specify a target that is very difficult to achieve, the works required to achieve it will be much more extensive, more expensive and perhaps less adoptable than for a modest target. If your target is too challenging, then you will either have to come back and moderate the target, or set this project aside in favour of one with a target that is more feasible. On the other hand, if you set the target too low, the project will not be very attractive. You have to balance these tensions between the target being doable, and it being worth doing.

Setting a target that satisfies the S, M and T criteria can be surprising difficult, but it is important to do so to facilitate subsequent monitoring and evaluation of the project (if it is funded and implemented). Developing an SMT target may be an iterative process, evolving as project design evolves, in response to the process of undertaking a BCA, or after seeing the results.

The INFFEWS BCA Tool requires you to specify the target or goal in part 1.5.

The with-versus-without principle

The with-versus-without principle is possibly the single most important idea behind BCA. Not applying it properly produces worthless BCA results. The idea is that the benefit of a project is the *change* in values generated as a result of the project. In other words, it is the difference between the values with the project and without the project. The values could be generated by income, by recreation, by health or whatever, and the question is, how much do they change as a result of the project? It sounds simple, but it can be challenging to put into practice.

Usually, when we are evaluating a project, the project has not yet been implemented. In that case, we have to predict results for both scenarios (with and without the project). You cannot observe either set of results, because they are in two different hypothetical futures.

Importantly, comparing values “with versus without” the project is not the same as comparing values “before versus after” the project. The reason is that conditions may not be static in the absence of the project. For example, it may be that an environmental asset would degrade in the absence of the project, but its condition would be improved by the project (relative to its current condition). This is illustrated in Figure 1.

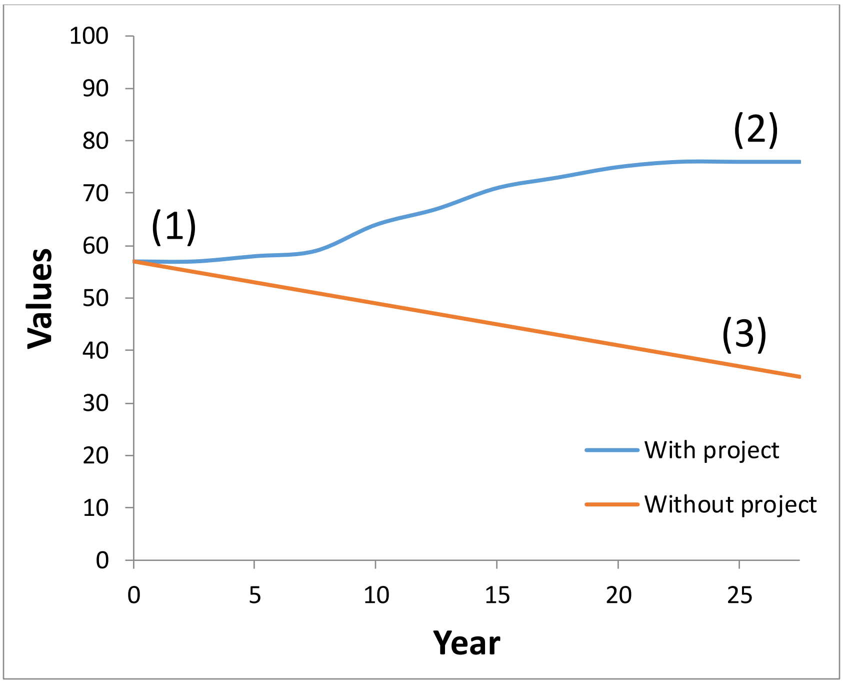

Figure 1. Estimating values with versus without the project when the project turns a predicted decline in value into a rise.

Figure 1 illustrates a case where current conditions are reasonably favourable, with a value of 57 [labelled (1)]. Without the proposed project, the value is expected to decline steadily, to a score of 37 after 25 years [labelled (3)]. With the project, value would increase to a score of 76 after 25 years [labelled (2)].

Clearly, in the example above, the benefits of the project grow over time (the two lines diverge in Figure 1). In a BCA, we would estimate the benefits in each year after the project is implemented and add them up (after allowing for discounting).

Because of the "with-versus-without" principle, a project can generate benefits even if it does not completely prevent a decline in values (such as environmental degradation). As long as it slows or reduces degradation, this should be measured as a benefit. Figure 2 illustrates this point. In this example, the future condition with the project (2) is below the initial condition (1), but is above future condition without the project (3). Since the project benefit is (2) minus (3), the benefit is positive.

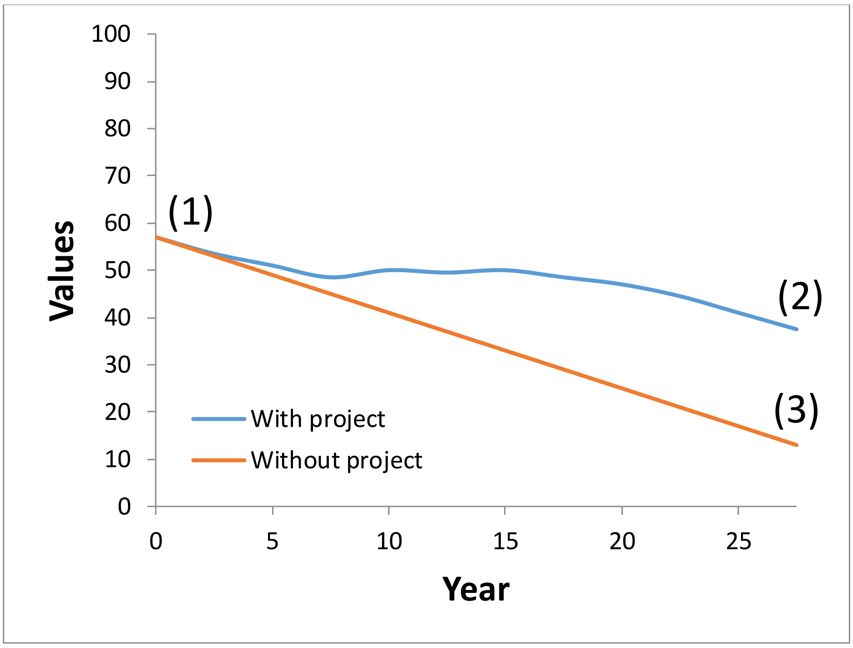

Figure 2. Estimating values with versus without the project when the project reduces the predicted decline in value.

On the other hand, a project that superficially appears to generate large benefits may actually not do so, because those benefits would have been generated even without the project. In other words, the benefits are not 'additional' to what would have happened anyway. The without project line in the graph would be almost as high as the with project line, so the difference between them (= the benefit of the project) would be minimal. This is illustrated in Figure 3.

For example, suppose a proposed project encourages householders to adopt a new type of water conservation technology that is cheap and highly beneficial. If the private benefits are large enough, it is a safe bet that people would have adopted the new technology even without the project. It would have been promoted by word of mouth and by private businesses.

Making good predictions about the without project scenario can be quite difficult, requiring good knowledge of the issue, the context, the proposed management practices and the people whose behaviour matters. Weak thinking about the without project scenario is a common failing, sometimes leading to exaggerated estimates of benefits. The BCA Tool User Guide includes a checklist of issues to consider when thinking about the with and without project scenarios.

In the BCA Tool, the user describes the with and without project scenarios in parts 1.15 and 1.16. Then while completing the *Benefit parameters* sheet of the spreadsheet, the must judge the quantitative differences made to particular variables as a result of the project (i.e. differences between the with and without project scenarios). On the *Benefit parameters* sheet, the headings for variables that reflect a with-versus-without difference are highlighted with a solid blue background.

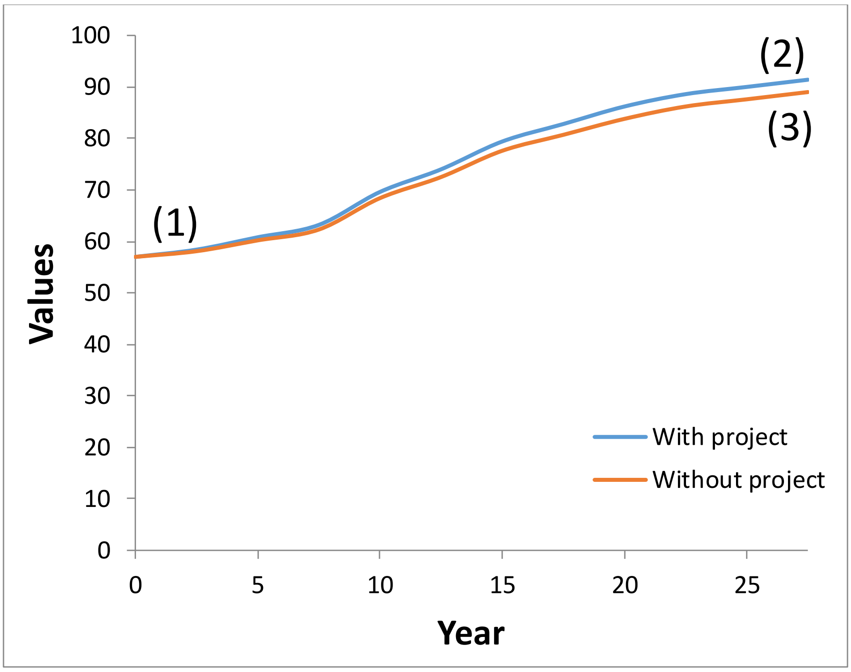

Figure 3. Estimating values with versus without the project when values would increase even without the project.

Benefits

Benefit types

The BCA Tool is designed to be fully flexible in the types of benefits that it can handle. It includes a number of specific benefit types that are expected to arise in certain types of water related projects, but it is flexible enough to also handle other benefit types that are not currently listed.

Benefit categories

The types of information required to quantify a particular benefit in a BCA can vary considerably. In many cases, a single benefit type can be estimated and measured in a variety of ways. To make the system simpler and more efficient, the BCA Tool uses eight benefit categories that have similar information requirements:

1. Benefit per person (on average) or per household for a particular population
2. Benefit per user specified unit
3. Benefit per unit of abatement
4. Total or aggregate benefit per year
5. Delay or reduction in a cost
6. Improved condition of an environmental or community asset, expressed as a benefit for the asset as a whole
7. Reduced probability of a risky event that could occur with a specified probability in any year
8. Custom benefits, specified year by year.

Choosing which category to use for a benefit largely depends on how the information about that benefit is available. For example, if the information is available per head, you would probably choose to represent it using category 1 (benefit per person).

The BCA Tool uses these benefit categories to collect the right data for the necessary calculations. One benefit category can include several different types of benefit. The common ground is that they require the same types of information and that benefits are calculated in the same way. We will refer to the benefit categories below, when we talk about how the BCA Tool includes the various benefits.

Market benefits

Some of the benefits generated by water sensitive cities projects are market benefits. They relate to goods that are priced in a market, and we can estimate these benefits by analysing prices.

Examples of relevant market goods are water (at least in Australia, although not in some other countries), water conservation technologies such as low-flow shower heads, and air conditioners (less in demand if the incidence of extreme heat is lower).

Theory

The theoretical basis for measuring market benefits is the supply and demand model. Preferably, a BCA analyst would obtain information from published studies about the supply and demand curves for the relevant market good, and use these to calculate how consumer surplus and producer surplus change as a result of the project. Consumer surplus monetises the utility gained from consuming the good, allowing for the cost of purchasing it. Producer surplus approximates the producers' profits. A project's benefit is equal to the change in total surplus (consumer surplus plus producer surplus).

These guidelines do not explain the economic theory behind consumer surplus and producer surplus. . (The "Learning more" section includes suggested resources.) The following explanation of market benefits assumes the reader is familiar with the supply and demand model, and with consumer surplus and producer surplus.

Consider this example. The domestic market for low-flow shower heads has the supply and demand curves shown in Figure 4. The supply curve is perfectly elastic (flat) because these shower heads are imported from China. If the market is operating freely, consumers make their own decisions about which shower heads to purchase, and consumers are well informed, then the market would converge on the optimal quantity of low-flow shower heads at 60. (The units could be thousands per year.) At this quantity, the consumer surplus is the shaded area *abc*, and the producer surplus generated in this market is zero.

In this case, no policy is needed to increase the quantity of low-flow shower heads. Indeed, any such policy will reduce net benefit. For example, in Figure 5, a new policy mandates low-flow shower heads in all new homes, increasing quantity to 80. However, for each unit above 60, the cost of the shower heads is greater than the marginal benefits (which are given by the demand curve). As a result, compared with the scenario without this policy (Figure 4), the new policy generates a loss equal to area *afg*.

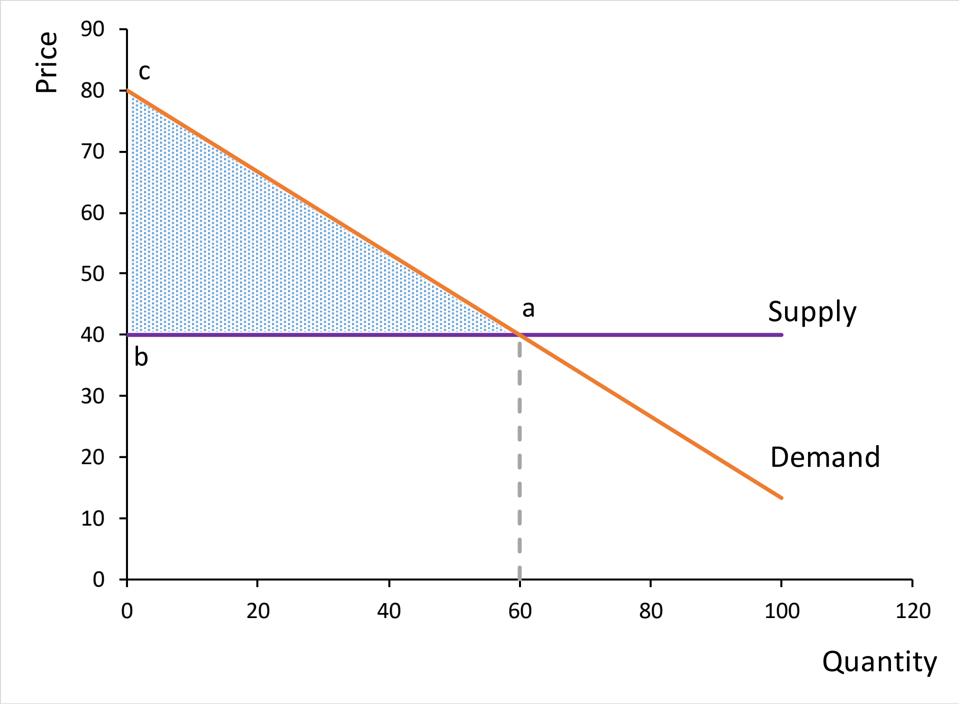

Figure 4. Supply and demand curves for low-flow shower heads, showing consumer surplus (shaded) for the optimal quantity of shower heads (60).

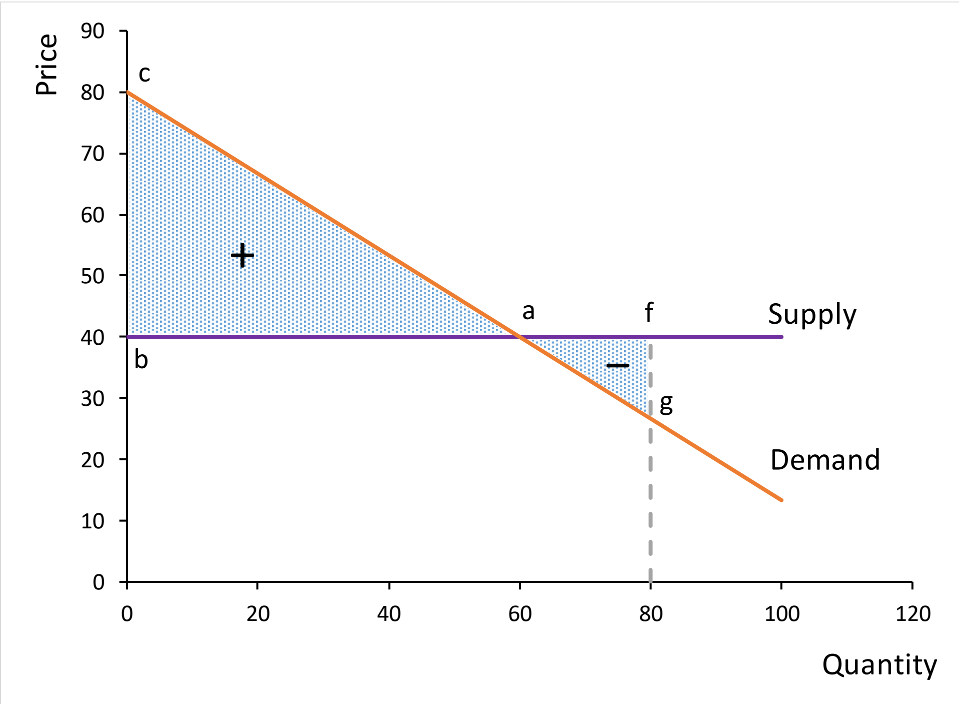

Figure 5. Supply and demand curves for low-flow shower heads, showing consumer surplus (shaded) if the quantity of shower heads is constrained to a higher level (80). The net consumer surplus is area *abc* minus area *afg*.

The demand curve, which indicates marginal benefits, captures all the different types of benefits to purchasers of low-flow shower heads. This could include the financial benefit of reducing water bills plus a warm-glow effect from conserving water. On the other hand, it also reflects any disadvantages of low-flow shower heads perceived by potential purchasers, such as showering under a low-flow shower head is less pleasurable than showering under a traditional shower head. A simplified approach based only on calculating water savings would miss parts of the story.

What if the quantity is below the optimum? Perhaps residential developers perceived incorrectly that people would prefer traditional shower heads and the quantity fell to 40 (Figure 6). In that case, the consumer surplus would be area *debc*. A policy that could increase the quantity up to the optimum would generate benefits equal to area *aed*. A serious challenge in this scenario would be knowing that the current quantity of the product was in fact below the optimum. The responsible organisation would need very good information about the supply and demand curves to determine this.

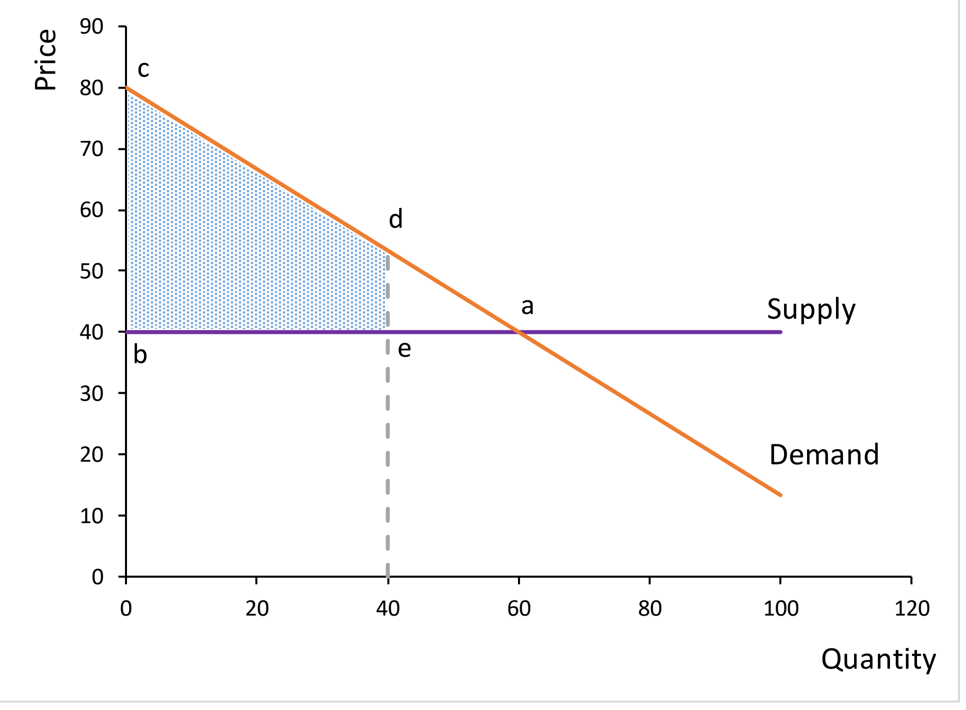

Figure 6. Supply and demand curves for low-flow shower heads, showing consumer surplus (shaded) for a sub-optimal quantity of shower heads (40).

Estimation

Some market goods have existing published evidence about their demand curves. A key example is water, for which various studies have estimated the price elasticity of demand (e.g. Grafton et al., 2011).

We can estimate the supply curve for some products, because we know the elasticity will be very high – imported shower heads, for example. In other cases, there may be evidence available. Water utilities analyse their own supply costs, for example.

If estimates of the supply and demand curves are not available, an option is to conduct original research to estimate them. However, that is expensive and time consuming and is unlikely to be warranted except for BCAs of very costly projects that require strong evidence to test their economic performance.

In the absence of such evidence, the BCA analyst has two main options: (a) subjectively estimate the demand and supply curves based on one data point (current price and quantity), evidence about elasticities for similar products, and judgements about realistic elasticities for this product based on its characteristics, or (b) break down the benefits into components about which judgements can be made, collect relevant data about each component, and approximate the benefits.

The weakness with approach (b) is that it is likely to consider only a subset of the issues that are relevant to consumers. For example, as mentioned earlier, an analyst might quantify the benefits of low-flow shower heads in terms of water savings, but overlook other benefits (warm glow) or costs (less pleasurable showers) which are not so easy to quantify. If using approach (b), it is important to at least complement it with a conceptual analysis using supply and demand curves, to identify how to think about the benefits in a market context.

Non-market benefits

Theory

Non-market benefits are generated by goods or services that are not bought and sold in markets. Examples include enhanced biodiversity and ecological conditions, improved aesthetics, improved public health, and improved thermal comfort. Some benefits have both market and non-market aspects (e.g. health, or recreation).

The lack of information about market prices and the changes in supply and demand as price changes makes it difficult to quantify these benefits in monetary terms. Even without a market, the theory behind consumer surplus theory still holds. The good has a demand curve, representing the marginal benefits that consumers gain from consuming it, and this demand curve, if we know it, can be used to calculate the consumer surplus. However, we cannot observe the demand curve because there is no market.

Some non-market benefits are non-excludable goods (a type of public good). We cannot charge a price for these goods (e.g. lower ambient temperatures in a region), so there is no market for them.

Some non-market goods relate to externalities – impacts on third parties who are not involved in the economic activity that generates the externalities. The downstream effects of water pollution is one example. The non-market benefit would be a reduction in water pollution due to abating emissions upstream. In this case, the market may not exist due to high transaction costs of negotiating between polluters and victims, and the absence of well-defined rights (e.g. a public right to non-polluted water).

Estimation

Estimating a project's non-market benefits requires two types of information: (a) the additional quantity of the benefit that results from the project, and (b) the monetary-equivalent value of that additional quantity. Information type (a) often requires advice from technical experts, such as scientists and engineers, but sometimes the information may be sourced from community members (e.g. through a survey or focus group). The appropriate technical experts will vary depending on the type of non-market benefit. For example, estimating improvements in biodiversity probably requires input from ecologists, estimating reduced morbidity requires input from public health researchers, and estimating increased vegetation requires input from plant scientists.

The second step (placing a monetary-equivalent value on the benefits) is often a stumbling block in conducting comprehensive BCAs of water sensitive projects. There are several well-tested techniques for monetising non-market values, but a limited range of existing case studies to draw on for new BCAs.

However, significant investment by the CRC for Water Sensitive Cities is addressing this gap. The CRCWSC conducted several new non-market valuation studies in its first phase, and is now running a project to collate, evaluate, and interpret the existing studies (nationally and internationally), and make them accessible. The result is the INFFEWS Value Tool. The Value Tool Guidelines include further background on non-market valuation and guidance on using non-market values in BCA.

Cost savings and cost delays

Theory

Cost savings are a benefit. For example, reductions in extreme heat due to vegetation could reduce power costs for air conditioning. Improved catchment management could mean that a lower capacity (and cheaper) water treatment plant could be installed. The second example may also change maintenance costs.

Cost delays are also a benefit. The longer the cost delay, the lower the cost is in present value terms (due to discounting), and present values are what matter in a BCA. For example, delaying a cost of $1 million from the present to year 50, given a discount rate of 7%, reduces its present value to $34,000.

Accurately calculating these benefits is complex for projects that affect the timing and scale of large infrastructure investments. For example, imagine a utility plans to upgrade a water treatment plant in 3 years, at a cost of $25 million. However, a project to exclude livestock from the catchment could delay the upgrade until year 5, using a less expensive water treatment technology, and reducing the cost to $15 million. We must also consider how maintenance costs will vary over time, with and without the project. The annual maintenance cost before investing in a new plant is $110,000. With the new treatment plant, the annual maintenance cost falls to $90,000 if there is no project to remove livestock from the catchment, and to $50,000 if the livestock removal project is implemented.

This complex scenario generates benefits in various ways: (a) reducing the cost of the treatment plant upgrade; (b) delaying the upgrade, which is a benefit due to discounting; and (c) lowering the maintenance cost.

Assessing the project’s overall benefits requires careful attention to the with versus without principle. We identify the costs in each year without the project, then with the project, and take the difference (Table 1).

Table 1. Estimating the benefits from a project that affects the size and timing of a major infrastructure project, and maintenance costs after infrastructure installation.

	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7
Cost without project	110	110	25,000	90	90	90	90
Cost with project	110	110	110	110	15,000	50	50
Difference	0	0	24,890	−20	−14,910	40	40

Note: All costs are in thousands of dollars.

The Difference row represents the year-by-year benefits of the project. This stream of benefits would be discounted to calculate the present value.

Estimation

To estimate private cost savings (such as the power savings arising from reduced heat) we need information about the reduction in purchases of a costly item that can realistically be expected to result from a project. In the heat example, we need predictions of the heat reduction (from scientists), the resulting reduction in air conditioner use (perhaps from social scientists), the resulting power savings (from electrical engineers) and the cost of power (from the power utility).

For cost savings or cost delays in infrastructure projects, engineers, managers and accountants may be useful sources of information.

Risk reductions

Theory

Decision theory works on the basis that, across a large number of decisions, the approach that delivers the greatest net benefits in the long run involves selecting those decision options that maximise expected net benefit. "Expected" in this context is a weighted average. Consistent with this, when evaluating projects that aim to reduce the probability of an adverse outcome, the BCA Tool evaluates risky outcomes using expected benefits. The different possible outcomes are weighted by their probabilities and added up. The set of possible outcomes needs to be complete, meaning its elements have probabilities that sum to one.

The BCA Tool allows for three facets of a risky event, such as a flood. The first is the expected cost if the risky event does occur in any year. The cost may be different between the with project and without project scenarios. The second is the probability of the risky event occurring in any year. This probability, too, may be different between the with project and without project scenarios. Third, once a risky event does occur, there may be a residual effect on the probability of another risky event occurring in subsequent years. For example, in some locations (depending on the hydrology), following a flood the probability of another flood occurring is increased for a period, because the water table remains high. On the other hand, following a wildfire in a water resource catchment (with risks to water quality), the probability of another fire is reduced for a period, due to a reduction in fuel. The BCA Tool represents the change in the probability of occurrence, and the duration of the residual period.

Estimation

We need technical advice from relevant experts to estimate the change in the probability and perhaps the cost of the risky outcome, like a flood, as a result of the project.

Emergency service agencies may be good sources of information about the costs of natural hazards and other adverse events. For most hazards, the distribution has a high variance and is highly positively skewed, with most of the costs occurring in a small number of extreme events. In many cases, a simple approach based on average cost per event is likely to be sufficient, although considering a range of potential severities (each with a probability attached) is also possible. The BCA Tool uses the simple approach based on averages.

The number of beneficiaries

Estimating benefits per person or per household requires estimating the number of beneficiaries. Factors to consider when estimating the number of beneficiaries include the following.

- Over what spatial scale will biological or physical benefits occur? What are the boundaries within which biological or physical benefits will occur?

- Will beneficiaries who live or work outside the boundaries of impact also benefit from the project? How far outside the boundaries can a person be and still benefit from the project? (For example, a person may benefit from existence values even if they live remotely from the project.)
- Can distinct groups of beneficiaries be identified? (For example, people who live locally and people who travel to the project site for recreation.)
- Does the estimate of benefits break down the benefits into different levels for different sub-groups of the population, or is it an average for a defined population? If the benefit estimate per person is an average for the population, it presumably allows for the fact that some people have zero benefits, while others have high benefits.
- If sub-groups are identified, what are the population sizes in each sub-group? If not, what is the whole population size within the relevant spatial boundary?

Overall, the aim is to think carefully about the relationship between the population or different sub-populations, and the benefits for which estimates are available. Use evidence about population sizes (usually from publicly available statistics) to scale up the benefits.

Multiplier effects

Advocates for projects sometimes argue that the projects will generate additional benefits through economic multiplier effects, as the benefits flow through the economy. However, this ignores the fact that there are likely to be negative (offsetting) multiplier effects from the process of imposing taxes to fund the project. The new activity is likely to displace other activity. In most cases, “multiplier effects should be ignored” (The Treasury, 2015, p.16).

Other benefits

If there are other benefit types that have not been captured here, consider using Categories 2, 4 or 8 to enter them into the BCA Tool.

Residual value of an asset

Guidelines from treasury departments in Victoria (Department of Treasury and Finance, 2013) and New South Wales (New South Wales Government, 2017) both recommend assuming that residual values from assets should to zero at the end of the BCA time frame. One practical reason for this is that, depending on the time frame and the discount rate, it may not be worth bothering to include a non-zero value: with a discount rate of 7%, the present value of a residual value in year 50 is only 3% as large as its non-discounted value. However, residual values of major long-lived assets can be significant in some cases, and can be included if relevant.

In the BCA Tool, a residual value can be entered in benefit Category 8, in the last year of the planning horizon, which is specified on the General sheet (Length of the analysis). Enter the label “Residual value of assets” in a line of the Category 8 table.

Adoption of required actions by private citizens and businesses

Adoption by private citizens and businesses

Often, the success of a project depends on the behaviour of certain people. For example, the aim of the project might be to reduce eutrophication in an urban river by having people reduce fertiliser use in home gardens.

But typically, not everybody adopts the behaviour being promoted. The degree of adoption varies from project to project, and we must account for this assessing projects. Otherwise we risk giving funds to projects that have great potential but little benefit in practice.

Define *A* as the level of adoption, as a proportion of the level needed to achieve the project's goal. If *A* = 0.5, then adoption was only half the level we needed to achieve the goal.

Usually, if *A* is less than 1.0, it doesn't mean the project generates no benefits. There is some relationship between *A* and the benefits generated. Figure 7 shows one possible example, where proportional benefits [*f*(*A*)] increase slowly at low levels of adoption, then rapidly for a while, before flattening off again at high adoption. Other shapes are possible, but whatever the shape, we know these important facts about it: it must range from zero (no adoption, so no project benefits) to 1.0 (full adoption, so full project benefits). This is because we define *f*(*A*) as the proportion of target project benefits achieved.

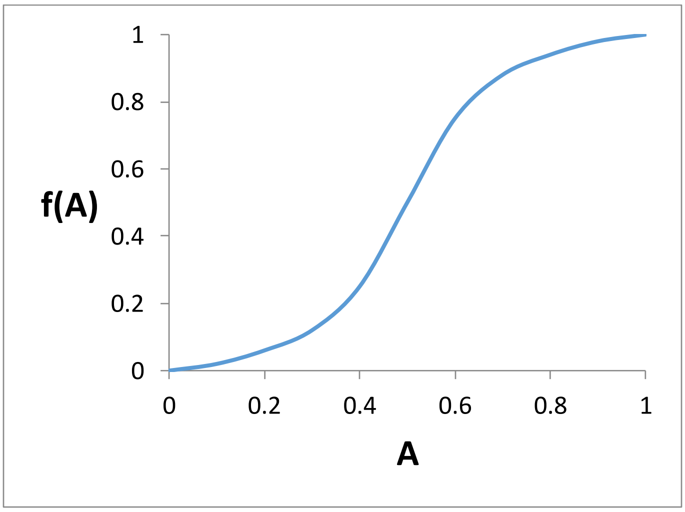

Figure 7. Potential relationship between community participation in a project (*A*) and the level of benefits generated (*f*(*A*)).

A reasonable simplification is to approximate *f*(*A*) by a straight line. In practice, we usually have too little information about the actual shape of *f*(*A*) in specific cases to argue that its shape should be non-linear. And even if it is non-linear, it is unlikely to be so non-linear that assuming linearity would have bad consequences. If you are comfortable with this approximation, you can just use *A* in the BCA formula rather than *f*(*A*).

This is what the BCA Tool does: in the absence of better information, and in the interests of simplicity, we use *A* rather than *f*(*A*) in the formula. However, if you did have accurate numbers for *f*(*A*), you would enter them into the tool in place of *A* (in part 4.3 Custom value for adoption).

Here are some final comments on predicting the level of adoption for a project. There has been much research into the factors that influence the uptake of new practices (e.g., Rogers 2003; Pannell et al., 2006). There are many different factors, and the important factors vary substantially from case to case.

However, despite the research, it remains difficult to make quantitative predictions about participation in a specific project. Predictions require specific knowledge about the population of potential adopters, and the practice we would like them to adopt. In general, it appears people who develop projects are usually too optimistic about the level and speed of adoption that is realistic – sometimes far too optimistic.

Typically, the more extensive are the changes required of people, the less likely they are to be attractive to people, unless the changes are highly attractive. Changes that may be attractive if adopted at a small scale can be highly unattractive if they have to be adopted at a large scale.

Factors influencing the attractiveness of a new practice include: its costs, its financial benefits, its riskiness, its complexity, its compatibility with existing practices and systems, social pressures for or against the practice, and the attractiveness of the existing practice that the new practice would replace. The strength of community networks, community attitudes, community knowledge/awareness, and so on also play a role.

In estimating adoption levels quantitatively, consider a range of evidence and opinion about adoption of the desired practices, including: their current levels of adoption; the extent to which that adoption has already been encouraged by awareness programs or similar; whether those past efforts were successful; and the private economic costs and benefits of the practice. To help form judgements about these issues, you might have discussions with the relevant citizens or businesses, run workshops with them, do financial analysis, conduct a survey, or look at mapped data on current adoption of the practices (e.g. reflected in uptake of incentive payments/grants). You might also draw on existing papers, reports, tools and resources that relate to the adoption question.

The BCA Tool asks two questions to guide the selection of a number for the adoption level: (a) How attractive are the required works and actions to the relevant private citizens and businesses? and (b) How favourable are the circumstances of this project for adoption (related to the size and diversity of the target audience, and the quality of links between the target audience and the project organisation)? Based on the answers to these questions, the BCA Tool suggests a default value for the adoption parameter. If you have additional information or insights into adoption for this project you can override the default value and enter a particular value.

The following report from the CRC for Water Sensitive Cities is not focused on predicting adoption, but its discussion of behaviour change may help support better predictions.

Ramkissoon, H., Smith, L., & Kneebone, S. (2014). Accelerating transition to water sensitive cities. Behaviour Assessment Database. Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities. https://watersensitivecities.org.au/content/how-influencing-behaviours-can-accelerate-the-transition-to-a-water-sensitive-city-behaviour-assessment-database-project-a2-2/

Adoption by other organisations

For some projects, the organisation that is responsible for the project relies on another organisation for delivering part of the project. If this is through a contractual agreement, confidence that the other organisation will deliver can be reasonably high. Sometimes, however, the arrangement is less formal. In that case, the probability that the project will fail due to the partner organisation failing to deliver should be factored into the estimate of project risk. In the BCA Tool, this would be included as part of the adoption risk.

Time lags

Different projects involve different time lags until benefits are generated. There are at least four potential causes of time lags:

1. Some projects take a significant amount of time to implement (implementation lags). For example, if a project relies on new research being conducted, it could take several years before results are available. Typically, implementation lags for different types of project range from a year to a decade.
2. It may take a while for the physical actions implemented in a project to take effect and to start generating benefits (effect lags). For example, if the project involves planting vegetation, that takes a while to grow. Realistic effect lags in projects range from zero to decades. For projects that address issues with groundwater, time lags can sometimes be very long.
3. The project may be addressing a threat which has not occurred yet but is expected to occur in future (threat lag). For example, between 2001 and 2008 the Australian Government invested in many projects that were intended to prevent the occurrence of dryland salinity in rural areas. In some of those areas, salinity was not predicted to occur until several decades in the future. In other cases, the threat lag was zero – the problem was already occurring.
4. If a project requires other people to change their behaviour or management, it may take a while for most people to change (adoption lag). Realistic adoption lags for substantial changes range from around five years to several decades.

Given this variety of lag types, and the range of lag lengths within each lag type, projects vary widely in the overall time lag until benefits are generated.

Figure 8 illustrates a pattern of benefits over time (combining all the types of lags). This project generates half of its benefits by year 18 and 90% by year 25.

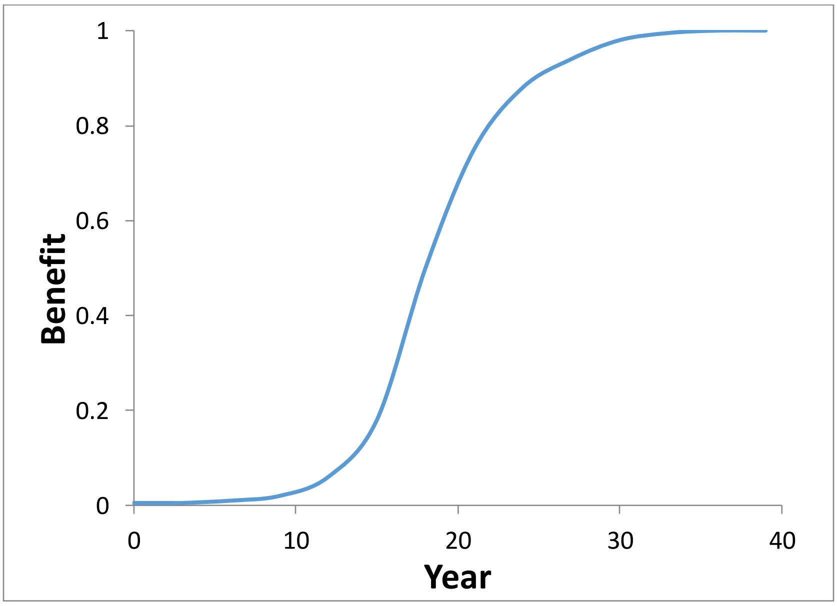

Figure 8. Illustrative pattern of the benefits over time, including all lag types.

Lag times matter in a BCA because we discount future benefits and costs to express them in present value terms (see later section on discounting). The further in the future a benefit occurs, the smaller its value in present value terms.

In practice, there is usually much uncertainty about how the benefits will play out over time. Recognising that uncertainty, it is usually not worth being too precise about the shape of the curve. A highly simplified curve, like the one in Figure 9, might be sufficient.

To specify this curve, all you need to know is the peak level of benefits (corresponding to the plateau in Figure 8), and the year when it will be achieved (corresponding to the year in Figure 8 when most of the benefits would be achieved). One could also include an end date for the benefits, if relevant.

The BCA Tool provides places to enter lag times for each individual benefit type and each cost type. For benefit categories 1, 2, 3, 4, 6, and 7, you specify the start year and the end year for each benefit type. In benefit category 5, you specify the timing of a cost with and without the project. In category 8, you specify the benefits each year individually, so time lags can easily be represented.

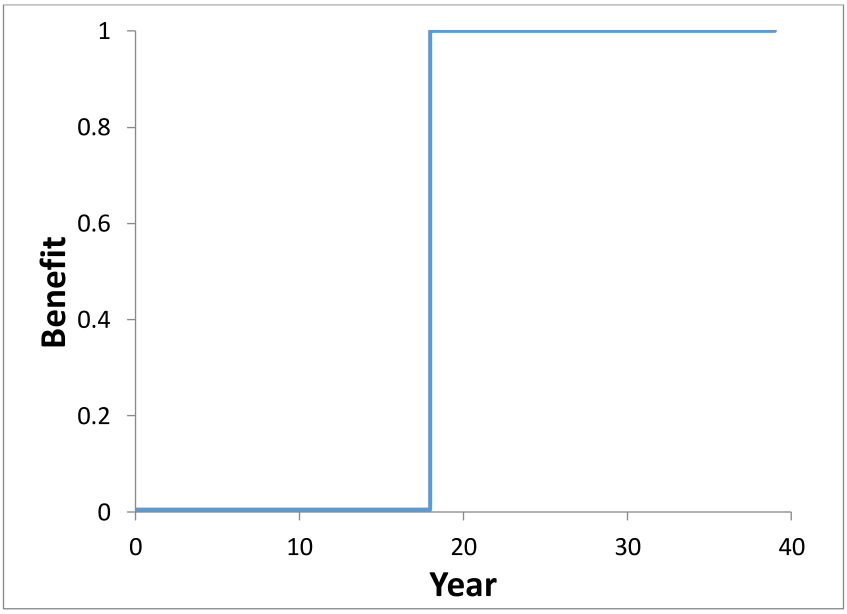

Figure 9. Simplified pattern of benefits over time.

Costs

Several different types of costs may need to be considered in a BCA. They are: the cost of the project itself (cash costs to the funder, in-kind costs to the lead organisation and private costs to participants), ongoing costs to maintain the benefits generated by the project, and the opportunity cost of the funds invested in the projects. The last one is different in nature from the others, and we will deal with it later, in the section on discount rates.

Project costs

Cash costs

For a project to proceed, money is needed for various purposes, potentially including: the time of people employed to implement the project or provide support to the project, cars, fuel, machinery and equipment, payments to people to encourage behaviour change, legal costs, office space, telephones, insurance, publicity, printing, and so on.

Whether an organisation is allocating its own cash resources among projects or applying to an external funder, the cash allocated to a project may not be enough to pay for all associated costs. Often the lead organisation bears some of the costs out of existing salary or operating budgets (in-kind costs), or people in the community voluntarily contribute time or other resources (private costs). These non-cash costs are covered in the next two sections.

The project developer needs to prepare a comprehensive budget for the project. The budget needs to be specified year by year, for the life of the project. Costs are discounted to calculate their present value in exactly the same way as benefits are, and using the same discount rates.

In-kind costs

If the cash funds provided for a project are not sufficient, the organisation that is running the project often makes up the difference. For example, they may cover some or all of the costs of: project staff salaries, administrative support, office space, stationery, telephone calls, and so on.

These 'in-kind' costs provided by the organisation responsible for the project are real costs and should be accounted for when assessing projects.

Generally, organisations have limited resources that they can use as in-kind support. Theoretically, this creates a problem, because different types of costs (cash and in-kind) are being drawn from two limited pools. Strictly speaking, this means that you cannot rank projects based on a single formula. The Benefit: Cost Ratio (BCR) ranks projects correctly only if there is only one constraint on costs (e.g. on the level of funds in the pool of new cash). If there are two constraints, it is impossible to specify a formula that is guaranteed to rank projects correctly. In theory, what one would have to do is build a constrained optimisation model with separate constraints for the two types of funding (e.g. using the technique of mathematical programming).

In practice, that is unlikely to happen, because of the additional time and expertise required, and the loss of transparency and intuitiveness in the results. Fortunately, treating all project costs as if they come from one large pool (i.e. including them all in the denominator of the BCR) is usually a very good approximation of the theoretically correct approach. (The loss of overall benefits due to poor decisions across a portfolio of projects was less than 1% in the examples I looked at.)

As was the case with cash costs, in-kind costs should be discounted to express them as present values.

Estimating in-kind costs requires the project organisation to estimate the level of in-kind time and resources that will be devoted to the project, and their costs per unit.

Private costs

People or businesses who participate in projects may bear costs. For example, people may contribute their time, their land, or other inputs to the project.

The first case considers private costs that are contributed voluntarily. They should be included in the BCA only if the corresponding private benefits are also included. (These costs and benefits may be financial, psychological and social.) Since people are doing the works voluntarily, it must be something they want to do. For them, the private benefits (broadly defined) must be sufficient to outweigh the private costs. So, including the private costs without also including the private benefits would bias the results.

The second case considers private costs that are not borne voluntarily, but are imposed on people against their will, such as through enforcement of a regulation. In this case, it is quite possible that private costs exceed private benefits and we must account for “compliance costs”.

The compliance costs are the losses incurred by the relevant people, aggregated over the whole group of people, and aggregated over the relevant time frame (including discounting). They may continue longer than the initial project costs if people are required to continue doing something that they would not otherwise choose to do. The BCA should include them for as long as they are expected to persist.

Compliance costs should be calculated as the change in private net benefits with and without the project. They should include any direct and indirect losses, and any offsetting benefits, if relevant. Estimating compliance costs can be quite challenging unless you have good survey information or an economic model. But it is better to make an educated guess than to leave them out.

Private costs (including compliance costs) are subtracted from the benefits rather than being added to the project costs and maintenance costs. This is because the denominator of the BCA is for costs that are limited in availability and, from the project funder’s point of view, there is no limit on the level of private costs that can be borne. There is usually limited funding available for project costs and maintenance costs, but compliance costs don’t need cash from the funder (except if the funder provides compensation, which becomes a project cost). The BCA Tool allows for this by allocating private costs to one of the specified stakeholders (i.e. define the relevant group as a stakeholder, and allocate their costs to them).

Maintenance costs

Often, projects need ongoing funding in the long term to preserve or maintain the benefits generated by an initial project. For example, funds may be needed to maintain, repair, or replace equipment or structures; to pay the wages of people responsible for ongoing education, training or enforcement; or for continuing payments to people to ensure ongoing adoption of improved practices. These costs might arise for a few years beyond the end of the initial project, or they might last more or less forever.

The required level of maintenance funding can be substantial, potentially exceeding the cost of the initial project. Plus, maintenance costs vary greatly between different projects, so it is important to account for maintenance costs when evaluating projects.

Estimating maintenance costs requires discussion with the project organisation or similar organisations.

Disposal or restoration costs

At the end of the life of some types of projects, there may be costs involved in disposing materials or restoring the site. If this occurs within the time frame of the BCA, then they should be included in the costs.

Costs to project organisation

The BCA Tool can calculate BCA results for society as a whole and for the project organisation alone. If the latter is of interest, then you can specify the proportion of each cost that is attributed to the project organisation in the BCA Tool.

Excess burden of taxation

The Victorian Department of Treasury and Finance explains this factor.

> Taxation generally generates a 'deadweight loss', which is also known as the 'excess burden of taxation'. This is a cost to society that comes about through taxation distorting economic behaviour (including decision making and resource allocation), leading to less than optimal outcomes for the economy. A simple example of this is the reduced incentive to work in the presence of high marginal income tax rates. In addition, there are administration and compliance costs associated with generating taxation revenue.
>
> To take this into account, any government intervention that uses taxation revenue not only needs to produce benefits of at least the amount spent, but the benefits also need to cover the associated 'tax distortion' ('excess burden') costs. (Department of Treasury and Finance, 2013, p. 49).

Different governments have adopted slightly different recommended practices for dealing with the marginal excess burden of taxation (MEB).

- Australia (Commonwealth of Australia 2006): Present results that include and exclude the MEB as a sensitivity analysis. No rate is specified but a 1997 estimate of the MEB for Australia of 0.25 is mentioned. (i.e. this estimate indicates that, for every dollar of tax spent on a project, there is an additional cost of $0.25 due to efficiency losses and administration costs – to spend $1.00 costs $1.25).

- New South Wales (New South Wales Government 2017): No requirement to include MEB. Optionally present results that include and exclude the MEB as a sensitivity analysis. No rate specified.

- Victoria (Department of Treasury and Finance 2013): Include MEB with a conservative default value of 0.08 (to spend $1.00 costs $1.08).

- Queensland (State of Queensland 2015): Include MEB. No rate specified.

- South Australia (Government of South Australia 2014): MEB not mentioned in the investment process guidelines.

- New Zealand (The Treasury 2015): Include MEB with a default value of 0.2 (to spend $1.00 costs $1.20).

Given this diversity, we suggest setting the MEB at 0.08 in the BCA Tool (part 5.7 on the *Costs time series* sheet). The *Sensitivity* sheet shows results of a sensitivity analysis in which MEB is set to zero. The same MEB should be used for all projects that are being compared.

Normally, the MEB is applied only to funds that are obtained from government taxes. If funds are obtained from other sources, such as service charges or sales of water to customers, the usual practice is not to impose the excess burden. On the other hand, there are administration costs involved in collecting and processing such funds, and it seems reasonable to allow for these. This could be done by allowing for administration costs in the project budget. Often, those administration costs are not drawn from the same pool of funds as the main project costs, and so should not be included in the denominator of the BCR. If you are expecting to use the BCR as your decision criterion, you could define financial administration as a separate stakeholder, to separate its costs from the main project organisation costs.

Project risks

Projects don't always go smoothly. Various things can stop them from delivering their intended benefits. To avoid over-optimism about projects, it is important to explicitly consider the risk that the project may be implemented but may still fail to deliver its intended benefits.

"Risk" is used in many different ways, so it is important to clarify what it means here. We are talking about things that might stop the project from delivering its intended benefits, not risks to the environmental or to human health or the economy.

There are various types of project risks, potentially including technical risk, socio-political risk, financial risk and management risk. They can all be important and are worth accounting for.

Risk refers to an unpredictable outcome about which it is possible to specify a probability, at least subjectively. Uncertainty – where you cannot specify probabilities – is also relevant, and can be usefully addressed using sensitivity analysis (discussed later).

Technical risk

There is some probability that the project will fail to deliver outcomes for technical reasons. Management actions are implemented but they don't work because something breaks, or newly planted vegetation dies, or there was a miscalculation when designing the actions, or there is some sort of natural event that makes the actions ineffective.

This risk may be estimated through discussions with experts who understand the technical issues, or with people who are experienced at implementing similar projects.

Socio-political risk

In some cases, social or political factors will prevent project success. For example, a project might rely on another government agency to enforce existing regulations, but that agency is not prepared to enforce them because of the likelihood of a political controversy. Or there might be community protest, or perhaps even legal action, to stop the project.

Estimating this risk is necessarily subjective. Consider: whether the project will be supported or obstructed by social, administrative or political factors, including support or opposition by local community groups and networks; likely resistance to the project at the political level; bureaucratic approvals that would be needed; support or opposition by local government, etc. What is the probability that the project will fail to reach its goal due to one or more of these factors? If legal approvals are required, what is the probability that they will not be forthcoming?

Another aspect of socio-political risk

The project may generate social or political controversy with adverse consequences for the responsible agency. This controversy may result from the project failing to deliver its intended benefits, or from completely unrelated factors. For example, the project may fully deliver its intended benefits, but have unintended adverse consequences in some other way, and these adverse consequences may generate political criticism or controversy.

Either way, this socio-political risk should be considered as a separate, and additional, negative factor, on top of any risk to the project benefits themselves. The adverse consequences that may be relevant include reprimands, suspensions, loss of promotion, demotion, or termination of employment contracts for individuals in the project organisation, and perhaps reduced funding or reduced powers for the agency as a whole.

The BCA Tool does not represent this risk quantitatively. However it could be captured qualitatively in part 6.4 (Negative spin-offs from the project) on the *Project risks* sheet.

Spin-offs such as this can be considered subjectively by decision makers when they are looking at the quantitative BCA results. Qualitative information about the risks would be presented to decision makers along with the quantitative results.

Financial risk

Most projects require some level of ongoing funding after the initial project phase. For example, this could be for maintaining or repairing infrastructure or equipment, operating costs, managing vegetation, or ongoing public education and awareness raising. Without funding for maintenance and operations, benefits generated during the initial project phase may be compromised or even lost entirely.

In some circumstances, the availability of funding in the long term for maintenance and operations is reasonably assured, perhaps because it will be a core responsibility of an agency. On the other hand, there may be doubts about the availability of maintenance funding, especially in situations where the decision to provide this ongoing funding is made independently of the decision to fund an initial project. For example, many project grants to community groups are made on the assumption (or hope) that the community group will be responsible for long-term maintenance, which may or may not occur in practice. Clearly, projects vary in the probability that their benefits will be lost due to a lack of maintenance funding.

Because this risk (lack of maintenance funding) reduces the expected benefits of some projects, it should be considered as part of the BCA. Estimating the risk requires knowing who will be responsible for funding ongoing maintenance and operations, and how decisions to provide that funding are made. With this knowledge, a subjective judgement about the risk can be made.

The risk of maintenance funding not being provided also has a positive aspect: it means that there is a cost saving. If benefits are scaled down because of this type of financial risk, maintenance costs should be scaled down by the same probability.

The discussion above relates to the risk that a project's benefits will not be delivered. There is also risk on the cost side: although we base the BCA on our best estimate of the project costs, once it is implemented, the actual costs may be higher or lower. This is included in the analysis as a sensitivity analysis on cost. In the *Sensitivity* sheet, the user specifies how total project cost may vary up or down relative to the default level, and this range is included as part of three types of sensitivity analysis: robustness of results to changing variables; sensitivity of results to individual factors; and break-even analysis for individual factors.

There may also be higher-than-expected costs associated with the base case. This would be captured in sensitivity analysis of the project's benefits.

Managerial risk

If different projects will be managed by different organisations, then there are likely to be differences in the risk of failure related to management. These risks might include poor governance arrangements, poor relationships with partners, poor capacity of staff in the organisation, poor specification of targets, milestones and timelines, or poor project leadership.

Estimating the risk requires knowing the organisation(s) that will be responsible for project delivery, and their track record for successfully managing similar projects. With this knowledge, a subjective judgement about the risk can be made.

Representing project risks mathematically

Some of these risks relate to all-or-nothing outcomes (e.g. there either is successful legal action against the project or there isn't), while others relate to continuous variables (e.g. maintenance funding might be deficient but not zero, resulting in some reduced level of ongoing benefits).

Representing risks for continuous variables is possible, but it requires detailed information. Given that we are usually relying on educated guesses when we specify these risks, going to that level of detail is probably not warranted. However, users can approximate each of the risks as the probability of a binary (all-or-nothing) variable turning out badly. To illustrate, rather than trying to specify probabilities for each possible level of maintenance funding, we would just specify the probability of maintenance funding being so low that most of the benefits would be lost. We would assume that there are two possible outcomes for each risk: it causes the project to fail, or the project is fully successful (or, at least, as successful as the other factors allow it to be). Appendix A provides a more technical explanation of this simplifying assumption.

Some risks might be correlated. For example, if there is social or political resistance to a project, it might reduce the probability of it getting long-term maintenance funding. In theory we should account for this correlation too, but I don't consider it worth going to that level of detail. Reasons include: the quality of information we generally have when specifying correlations between risks is low; the formula used for ranking projects would have to get complicated; it would be confusing to many people; and it probably would not make much difference.

Given those simplifications, the expected benefits of a project are proportional to the probability of the project NOT failing (1 minus the risk). With these risk variables included, the benefits are now probability weighted, so they are "expected" benefits, in the statistical sense of a weighted average, where the "weights" are the probabilities of success (1 minus the probability of failure).

Any or all of these risks may apply to a particular project. The overall project risk is the combined effect of all the individual risks. The BCA Tool includes eight risk variables: one for each of the eight categories of benefits. (There is an option of using the same risk value for all eight benefit types.)

The overall risk for each category of benefit may be judged subjectively based on identifying and discussing the individual risks, or it may be calculated from the individual risks if each has been specified quantitatively. The latter is simplest if we assume that the four risks are independent of each other, which seems a reasonable assumption in most cases. Then we can employ the following equation:

$$(1 - R) = (1 - T) \times (1 - S) \times (1 - F) \times (1 - M) \tag{1}$$

where R = overall project risk, T = technical risk, S = socio-political risk, F = financial risk and M = managerial risk, all expressed as probabilities.

Rearranging equation (1), we can calculate R as

$$R = 1 - [(1 - T) \times (1 - S) \times (1 - F) \times (1 - M)] \tag{2}$$

If the base case is risky, the relevant project risk for the BCA is the additional risk, on top of the base case risk.

Some organisations like to break risks down into likelihoods and consequences (as suggested in the ISO 31000 Risk Management Standard). Likelihoods represent the probability that a bad thing will happen (often scored on a scale like this: almost certain, likely, possible, unlikely or very unlikely), and consequence means how bad the bad thing would be if it did happen (e.g., scored as insignificant, minor, moderate, major or catastrophic). Depending on the combination of these two scores, the overall risk is assessed as minimal, low, medium, high or extreme.

This is a rather drawn-out way of getting a risk score (compared with just stating the probability of project failure), and I don't think it's necessary, but it is logical and may help people to think clearly about the issues.

Risk assessment

"Risk" can also mean a threat to the environment, human health or the economy, for example. In this context it is the probability of a bad outcome in relation to a particular issue, as opposed to the probability of project failure. Some organisations conduct "risk assessments" in which they try to identify and quantify the likely future problems that they may need to address. This document deals with that aspect of risk in the section on the with versus without principle. It is represented by the difference between current condition and future condition without the proposed project ((1) – (3) in Figure 1).

A concern with this sort of risk assessment is that it may distract attention away from the correct measure of project benefits. Having done a "risk assessment" and come up with estimates of (1) – (3), people may feel that the results should be included in a BCA. However, the correct measure of project benefits is (2) – (3), and if you include (2) – (3), also including (1) – (3) can only make the assessment worse. That this type of "risk assessment" provides only the "without" half of the information you need to estimate potential project benefits. You also need to know what would happen "with" the project.

Discount rates

Each organisations may have its own policy about which discount rates to use. For example, some water utilities use their weighted average cost of capital. In the absence of a particular policy, Table 2 provides information about discount rates recommended by treasury departments in each Australian state and nationally.

Despite the variations, there is a reasonable level of consistency. In the absence of other requirements, using 4, 7 and 10 is consistent with the majority.

Debates about climate policy have prompted some new thinking about discount rates, but this has not yet made it into the Australian guidelines. Government guidelines expect a given real discount rate will be applied at a constant level over the entire time horizon for the analysis. However, environmental economist Martin Weitzman (1998) noted there is uncertainty about what the discount rate will be in the future. Instead of varying the rate in a sensitivity analysis (using a single rate for the whole time period), he proposed defining the future discount rate as a probability distribution. Even if it is expected that the mean of the probability distribution of discount rates will stay constant over time, for mathematical reasons, representing uncertainty about the discount rate as a probability distribution is equivalent to using a discount rate that falls over time. Recently this idea was given new impetus when it was endorsed by a large team of leading economists (Arrow et al., 2013). The UK Government BCA guidelines are now loosely based on this approach – they recommend using a real rate of 3.5% per year for the early years, 3.0% after year 30, 2.5% after year 75 and eventually declining to 1% over 300 years.

Table 2. Discount rates suggested for BCA in different Australian jurisdictions. These are all real rates, not nominal.

Jurisdiction	Reference	Default rate (%)	Suggested rates for sensitivity analysis
Australia (Office of Best Practice Regulation)	Australian Government (2016)	7	3 and 10
Australia (Infrastructure Australia)	Infrastructure Australia (2018)	7	4 and 10
Australia (Productivity Commission)	Harrison (2010)	8	3 and 10
New South Wales	New South Wales Government (2017)	7	3 and 10
Victoria	Department of Treasury and Finance (2013)	Projects with monetary benefits: 7 Projects with non-monetary benefits: 4	4 and 9 (around 7) No rates suggested for around 4
Queensland	Email consultation with Queensland Treasury	7	4 and 10
Western Australia	The state's "Options Analysis Model" guidelines	7	4 and 10
South Australia	Government of South Australia (2014)	2.7 to 6.7 depending on market risk of the project. Medium = 5.	−2 and +2 relative to the default
Tasmania	No guidelines issued by Treasury	Agencies generally use 7	Not specified

Therefore, use of Weitzman discounting in BCAs is an alternative to the traditional approach based on sensitivity analysis of the rate. We could use the same range of rates (e.g. 4, 7 and 10%) and assign probabilities to them. Experiments with the approach show that, with a time frame up to 50 years, it would make only a small difference to the results. For example, assuming a discrete probability distribution for discount rates with three levels (4, 7 and 10) with symmetric probabilities (0.25, 0.50, 0.25) and allowing 40 years linear transition to the alternative rates, the certainty-equivalent discount rate in year 50 is 0.06, only 1% less than the mean rate. At this stage, Weitzman discounting is not included in the BCA Tool.

Another point of active discussion and some disagreement is the conceptual basis that should be used to set discount rates. Harrison (2010) noted two broad approaches:

- "a 'descriptive' approach based on the opportunity cost of drawing funds from elsewhere in the economy, and
- a 'prescriptive' approach that derives from ethical views about intergenerational equity." (p. vii).

All Australian governments that recommend discount rates do so on the basis of the opportunity cost of funds. On the other hand, the UK Government guidelines employ the prescriptive approach, and as a result they recommend substantially lower discount rates.

I consider the descriptive approach (as used by Australian governments) is more logical and defensible. In his review of the issues, Harrison (2010) concluded:

> *Market rates reflect the opportunity cost of investing in public projects, and there is no case for allocating resources to low return investments when higher returns are available. Using an artificially low discount rate for project evaluation can make future generations worse off. (p.vii)*

He also noted that the ethical basis for lowering rates is weak, and that stronger ethical arguments can be raised for using market rates. Harberger and Jenkins (2015), in commenting on the prescriptive approach, stated “such exercises have it all backwards” (p.25). They explain the Ramsey equation, which underpins the prescriptive approach, and conclude that “using the Ramsey equation to derive an *r* [rate of time preference] that is different from the relevant market rate is, we believe, a mistake” (p.26).

At 2019, interest rates are at record low levels. While this suggests that discount rates used currently should be lower than they have been in recent decades, it should be recognised that current interest rates may not persist in the long term, whereas a discount rate should be relevant to the entire timeframe for the BCA.

Timeframe for the BCA

Some projects would generate benefits and/or costs more or less forever. The question arises, how long should the timeframe be for calculating the BCA results? There is no clear cut answer to this. The length of time used for the calculations needs to be fairly long, but if it is extremely long, discounting means that benefits and costs in the distant future are quite insignificant in the present. Also, uncertainty about what might happen in the distant future is very high, so one might judge that it is not worth factoring in benefits or costs that may never arise in reality. Depending on the perspective of the project organisation and its funders, anything between 20 and 50 years could be reasonable. Anything beyond 50 years is highly speculative. NSW Treasury recommends that 20–30 years is often sufficient.

The BCA Tool allows the user to specify any time frame up to 50 years. **It is important that all projects that are going to be compared have the same timeframe in the BCA.**

Sensitivity analysis

Sensitivity analysis (SA) is the formal term for “what if” analysis. It is one of the things that makes economic models so useful. We know that the numbers used in any BCA are subject to uncertainty, and that the variables that drive it will vary somewhat unpredictably over time. But, by using sensitivity analysis, we can still get useful information and insights.

Uses of sensitivity analysis

There are many possible uses of SA (see Pannell, 1997), but in BCA the main ones are as follows.

Testing the robustness of an optimal solution. SA can test the stability of results. For realistic changes in the parameters, how widely do the results (the Net Present Value (NPV) and Benefit: Cost Ratio (BCR)) change?

Identifying sensitive or important variables. By comparing the SA results for different individual variables used in the analysis, analysts can determine which variables have the biggest influence on results. The analyst can then focus on those variables, and collect the best available data about them.

Identifying critical values, thresholds or break-even values. Consider the question: "If variable X were to change from its current value, by how much would it have to change for the BCA's core result to change from favourable (BCR > 1) to unfavourable (BCR < 1) or vice versa?" This break-even approach is particularly useful for assessing whether the threshold value of the variable (the point at which the BCA result changes) falls within a range of reasonable values. A break-even value within the reasonable range may justify collecting additional information to predict the variable's actual value. If not, the decision maker can be advised (for planning purposes) to disregard the possibility of the variable taking a different value.

Making recommendations more credible, understandable, compelling or persuasive. With SA results, decision makers can judge how much faith they can place in the BCA results. A BCR greater than one in almost all cases despite wide variations in the assumptions provides confidence in supporting the project. Similarly, a BCR less than one in almost all cases provides confidence in rejecting the project.

Sensitivity analyses built into the BCA Tool

There are many different ways of conducting SA for different purposes (Pannell, 1997). The BCA Tool includes five different SAs on the *Sensitivity* sheet.

1. Robustness of results to changing variables. The first function (known a "Monte Carlo analysis") tests the robustness of results, based on 1000 simulations that change key variables up or down or leave them at their default levels. The user specifies changes up or down at the bottom of the Sensitivity sheet. To use this function, the user requests a "Range for sensitivity analysis" for each benefit category on the Benefit sheet. This request provides a lower value than the default value and a higher value, much like a "confidence interval" for the variable. (For example, the user could select a range for which there is a 75% chance that the true value lies within that range.) A table at the bottom of the Sensitivity sheet specifies the probabilities of the different values for the variable (low, default and high). The Tool assumes these three values represent the full range of possible values for the variable, and so represent a discrete probability distribution for that variable. The Tool also assumes the distributions are independent of each other, making it easy to draw random samples from the joint probability distribution of all the variables. The Tool does this 1000 times to generate the results on the Sensitivity sheet. These simulations include variations in all the variables at once, not one at a time.

   The Sensitivity sheet presents: the minimum and maximum values for NPV from the 1000 simulations; the probability that NPV > 0; and the probability distribution of NPV results, shown as a discrete distribution with five levels.

   The same test is available for the BCR. And results for both the NPV and the BCR can provided for the project organization alone and for the overall community.

2. Sensitivity of results to individual factors. The Tool provides a "Sensitivity Index" for each main variable, again based on 1000 simulations. This index is the average BCR for high values of the variable (from 1000 simulations), minus the average BCR for low values of the variable, all divided by the BCR for the base case. A positive Sensitivity Index value indicates an increase in the variable increases the BCR; a negative value indicates an increase in the variable decreases the BCR. The larger the absolute value of the Sensitivity Index, the greater the variable's influence over the range specified. The Sensitivity Index accounts for both the slope of the relationship, and the specified range of values. For example, a variable might have a big impact on the BCR per unit change in the variable, but if the realistic range for that variable is narrow, then its Sensitivity Index will not be high.

3. Break-even analysis for individual factors. For each variable, this function shows the break-even values at which the BCA results change. Based on 1000 simulations, the Tool calculates the rate of change of the BCR per unit change in the variable, to calculate the percentage change in the variable needed to change the overall BCR to 1. If the base case BCR is above 1, the break-

even analysis provides the percentage changes needed to drop the BCR to 1; if the base-case BCR is below 1, the break-even analysis provides the percentage changes needed to increase the BCR to 1. If the required percentage changes are small enough, this analysis suggests plausible changes in the variable could change the BCA result. It provides further evidence about the robustness of the BCA results, and indicates which variables are likely to affect the BCA results and therefore may require additional information. These variables are shaded red if the break-even value falls within the range specified for sensitivity analysis. If the break-even value is greater than 100% or less than −100%, this is indicated with a text message rather than showing the actual number. Changes in these variables are extremely unlikely to alter the BCA result.

4. Sensitivity to discount rate. Most of the BCA guides produced by Australian governments advise users to conduct SA on the discount rate. This can contribute to judgements about the robustness of results.

5. Sensitivity to excluding the excess burden of taxation. Two BCA guides produced by Australian governments (national and New South Wales) suggest conducting this SA. This reflects the variation in advice about whether the excess burden of taxation should be included in the analysis. I consider it should be, and if you specify a non-zero value for marginal excess burden on the *General* sheet, it will be. This SA shows how including or excluding the excess burden affects results. For further explanation of the excess burden of taxation, see the sub-section about it in the Costs section above.

Pitfalls and errors to avoid

Double counting benefits

As outlined in the companion document, *INFFEWS BCA Tool: BCA and Strategic Decision Making for Water Sensitive Cities*, analysts must take care to avoid double counting benefits. Generally, the greatest risk of double counting occurs when benefits are reflected in the prices of land or houses. For example, suppose an investment in green infrastructure in a particular location generates recreational and aesthetic benefits, which are estimated using a choice experiment. A secondary effect is that house prices in the area rise, which may be estimated using hedonic pricing. However, the BCA should not include both the choice experiment and the hedonic pricing results because there is overlap in the benefits they are measuring. The reason that house prices have risen is that potential purchasers anticipate their access to the new green infrastructure, perceive the extra benefits that this would provide to them, and raise the price they are willing to pay for the house. To include both the choice experiment results and the hedonic pricing results would be double counting. If both are available, results from the choice experiment captures benefits for a larger number of people and may be preferred for that reason.

There is also a risk of double counting if the analysis includes both (a) estimates of market benefits and (b) results from a stated preference survey (Contingent Valuation or Choice Experiments) that estimates non-market benefits. If there are private market benefits to the survey respondents as a result of the changes being assessed, they are likely to factor them into their responses to the survey. Including the survey results together with other estimates of those market benefits (e.g. based on their market demand curve) would be double counting.

Guarding against double counting cannot readily be automated. It is up to BCA practitioners to be aware of the risks and how to avoid them.

Other non-benefits

In some cases, the new project will provide benefits that were already being provided by other resources or infrastructure. In this case, there is no net benefit, just a substitution between the sources of the benefits. For example, if a new green space provides recreation opportunities in a suburb that is already well served with recreational opportunities, any users of the new facilities are likely to substitute away from existing facilities. In other words, the gain in value due to the new facilities is largely cancelled out by a loss in value for the old facilities. If the benefit is a market benefit, the existence of substitute facilities will be reflected in very low prices. Similarly, for non-market values, the willingness to pay estimates will be low. If the BCA analyst estimates the benefits in some way other than obtaining evidence on willingness to pay, then there is a strong risk of missing the substitution opportunities and overstating the benefits.

Creation of jobs is not necessarily a benefit. The advice from Commonwealth of Australia (2006) about this is: “To say that a project will create 100 jobs is not to say that a project will reduce unemployment by 100 people. As a general rule, it is recommended that analysts assume that labour, as with other resources, is fully employed [i.e. that job creation is not a benefit]. Moreover, unless the project is specifically targeted towards the goal of reducing unemployment, it can be expected that many of the jobs will be filled by individuals who are currently employed but who are attracted either by the pay or by other attributes of the new positions.” (Commonwealth of Australia, 2006, p.40).

Multipliers

As noted in the Benefits section, multiplier effects should be ignored (The Treasury, 2015).

Poor definition of the without project scenario

The baseline for comparison with the project scenario(s) should probably not be the pre-project condition, because things are likely to change in the absence of the project. Some aspects of the relevant conditions may worsen or improve without the project, with implications for the benefits that could be generated by this project. For example, if conditions were improving anyway, a predicted increase following implementation of a project may be largely due to the changes that were already going to happen rather than to the new project. The BCA analyst must fully think through and record the without project scenario in sufficient detail so it can be used as the base case for comparison in the BCA.

The BCA Tool asks you to be explicit and clear about the without project scenario. You are asked to consider the without project scenario at each stage of estimating the project benefits.

Logically inconsistent project definition

It is easy to plan a project in a way that is not logically consistent. Examples include the works and actions clearly would not achieve the project’s targets; the project activities would not result in sufficient participation by private citizens; project activities do not align with the budgeted costs.

The BCA Tool is structured to assist with maintaining logical consistency throughout the process. For example, it separates actions by citizens from the project activities to encourage those actions. There are a number of consistency checks included in the BCA Tool User Guide, to guard against logical inconsistency.

Poor justification of the numbers

Given uncertainty, specifying numbers with high accuracy is not achievable in most cases. However, the choices of numbers must be well considered. It is good practice to record explanations and justifications for the numbers used. This assists with peer review of the BCA. See the companion document *Benefit: Cost Analysis and Strategic Decision Making for Water Sensitive Cities* for further discussion of peer review.

Including interest payments on capital

The equivalent of interest payments is already captured in a BCA through the process of discounting. The correct procedure is to include the initial capital costs only. To include interest payments on the capital would double count costs.

Including depreciation costs

"Capital costs are recorded on a lump-sum or cash basis in cost-benefit analysis in the period in which they occur. To include periodic depreciation (in line with accounting practice) in addition will lead to double counting of these costs." (Commonwealth of Australian, 2006, p. 119).

Ranking projects by Net Present Value when the budget is limited

If the budget available for funding projects is not limited, all projects with Net Present Values (NPVs) greater than zero (or, equivalently, Benefit: Cost Ratios (BCRs) greater than one) should be funded.

When there is a limited budget, the choice between using NPV and BCR depends on whether the projects are separate, unrelated projects. If projects A and B are separate, unrelated projects, it means that if you did project A, you could still also do project B, if you had enough money. The other possibility is that they could be mutually exclusive, meaning that if you do Project A1, you can't do Project A2. This latter scenario would be the case if you are evaluating different versions of the same project, and you can only do one of them, even if you have unlimited money available.

For unrelated projects and a limited budget, we rank projects. We fund the best ranked projects up to the point where the available budget is exhausted. And, to generate the largest net benefits overall, the correct way to rank projects in this scenario is by BCR. In that situation, ranking by NPV can give highly inferior results.

In this scenario: the costs included the denominator of the BCR are only those costs that would be drawn from the limited pool of funds that are being allocated to projects. Other costs (e.g. costs borne by affected businesses that are not the project organisation) should be subtracted from the numerator because they are not constraining the selection of projects.

This issue causes some confusion, even among treasury departments. Unfortunately some government guidelines provide advice that may be reasonable for treasury departments, for which budgets can always be increased if necessary (by increasing taxes), but quite unhelpful for individual agencies, local governments or utilities. For example, Commonwealth of Australia (2006) specifies using NPV and not BCR. Some guides incorrectly say that BCR can provide misleading project rankings (e.g. Department of Treasury and Finance, 2013; The Treasury, 2015). That is true only if unconstrained costs (e.g. external costs) are included in the denominator, but that is an error that is easily avoided. The New South Wales Government (2017) guideline presents this issue correctly.

In the BCA Tool, both NPV and BCR are reported, but only the BCR should be used for ranking separate, unrelated projects. Unconstrained costs (costs to stakeholders and the excess burden of taxation) are subtracted from the numerator of the BCR, ensuring that projects are correctly ranked by BCR.

Box 2. Comparing multiple versions of the same project

It is good practice to assess multiple versions of the same project before settling on a particular version. Versions of a project with more ambitious targets can deliver greater benefits, but also incur greater costs, so it is usually not readily apparent how ambitious the project should be. (Project versions also vary on dimensions other than ambition, such as their spatial targeting, or the specific actions they will include.) The first project version to be specified may or may not end up being the best version when several versions are compared.

However, if you are ranking projects, and the projects consist of multiple versions of the same project, using BCR for the ranking process will probably not give you the correct result.

The following example explains why BCR does not give you the correct project ranking in this situation.

Suppose that projects X1 and X2 are two versions of project X. If you did project version X2, you would have to bear the cost of doing X2, and in addition, you would bear the opportunity cost of not doing project X1 (i.e., you would miss out on the net benefits of doing X1). Similarly, the full cost of doing X1 should include the opportunity cost of not doing X2. That's why the traditional BCRs of projects X1 and X2 do not provide a reliable ranking – there are additional costs that a BCR doesn't capture.

The obvious solution is to include the opportunity cost of not doing the best alternative project when calculating the BCR. However, this is an inconvenient approach because the identity of the best alternative project depends on the available budget. Each time you generate results for a different budget level, you would have to recalculate all the BCRs based on different opportunity costs.

A much simpler approach (that gives the same answer) is to choose the project with the largest NPV that you can afford within the funds allocated for this project.

If simultaneously comparing multiple versions of multiple projects, things are trickier. See http://www.pannelldiscussions.net/2019/09/324-npv-vs-bcr-3/ for advice.

Learning more

Here is a suggested strategy for somebody who wishes to develop their knowledge of BCA to underpin their effective use of the technique.

1. Read the first document in the INFFEWS BCA Tool package: *Benefit: Cost Analysis and Strategic Decision Making for Water Sensitive Cities*. This document provides advice on a set of high-level strategic issues around BCA and its usage. It is aimed at managers, but is also highly relevant to BCA practitioners.

2. Develop a good grasp of the essentials of BCA. Guidelines produced by various Australian or New Zealand governments may be useful for this. I recommend the following guidelines:

- The Victorian Department of Treasury and Finance (Department of Treasury and Finance, 2013). This is reasonably comprehensive and includes useful examples. But ignore its incorrect advice about the unreliability of BCRs.
- The New Zealand Treasury (The Treasury, 2015). This one has a practical flavour, and gives good advice about conducting a "rough" BCA. It makes the same mistake as the Victorian Treasury regarding BCRs.
- The New South Wales Treasury (New South Wales Government, 2017). This covers the standard issues well and provides the correct advice on BCRs. It includes a good glossary.

These are all about the same length (70-80 pages). They vary in their styles and emphases, but each provides a good overview of the essentials of BCA.

They are intended for use by government agencies who are preparing BCAs for their department of treasury, so some of their advice is not relevant to other types of bodies.

The Queensland Government's guidelines (State of Queensland, 2015) are shorter and relatively accessible and readable, but are a bit more superficial.

3. Prepare a rough BCA, using the template provided in the BCA Tool package.

4. Read the BCA Tool Guidelines (this document).

5. Use the BCA Tool User Guide and Spreadsheet to prepare some full BCAs using the BCA Tool, under the guidance of an experienced BCA practitioner.

This strategy can be complemented by:

- Attendance at one of the BCA Tool training sessions, when they are available.
- Watching some of the available free online videos on BCA. I recommend the series of excellent videos produced by the Conservation Strategy Fund which provides an introduction to BCA. The context for these videos is conservation projects, but the issues raised are fully relevant to water sensitive cities projects. Go to: https://www.conservation-strategy.org/en/csf-econ-video-lessons?term_node_tid_depth=380 Scroll down the page to see all the videos.

For the fullest depth of knowledge about the theory and methods behind BCA, study the text book by Boardman et al. (2017). Like most text books, this is strong on the theory, but relatively weak on many of the practical issues we have covered here.

For an introduction to the standard supply and demand model, I recommend the series of free videos provided by the Khan Academy: https://www.khanacademy.org/economics-finance-domain/microeconomics/supply-demand-equilibrium

The Khan Academy also provides a good explanation of consumer surplus and producer surplus, which are used to measure the market benefits from a project, with consumer surplus also used for non-market benefits. https://www.khanacademy.org/economics-finance-domain/microeconomics/consumer-producer-surplus. Watch the supply and demand videos before you watch these ones.

If you are looking for a book that provides a good brief introduction to the microeconomics, you could try *Microeconomics Made Simple: Basic Microeconomic Principles Explained in 100 Pages or Less* by Austin Frakt and Mike Piper.

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Appendix A. Technical explanation of project risk

When planning ahead for a project, we usually don't know exactly how beneficial the project will be, but the benefits can be represented as a probability distribution. In Figure A.1 they are shown as a cumulative distribution, for a project that generates water savings.

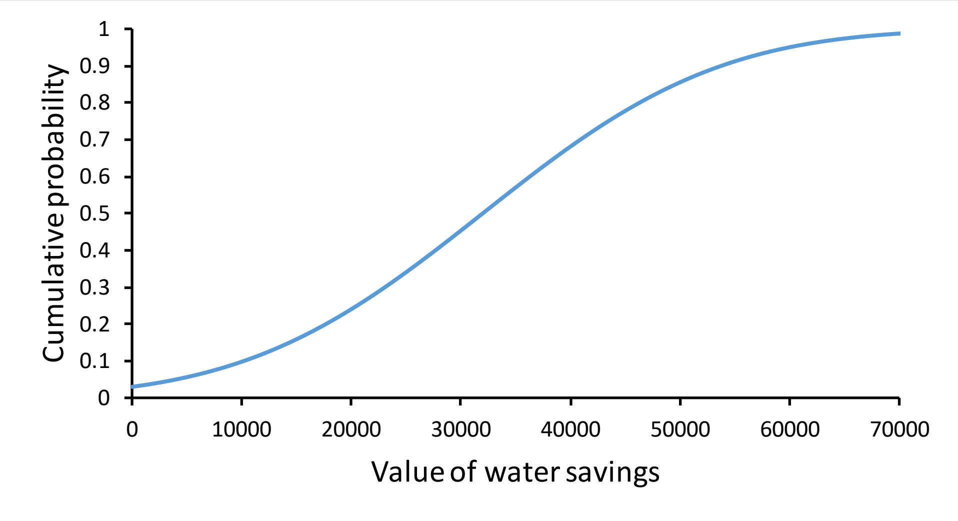

Figure A.1. Cumulative probability distribution of benefits from a project.

In the BCA Tool, the project risk is represented as the probability that most of the hoped-for project benefits will not be realised. Conceptually, this could be thought of as the probability that benefits are, say, 20% or less of the mean of the distribution (Figure A.2). In this way, the continuous probability distribution of project benefits is simplified down to two levels: the project fails and is assumed to deliver zero benefits, or the project succeeds and is assumed to deliver the mean of the distribution of benefits.

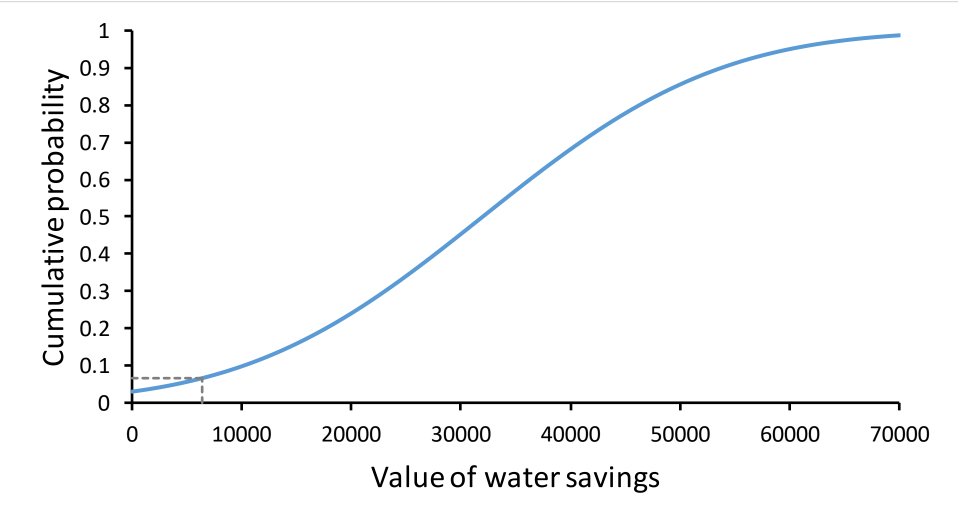

Figure A.2. The probability that the project benefits will be 6,400 or less (20% of the mean of the distribution, 32,000) is 0.066.

A further complexity is that there is likely to be risk associated with the without project scenario as well. Figure A.3 shows an example where the distribution of an outcome (e.g. water savings) is risky for both the without project and with project scenarios. In this example, the without project scenario is less risky (the distribution has a smaller standard deviation) but that will not necessarily be the case.

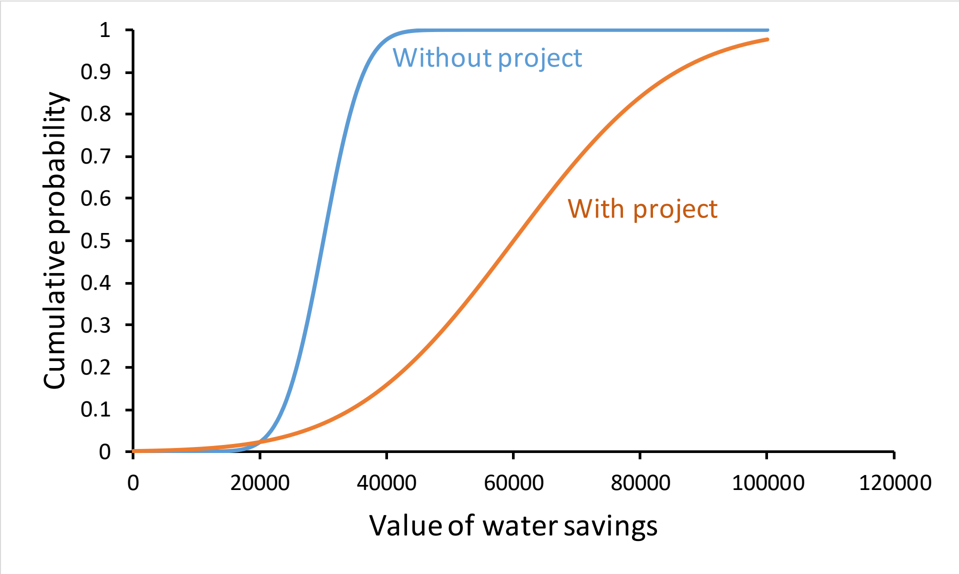

Figure A.3. Risk in both the without project and with project scenarios.

The distribution of benefits for this project is based on the horizontal difference between the two distributions in Figure A.3. This is depicted in Figure A.4. We end up with a cumulative probability distribution of benefits. It is a different shape to the distribution in Figure A.1 but we can still use it to work out the probability that the project benefits will be 20% or less of the mean of the distribution, which is what we need for the simplified approach in the BCA Tool. Thus, the approach works even when there is risk in the base case.

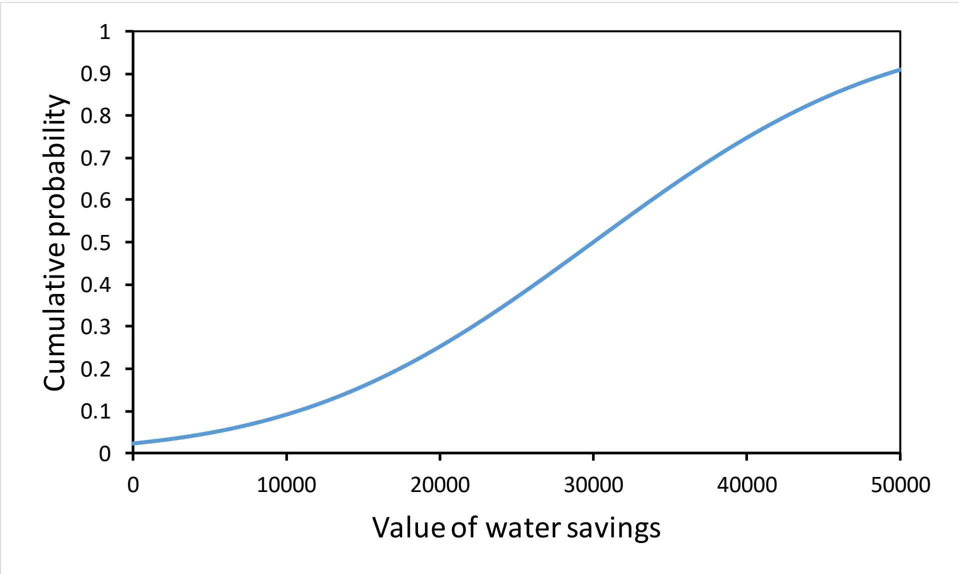

Figure A.4. Distribution of project benefits, calculated as the horizontal difference between the without-project and with-project cumulative distributions in Figure A.3.

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