TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

T2 Cost Benefit Analysis

May 2018

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At a glance

This Part of the ATAP Guidelines provides guidance on the use of cost-benefit analysis (CBA) in the appraisal of transport options/initiatives and their prioritisation.

The context is the first five steps of the ATAP Framework:

- Step 1 identifies jurisdiction goals, transport system objectives and targets (see Part F1)
- Step 2 identifies and assesses priority problems preventing the achievement of transport system objectives identified in step 1 (see Part F2)
- Step 3 involves generating and assessing a broad range of options for addressing a priority problem(s) identified in step 2 (see Part F3).
- The end result of step 3 is the identification of a preferred option that becomes a proposed justified initiative through the advancement of a supporting business case in step 4 (see Part F4).
- Prioritisation across proposed initiatives occurs in step 5 (see Part F5).

Cost-benefit analysis (CBA) plays a central role in step 3 Options Generation and Assessment, in which it is a key element of the appraisal process. It also influences decisions in step 5 Prioritisation of Initiatives and Program Development.

Chapter 3 of Part F5 presents the ATAP Guidelines' three stage approach to the assessment of options / initiatives:

- Strategic Merit Test (SMT)
- Rapid appraisal – including a rapid CBA
- Detailed appraisal – including a detailed CBA.

The appraisal process involves monetised benefits and costs as well as non-monetised benefits and costs. All of the above are brought together in an Appraisal Summary Table (AST) to demonstrate the overall benefits, costs and net benefits (benefits minus costs) of an initiative.

The discussion in this Part supports the guidance given in Part F3 by providing an extensive coverage of CBA to facilitate good understanding and application by transport practitioners.

Note that the discussion in this Part applies to the assessment of both options and initiatives as defined above. While the discussion generally refers to initiatives, it is meant to refer equally to options.

Introduction

What is cost–benefit analysis?

Cost-benefit analysis (CBA) is the primary appraisal tool at the options assessment and initiative prioritisation stages of the appraisal process. It is a rigorous, transparent, quantitative method that measures the degree to which individual initiatives generate net benefits (benefits minus costs) across Australia and allows comparison and ranking of options and initiatives.

CBA is a standard technique used all over the world and can be applied to a wide range of initiatives in a defensible, comprehensive, transparent and rigorous way. The CBA methodology set out in the ATAP Guidelines is tailored to suit transport initiatives in a multi-modal context and where a wide range of options are being explored.

CBA aims to identify and express, in monetary terms, all the gains and losses (benefits and costs) created by an initiative to all members of society and to combine the gains and losses into a single measure of net benefit (benefits minus costs). If the result, expressed as a net present value, is positive — that is, total benefits exceed total costs — implementation of the initiative will be an economically efficient use of resources: Australia, *as a whole*, will be better off. The words ‘as a whole’ are emphasised because there will be losers as well as gainers. A positive result from a CBA means that the total gains exceed the total losses.

CBA is a well-established methodology that is widely employed by government departments and consultants in a range of areas. It permits initiatives to be compared, not only in respect of different transport modes, but also between the transport sector and other sectors of the economy. It can also be applied to non-infrastructure solutions such as the introduction of new technology or changed management practices.

CBA aims to summarise, in a single number, the combined benefits and costs to *all members of society*. Non-monetised benefits and costs are considered and presented alongside the monetised results.

In contrast, financial analysis aims to summarise, in a single number, the combined benefits and costs to *a single entity*: the owner or operator (if leased) of the initiative. Financial analysis considers the monetary costs and revenues to the owner or operator contemplating the investment: in this analysis, benefits are replaced with revenues from sales minus operating expenses. Identifying and measuring benefits and costs are usually simpler for a financial analysis than for a CBA because in financial analysis, the analyst needs to focus only on cash flows. Financial analysis becomes more complicated when taxation and financing costs are also included in the analysis.

While analysts have considerable leeway in making assumptions, the rules about which benefits and costs to include in a CBA and ways of valuing them are, for the most part, straightforward. If correctly followed, a CBA can result in comprehensive coverage of benefits and costs, without double-counting.

Structure of CBA guidance

This Part of the ATAP Guidelines sets out general guidance for undertaking CBAs in a series of steps.

- Step 1: Specify the initiative and analyse options
- Step 2: Identify the benefits and costs
- Step 3: Estimate investment costs
- Step 4: Make demand forecasts
- Step 5: Estimate infrastructure operating costs
- Step 6: Estimate user benefits
- Step 7: Estimate cross-modal and network effects
- Step 8: Estimate safety benefits
- Step 9: Estimate externality benefits and costs
- Step 10: Discount benefits and costs, calculate summary results
- Step 11: Assess risk and uncertainty.

More detailed discussion of each step is provided in NGTSM 2006 Volume 5. For ease of use, the CBA category has the same chapter and section headings as the steps.

Category M of the Guidelines establishes related guidance on the application of CBA to specific transport modes and specific types of initiatives. The present coverage includes roads, public transport, rail transport, active travel, travel behaviour change, maintenance and flood mitigation. Future editions of the Guidelines will introduce other aspects such as climate change adaptation, regulatory change and other non-infrastructure initiatives.

The PV category of the Guidelines provides parameter values for public transport, road, rail and active travel and for environmental externalities.

The last chapter of this part of the Guidelines covers the adjusted CBA technique, which is a hybrid of CBA and multi-criteria analysis. Using the CBA as the starting point and retaining the monetary measuring rod of CBA, adjusted CBA avoids some of the deficiencies of score and weight systems of multi-criteria analysis (see Box 1 in F3). Productivity metrics (see Part T4) is a form of adjusted CBA, with the emphasis placed on impacts on national productivity.

Rapid and detailed appraisal

Part F3 of the Guidelines introduces rapid and detailed appraisal as the second and third stages of options assessment. This split of appraisal reflects the fact that the appraisal of initiatives is not costless. To limit the cost of assessing a large number of options in the early stages of identifying and sifting potential initiatives and options, a simpler 'rapid' assessment process is required. This also applies to smaller initiatives where the consequences of a wrong decision are small.

Rapid appraisal is a cost-effective way of gauging whether an initiative is likely to pass a detailed appraisal. The resources required for a detailed appraisal can then be expended only on initiatives that have a good chance of succeeding.

A rapid appraisal should consider as many benefits and costs as necessary to establish whether an initiative is worth developing further. Rapid appraisal assists with considering or rejecting options by assessing their net benefit, indicating their net economic worth.

It is appropriate to undertake a rapid appraisal as the only form of CBA for small-scale initiatives where the costs of a wrong decision are small. Jurisdictions will have their own views about what constitutes a small-scale initiative. The ATAP Guidelines suggest an upper limit of investment costs of about $15 million for small-scale initiatives. This figure may need to be adjusted over time.

Most small-scale initiatives will probably be for road and active travel, but small initiatives involving rail initiatives or technology solutions should be treated the same way. Intelligent transport systems initiatives will often fall into the small-scale initiative category.

A rapid CBA allows consideration of monetised benefits and costs. In a rapid appraisal, non-monetised benefits and costs also need to be explored at an indicative level.

The methodology used for rapid CBA is the same as for the detailed CBA. However, the estimates for a rapid CBA are less precise and the benefits and costs that are small, or difficult to estimate, can be omitted altogether.

The majority of initiatives submitted for rapid appraisal are likely to be at an early stage of development, with limited planning and limited available data. An estimate of investment costs is essential. Based on the experience of Australian jurisdictions, the expected margin for error in rapid CBAs for investment costs is -20 per cent to ±40 per cent.

Where any of the following benefits (or costs) amount to more than 10 per cent of total benefits (or costs), they should be quantified if possible:

- Changes in infrastructure operating costs
- Savings in transport user costs — vehicle operating costs
- Savings in transport user costs — time for passengers and freight
- Improvements in service quality to users (e.g. reliability)
- Gains for generated traffic or traffic using a new service
- Benefits or costs from route or mode diversion
- Savings in crash costs
- Externality impacts.

Where benefits or costs can be readily estimated using default parameter values (such as externalities), an estimate should be made, even if they amount to less than 10 per cent of the total benefits or costs. Where the estimation of a benefit or cost is impossible without using resources above a level appropriate for a rapid CBA, describe the impact qualitatively, with quantitative measures in physical units where possible.

Risks associated with the initiative should be discussed in qualitative terms. Particular attention should be given to risks that could lead to construction costs being substantially higher than estimated and risks that could lead to benefits being substantially less than estimated.

In a rapid CBA, externalities can be valued using ‘default values’ if this can be done with little effort. This helps to determine the significance of each externality benefit or cost.

Significant externalities should be re-estimated at the detailed CBA stage, with site-specific data and modelling, to obtain a more detailed value of the externalities. For detailed CBAs, studies may be required to obtain initiative-specific unit values for externalities. For the most part, other parameter values are well-established; hence, the same values are used in both rapid and detailed CBA.

The detailed CBA should include a comprehensive risk assessment with adjustments made to ensure the final results are not biased by over-optimistic estimates of benefits and costs. Sensitivity testing should also be undertaken; although, if a thorough risk analysis has been undertaken, sensitivity testing may not be required.

1. Step 1: Specify the initiative and analyse options

Steps

1.1. Describe the initiative.

1.2. List the objectives the initiative will achieve.

1.3. Check whether the initiative is properly scoped.

1.4. Consider whether the initiative should be staged.

1.5. Identify constraints that could inhibit the initiative from proceeding.

1.6. Specify the Base Case.

1.7. Identify and analyse options.

1.8. Consider pricing assumptions (where applicable).

1.9. Consider private sector funding.

1.10. Is a financial analysis needed?

1.1 Describe the initiative

Describe the initiative, including its location, physical characteristics, function, estimated cost, timing and main benefits. At the detailed appraisal stage, describe the initiative in much greater detail than at the rapid appraisal stage.

1.2 List the objectives the initiative will achieve

It is important to show that the initiative will contribute to achieving government transport system objectives. As discussed in Part F3 of the Guidelines, this alignment is demonstrated through the Strategic Merit Test (SMT).

Part F1 of the Guidelines discusses transport system objectives. At the broadest level, these objectives are likely to include promoting:

- Economic efficiency
- Economic development and trade
- Environmental amenity and sustainability
- Safety
- Security
- Accessibility, social cohesion and equity.

If the SMT shows that an option or initiative does not align well with the transport system objectives, it should either be dismissed at that stage or re-scoped until it does achieve strategic alignment.

Practitioners may also choose (optional) to create initiative-specific objectives that are consistent with and support the transport system objectives. The CBA can assist to clarify initiative-specific objectives. After the results of the CBA become available, practitioners should look at the relative sizes of the different benefits to see if they correspond with the stated objectives. For example, it would be expected that for a initiative aimed at relieving congestion, the bulk of the benefits would be savings in travel time and vehicle operating costs.

1.3 Check whether the initiative is properly scoped

If the initiative consists of discrete or separate components, each one must be justified as if it were an independent initiative. (See Chapter 5 of Part F3 and NGTSM 2006Volume 5, Section 2.2.11 for a discussion on relationships between initiatives). Where the impacts of a series of initiatives are closely interdependent, consider grouping the initiatives together and then treating them as a single initiative.

Only combine initiatives when a single initiative, implemented by itself, produces little or no benefit until another initiative (or initiatives) is completed. In other words, there has to be significant synergies between the initiatives. To test this, there are said to be significant synergies if the NPV of the group of related initiatives, assessed together as though they were a single initiative, is significantly greater than sum of the NPVs of the initiatives assessed individually.

If there are few, or no, synergies between initiatives, they should be appraised separately.

1.4 Consider whether the initiative should be staged

Breaking an initiative into stages can make financing easier, by spreading funding needs over time, and can reduce risks by providing opportunities to delay or cancel later initiative stages.

1.5 Identify constraints that could inhibit the initiative from proceeding

The next step is to identify any major constraints and show that the initiative is feasible given these constraints. The Strategic Merit Test template in Part F3 of the ATAP Guidelines asks for this information.

Many options can be ruled out quickly because they fail to satisfy constraints. Constraints may involve technical, environmental or public acceptability considerations.

1.6 Specify the Base Case

The proposal should specify the Base Case, including any significant assumptions about actions that need to be undertaken in the Base Case, and other future events that affect benefits or costs. A CBA is always a comparison between a Base Case (without the initiative) and a Project Case (with the initiative). Text Box 1 provides supporting background discussion on the Base Case.

The Base Case consists of a ‘real world assessment’ (IA 2017) of what would be done in the absence of the Project Case being implemented. A do-minimum Base Case is preferred, and should:

- Include ongoing maintenance of associated assets for structural integrity and public safety (this also applies to a do-nothing base case)
- Include a ‘minimum’ level of intervention (based on existing capacity) to manage the problem. It could maintain the existing level of service over the appraisal period if possible (i.e. prevent the problem from getting worse), or at least minimise the rate of degradation in service level (i.e. minimise the rate at which the problem gets worse)
- Be of modest cost (If the cost is too high, the option should be treated as a project case option)
- Not include significant asset augmentation or enhancement to meet incremental demand beyond the capacity of the existing infrastructure. However, include modest spending to improve the effectiveness of existing assets, such as minor road intersection improvements or minor improvements on a rail corridor such as fixing a signalling system.
- Adopt the option that is most effective at maintaining level of service at least cost (if several options fit the do-minimum definition).
- Include relevant initiatives elsewhere in the network (see below for more detail) where funding for those initiatives is approved, committed or expected in the absence of the proposed initiative being appraised.

Relevant initiative`s elsewhere in the network

Clearly specify what assumptions are being made about relevant future initiatives elsewhere in the network to address other problems (i.e. initiatives that will affect costs and benefits of the initiative being appraised). Such initiatives are not part of the proposed initiative being appraised but can affect (via network effects) benefits and costs of the latter and CBA results. The benefits of the initiative being assessed can be increased as well as decreased, by the implementation of other initiatives elsewhere in the network (increased where the other initiatives are of a complementary nature and decreased where they are of substitutable nature—see discussion in APAP Part F3 Appendix A).

These assumptions must be identical in both the Base Case and the Project Case, and be reflected as such in the demand modelling. The only difference between the Base Case and Project Case is therefore the initiative being appraised (and its do-minimum alternative in the Base Case).

ATAP acknowledges that two approaches are used around Australia for recognising initiatives elsewhere in the network:

- The committed expenditure approach: Include in the Base Case and Project Case only future initiatives that are committed and funded. IA (2017) requires this in submissions to it.
- The planning reference case approach: Specify a 'planning reference case' of initiatives across the transport network for the entire appraisal period—reflecting strategic planning. Reflect realistic future funding in the reference case—requiring liaison with Treasury Departments on future funding envelopes.

If there is uncertainty about initiatives elsewhere in the network proceeding, or their timing:

- Undertake the main CBA assessment assuming the most likely scenario, which includes committed and funded projects; and then
- Undertake sensitivity tests with alternative assumptions, including potentially different funding envelopes.

One-off events

One-off events such as Olympic or Commonwealth Games could also affect benefits and costs of initiatives. These developments are equally relevant to, and should feature in, both the Base Case and Project Case. Where there is some uncertainty about a one-off event, make the CBA calculations with and without the assumption, as a sensitivity test or as part of the risk assessment (see Chapter 11).

Box 1: The Base Case

A CBA is a comparison with and without the initiative—not before and after. Specifically, a CBA compares two situations over the appraisal period:

- Base Case—without the proposed initiative, and
- Project Case—with the initiative (doing something to reduce the observed problem).

The Base Case has also been described as:

- The scenario in which current arrangements are maintained (Productivity Commission 2014)
- The 'business-as-usual' or 'keep safe and operational' situation (IA 2017)
- What would happen if the current arrangements were to continue (DFA 2006).

Benefits of a well-specified Base Case

A well-established Base Case provides an unbiased fundamental foundation for problem definition and CBA of prospective initiatives and options. An incorrectly specified base case can lead to poor estimates of both benefits and costs, which potentially renders the analysis speculative at best and redundant at worst (IA 2017).

Choice of Base Case

The choice of Base Case can significantly influence the outcome of the CBA. The two most commonly discussed options for the Base Case are the 'do-nothing' and 'do-minimum' options (DFA 2006, Productivity Commission 2014, IA 2017). These are not the same thing—the former does nothing to address the problem, while the latter does a minimum to manage the problem. The do-minimum option is the preferred approach because:

- There is usually a do-minimum option that could be used to manage the problem in the absence of the initiative
- If solving the problem is a priority, doing even a minimum will usually be expected
- Where a reasonable do-minimum exists, a do-nothing can artificially inflate the CBA results.

If a thorough investigation of do-minimum options shows there are no do-minimum interventions available because they have all been implemented, then the do-nothing option must be accepted as the only possible Base Case.

1.7 Identify and analyse options

See Part F3 of the ATAP Guidelines for guidance on the generation and assessment of options.

Always use the NPV, or incremental BCR, to choose between options on economic grounds - never the BCR or internal rate of return (see Sections 11.3 and 11.6).

1.8 Consider pricing assumptions (where applicable)

Specify any assumptions about charging for infrastructure usage. See Section 5.7 on developing pricing assumptions.

1.9 Consider private sector funding

Show that consideration was given to private sector funding for part, or all, of the initiative.

1.10 Is a financial analysis needed?

State whether a financial analysis is required. Financial analysis is required when the initiative generates revenues and/or involves a public private partnership (PPP). It demonstrates the impact of the initiative on the financial performance of the entity that will own the initiative.

2. Step 2: Identify the benefits and costs

Steps

2.1. List the benefits and costs and classify them.

2.2. Leave out depreciation.

2.3. Be clear about the point of view of the CBA.

2.4. Set the appraisal period.

2.5. Be clear about whether you are working in real or nominal terms.

2.1 List the benefits and costs and classify them

Having specified the initiative (or initiatives if options are being assessed) and the Base Case, a good place to start a CBA is to prepare a list of all the benefits and costs. As explained in the introduction, CBA aims to be as all-encompassing as possible, taking into account all impacts on society. Table 1 provides a checklist that covers most of the benefits and costs associated with transport initiatives, with boxes 2, 3 and 4 providing supporting definitions and discussion.

The table distinguishes three types of benefits and costs:

- Monetised benefits and costs (see Part F3 Section 3.2) are always included in the CBA.
- Non-monetised benefits and costs (see Part F3 Section 3.2) are considered explicitly alongside the monetised benefits and costs in decision making. They should be described in qualitative terms and, where possible, quantified using physical units. In some cases, it may be possible to attempt to value non-monetised benefits and costs in dollar units, but this can involve expensive surveys that yield results with very wide margins of error.
- Secondary or flow-on impacts, are benefits and costs that are passed on, or redistributed, within the economy. The most accurate measurement of benefits and costs can usually be achieved by measuring them directly as close to their sources as possible. Therefore, it is better to measure them as the primary impacts listed in the first column of Table 1, rather than as secondary impacts. Counting both primary and secondary impacts in a CBA is double-counting and leads to distorted results.

Benefits and costs can be further classified according to whether they accrue before the initiative commences operation (investment costs) or during the operating phase.

The Guidelines presents guidance on the related process of benefits management, which is aimed at assessing whether an initiative actually delivers its expected benefits once it has been delivered. Box 4 in Part F3 compares the role of benefits in appraisal versus benefit management. Part F7 provides a full discussion of benefits management.

Table 1 List of potential benefits and costs for transport CBAs

MONETISED	NON-MONETISED	SECONDARY IMPACTS
Investment costs • Planning and design • Site surveying • Site preparation • Investigation, data collection and analysis Legal costs • Administrative costs • Land acquisition • Construction costs • Consequential works Benefits and disbenefits* • Savings in vehicle/train operating costs • Savings in time costs for passengers and/or freight • Improvements in service reliability • Savings in crash/accident costs • Reduced environmental externalities (noise, pollution) • Savings in infrastructure operating costs including maintenance and administration • Benefits associated with diverted and generated traffic • Scrap or residual values of assets	Amenity value Barrier effects on humans and on biodiversity Biodiversity and ecosystems Heritage Aesthetic value Culture Increased comfort, cleanliness and security for passengers Reduced damage to freight and reduced pilferage	Employment (construction and operation phases) Tourism Land values Industry development Community spirit/pride Communication Connectivity Information sharing Social cohesion Increased incomes Access to services Production levels Productivity for industries

Note: The list is not exhaustive.

** Some of these benefits could have a negative sign because they are disbenefits (e.g. increases in environmental externalities).*

*** In most cases, the reason these benefits and costs are ‘non-monetised’ is because it is too expensive to undertake the surveys necessary to produce reasonable estimates of the values people place on them. See NGTSM 2006 Volume 5, Section 2.9.2 for a brief discussion of the techniques available for estimating externality costs. For damage and pilferage to freight, consigners and transport operators are often unwilling to divulge the extent of the problem*

Box 2: Economic benefit and cost terminology

The following definitions from the ATAP Guidelines Glossary (Part A2) **are** repeated here for the convenience of users.

TERM	DESCRIPTION
Willingness-to-pay (WTP)	The maximum amount consumers are willing to pay for a given quantity of a particular good or service (rather than go without it). It indicates the value that consumers place on a given quantity of a good or service. The *marginal* WTP for a given quantity is the height of the demand curve at that quantity. The *total* WTP is measured as the total area under the demand curve up to a given quantity. Total WTP is comprised of consumers' surplus plus the total money price paid by consumers' times the quantity consumed.
Consumers' surplus	The surplus of consumers' willingness-to-pay over and above what they actually pay for a given quantity of a good or service. It is measured as the willingness-to-pay area under the demand curve above the price paid.
Resource cost / opportunity cost / social cost	The value forgone by society from using a resource in its next best alternative use. Reflects market prices where there is an absence of market failure. Where market failure exists, appropriate adjustments are required to estimate the true resource cost.
Private cost	Cost incurred by an individual transport user or service provider. Excludes external costs.
External cost	The cost of an externality – the cost imposed on third parties, including time lost from delays, non-internalised accident risks and environmental impacts. Valued at resource costs or willingness-to-pay.
Money price	The money price paid to use a transport service (such as a fare, toll or road user charge).
User cost	All private costs (in addition to the money price) incurred by a transport user in undertaking a door-to-door journey between origin and destination - waiting time, time in transit, unreliability, walking time, vehicle operating costs, parking, internalised crash risk, any health impacts, damage to freight, passenger discomfort, pick-up and delivery costs for freight. Quality attributes (such as time and reliability) need to be expressed in dollar terms based on user valuations.
Generalised cost/ private generalised cost	The sum of money price and user cost.
Social generalised cost	The full cost to society to complete the door-to-door journey from origin to destination – the sum of user cost and external cost. Valued at resource costs or willingness-to-pay.
Perceived cost	The subset of private generalised cost that is actually perceived by the user. For example, car drivers may perceive time but not all vehicle operating costs. Valued at market prices.
Financial cost / money cost	Cash-flow expense incurred by purchasing resources through markets at market prices.

Box 3: Resource and opportunity costs

The term 'opportunity cost' refers to the benefit that would accrue from using a resource in its next best alternative use. For example, the value of land in CBA (and financial analysis) should be the current market price, not the price paid for it in the past. 'Resource cost' is the opportunity cost of resources used, measured from the point of view of society as a whole.

Differences between private and resource costs arise when, for a given cost, the opportunities forgone are different for the individual incurring the cost and for society as a whole.

Taxes, subsidies, tariffs, import quotas and non-competitive pricing by producers can all cause resource costs to differ from private costs. Take the excise on fuel as an example. The cost to society of an extra litre of fuel consumed (excluding externalities) consists of the cost of earning the foreign exchange required to pay for importation of oil, plus refining, transport and storage costs. The private cost consists of this resource cost plus the tax, which is a 'transfer' to the government. Resource costs values used in CBAs are sometimes referred to as shadow prices.

To convert private costs to resource costs, it is usually sufficient to simply exclude taxes (fuel excise, goods and services tax), subsidies and tariffs from inputs such as fuel, tyres, vehicles and trains.

For labour costs, it is usually more correct in CBAs not to deduct income taxes and payroll taxes to obtain resource costs because of a different assumption about labour supply. The opportunity cost of additional labour resources is assumed to be forgone production elsewhere in the economy. The wage cost incurred by the employer measures the value of this production.

In rare cases, where labour would be otherwise unemployed, a shadow price below the market cost may be used. The shadow price is given by the following formula:

(pre-tax wage – income tax – payroll tax – unemployment benefit + presentation costs)/2

where presentation costs consist of items such as annualised relocation costs, transport to and from work, and special clothing. For further explanation and a derivation of this formula see NGTSM 2006, Volume 5, Section 2.3.5.

If production of an input causes an externality, the cost of the externality should be included in the resource cost.

Box 4: Generalised and perceived costs

Allowance for changes in the quality of transport services in CBAs can be simplified by using the ‘generalised cost’ concept.

To make a journey, transport users incur additional costs on top of the money price. The additional costs, termed ‘user costs’ here, fall into two categories: (1) negative quality attributes, and (2) costs incurred by transport users at the start and end of a trip to complete the door-to-door movement.

Time taken is usually the most important negative quality attribute, followed by unreliability. Unreliability can be measured in a number of ways. The ATAP Guidelines use the standard deviation of trip time for roads and average number of minutes late for public transport.

To incorporate them into generalised cost, time taken and unreliability need to be expressed in dollar amounts. Transport users will have a distribution of values for time and unreliability. Calculation of user costs for a group of users requires quality aspects to be costed at average values.

Examples of the additional costs of a door-to-door journey include:

- For passengers - waiting time, walking and parking
- For freight - pick-up, delivery and packaging. In some cases, these involve money costs and, in some cases, time lost.

The value of waiting time is usually different from the value of in-vehicle time.

The different components of user cost, all expressed in dollar terms, are simply summed. The generalised cost is the sum of user costs and the money price of the main mode of transport used.

When estimating benefits of transport initiatives using prices defined in terms of generalised costs, it is necessary to define supply costs as ‘social generalised costs’. Social generalised costs are the full costs to society of a door-to-door journey, including costs of negative quality attributes, valued in resource terms. While the private and resource values of time and other quality attributes will be the same, taxes and subsidies could cause private and resource costs of vehicle operation to diverge. Hence, social and private user costs may differ.

Transport users may ignore some costs when making decisions. Car drivers may see fuel and other vehicle operating costs as a fixed cost they pay periodically, rather than a variable cost that changes with distance and speed. ‘Perceived cost’ is derived by deducting from generalised cost the costs that users are assumed not to perceive.

See NGTSM 2006 Volume 5, Section 2.3.5, for further discussion.

2.2 Leave out depreciation

Never include depreciation of capital assets in a CBA, because the full cost of the asset to society is taken into account when the resources are consumed to create the asset. This means that to also include depreciation would lead to double-counting. Depreciation is a bookkeeping entry designed to spread capital costs over time in order to facilitate comparisons with operating profits for performance monitoring. For financial analysis, exclude depreciation on the grounds that it is not a cash flow. For financial analyses carried out after tax, depreciation is relevant where it affects taxation payments.

2.3 Be clear about the point of view of the CBA

CBAs are normally undertaken from the point of view of society as a whole. They may be undertaken from the point of view of a subset of society such as people living in a particular state, territory or region. If a CBA is undertaken from the point of view of a subset of society, indicate it clearly and never present the regional result in isolation from the whole-of-society result.

CBAs from the point of view of a state, territory or region can be extremely difficult to carry out in practice because of the problem of distinguishing between benefits that accrue to people within the area and benefits that accrue to people outside the area. A regional CBA is therefore likely to have a higher margin of error.

2.4 Set the appraisal period

The appraisal period should be set at the expected life of the asset created by the initiative in its intended use, plus the construction period. It is usual to assume a 30-year life for road initiatives (except bridges, which have much longer lives) and a 50-year life for rail initiatives. Intelligent transport system (ITS) initiatives have shorter lives, normally 10 years. The mode specific guidance contains typical economic lives for some infrastructure assets. Prepare forecasts of benefits and costs for each year of the initiative’s life.

When comparing options with different lives for a particular initiative, make adjustments to ensure a valid comparison. There are two ways to do this:

- Find a common multiple of the lives (for example, 150 years for a 30-year road initiative and a 50-year rail initiative)
- Convert the NPV to an annuity over the initiative’s life.

Note that adjusting for different lives is necessary only for estimating NPVs to compare mutually exclusive options. It is not required for ranking initiatives by BCR to satisfy a budget constraint.

Where jurisdictions set maximum appraisal periods (for example, 30 years) that are shorter than the life of the assets, add a residual value to allow for net benefits beyond the end of the appraisal period (see Section 4.3 on residual values).

2.5 Be clear about whether you are working in real or nominal terms

It is usual to undertake CBAs in real terms and financial analyses in nominal terms. In proposals that include both a CBA and a financial analysis, ensure that the assumptions are consistent and, in so far as possible, show how the two analyses relate to each other (for example, by links within a spreadsheet). There should be inflation adjustments that convert between the CBA in real terms and the financial analysis in nominal terms.

Provided real or nominal prices are used consistently, the end results should be identical. Discounting nominal values at a nominal discount rate produces the same discounted result as discounting real values in real terms. The reason is that using a nominal discount rate converts nominal prices back into present day dollars. The relationship between a real and a nominal discount rate is as follows:

$$(1 + i) = (1 + r)(1 + f)$$

where i is the nominal discount rate, r is the real discount rate and f is the inflation rate. If working in nominal terms and the inflation rate varies, allow the nominal discount rate to vary accordingly.

3. Step 3: Estimate investment costs

Steps

3.1. Develop a time line for tasks from planning to completion.

3.2. Estimate costs for each year.

3.3. Estimate a residual value (if applicable).

3.4. Estimate land costs (if applicable).

3.1 Develop a time line for tasks from planning to completion

Investment costs are costs that:

- Are essential for the initiative to proceed
- Will be avoided if the initiative does not proceed[1]
- Will be incurred before the initiative commences operation
- Are paid for by the investors.[2]

Investment costs include:

- Planning and design
- Site surveying
- Site preparation
- Investigation, data collection and analysis (economic, environmental, social, market research, etc)
- Legal costs
- Administrative costs
- Land acquisition
- Construction costs (labour, materials, insurance, etc)
- Consequential works.

[1] Leave out any planning, design and investigation costs already incurred at the time of undertaking the CBA. The decision about whether or not to proceed with the initiative will have no effect on these costs.

[2] Investment costs form the denominator in the BCR, used to rank initiatives for the purpose of allocating funds from a budget (see Section 10.4). Costs of negative externalities caused by construction should be included in a CBA, but are not relevant for capital budgeting. They should therefore be treated as disbenefits.

3.2 Estimate costs for each year

Value all costs in a CBA at social cost. See Boxes 2 and 3 for an explanation. For most investment costs, the social cost will be the same as the market price. For financial analysis, use financial costs.

Include land costs where appropriate. See Section 4.4 for further detail.

Buildings or houses that have to be demolished to make way for the initiative should be valued at market prices (net of selling costs), plus demolition costs minus scrap value. Include relocation costs for occupants.

Labour costs should generally reflect market rates with an allowance for labour on-costs. Income and payroll taxes should not be deducted. (See Box 3 for details).

'Construction externalities' refers to costs imposed on others by the construction process, for example, disruption to traffic, severance, noise and dust. Valuation of environmental externalities is discussed in Chapter 10.

For vehicles used in construction, a rental cost should be included to cover wear and tear and usage of capital tied up in the equipment. Value the fuel they consume at resource cost; that is, exclude fuel excise, goods and services tax (GST) and subsidies.

Estimate the amount of time required for each phase of implementation of the initiative and total the costs for each year.

Be transparent about how the investment costs are estimated by showing them item by item, including physical quantities of inputs and unit costs. The level of detail should differ between rapid and detailed CBAs. If financial and resource investment costs are different, provide both costs. Financial costs are required for financial analysis, funding and budgeting purposes.

For rapid CBA, expect investment costs to be estimated within ±40 per cent of the actual amount. For detailed CBA, the expected level of accuracy is ±10 per cent.

Forecasts of construction costs are notorious for optimism bias. People fail to consider what can go wrong and there is an incentive to keep investment costs down to improve CBA and financial results. Chapter 12 on risk analysis provides a way to minimise optimism bias, but it is unlikely to be applied at the rapid CBA stage.

3.3 Estimate a residual value (if applicable)

There may be some value remaining in infrastructure at the end of its life. It could have value when sold intact or as scrap. One way to estimate the resale or scrap value is to take a proportion of the replacement cost.

There is a variety of ways to calculate a residual value where asset lives extend significantly beyond the end of the appraisal period. Some of these involve extrapolating benefits. The approaches recommended here are based on straight-line depreciation of capital costs.

Under the straight-line depreciation (SLD) method

$$Residual\ value\ (SLD) = Capital\ cost \times \frac{Asset\ life\ remaining\ after\ appraisal\ period}{Asset\ life}$$

All capital costs incurred are depreciated at a constant rate during the estimated asset life for the whole road initiative without discounting such that the RV at the end of the appraisal period is simply a fraction of the capital costs.

The component SLD method distinguishes between components of capital costs with different asset lives (*n* components, subscript *i*).

$$Residual\ value\ (component\ SLD) = \sum_{i=1}^{n} Capital\ cost_i \times \frac{Asset\ life\ remaining\ after\ appraisal\ period_i}{Asset\ life_i}$$

Benefit-based methods include estimating post appraisal period benefits for the remaining asset life

- In the same way as for benefits during the appraisal period (for example from a model)
- Final year benefits projected to grow at the same rate as for forecast traffic
- Final year benefits assumed to remain constant
- Final year benefits projected to decline linearly to zero.

These benefit-based methods are not recommended for the main CBA result, but as possible sensitivity tests to use where the residual value amounts to a substantial proportion of the present value of total benefits. Because SLD residual values are independent of benefit levels, residual values calculated under SLD and benefit methods will diverge more where benefit–cost ratios are significantly different from one.

Count the residual value of an initiative as a benefit at the end of the final year of the appraisal period.

3.4 Estimate land costs (if applicable)

Determine whether the land required for an initiative has an opportunity cost. Examples of land having no opportunity cost include land required for access purposes and land that is too narrow to have an alternative use.

Value land at its market price at the time of commencement of the initiative, even if it has been acquired in the past at a lower or higher price, because this represents its opportunity cost. If the land has already been acquired, use the market price net of selling costs. If the land is yet to be purchased, include all acquisition costs.

Be wary about the possible effects on land prices of expectations about the initiative proceeding.

Unlike built-assets, the value of land does not depreciate over time. If land costs are included with investment costs, and the land is likely to have an alternative use at the end of the initiative's life, it may be appropriate to include the value of the land as a residual at the end of the appraisal period. The difference between the present value of the land costs at the start and end of the appraisal period represents the present value of the rental cost of occupying the land for the duration of the appraisal period. If land values are expected to rise over the appraisal period, adjust the end-of-appraisal-period land value accordingly. The forecast increase in land value should be that for the base case, so there is no increase in land value caused by the initiative. The forecast growth rate in land value should never exceed the discount rate.

Land rental costs in the residual value can be calculated in the same way

- The present value discounted over the number of years given by asset life minus appraisal period, less
- The value of land at the end of the appraisal period. Due to the level of uncertainty, do not allow for any increase in land value after the appraisal period.

If using the component SLD method for estimating residual value, take the weighted average asset life using investment costs of as the weights.

If there are land clean-up or infrastructure demolition costs at the end of the asset life, deduct them from the residual value, after discounted them to the end of the appraisal period.

4. Step 4: Make demand forecasts

Steps

4.1. Decide on the unit of demand.

4.2. Segment the market.

4.3. Ascertain the base for projection.

4.4. Make Base Case forecasts.

4.5. Make Project Case forecasts - diverted traffic.

4.6. Make Project Case forecasts - generated traffic.

4.7. Develop pricing assumptions (if applicable).

Benefits from transport initiatives are usually strongly related to forecast infrastructure utilisation levels. So demand forecasts play a critical role in appraisal of initiatives.

Additional discussion of demand forecasting methods is available in Part T1 Travel Demand Modelling and in the mode specific guidance.

4.1 Decide on the unit of demand

Possible units of demand include:

- Passenger, cyclist, walker, vehicle or train numbers
- Freight tonnes or containers
- Passenger, cyclist, walker, vehicle, or train-kilometres or freight tonne-kilometres.

All of these are expressed per period of time (day, week, year).

If forecasts are in passenger numbers, freight tonnes or freight containers, they need to be converted into vehicle or train numbers at some stage of the appraisal in order to estimate operating costs and congestion impacts. Be transparent about the conversion factors used.

4.2 Segment the market

The level of accuracy achievable in the demand forecasts will depend, in part, on the extent to which the analyst segments the market. Classifications include trip purpose (people only), time (peak/off-peak), commodity (freight only), transport mode, load type (freight only, bulk, non-bulk), vehicle or train type and origin–destination pair.

The level of market segmentation will depend on data availability, the nature of the initiative and whether the analysis is a rapid or detailed CBA.

4.3 Ascertain the base for projection

Recent demand data is needed to serve as a starting point for the projections. Consistent data are required for trend analysis and aggregating across transport modes.

4.4 Make Base Case forecasts

Make demand forecasts for both the Base and Project Cases. In the absence of generated and diverted traffic, they will be identical.

There are three broad categories of forecasting methods:

- Simple extrapolation of past trends
- Extrapolation by relating the forecast variable to one or more explanatory variables (usually through an econometric model based on economic theory)
- Application of informed judgment based on available evidence, including guidance from scenario analysis.

These methods are not mutually exclusive and will often be used in combination. The choice of technique will depend on data availability, the amount of effort chosen to apply to forecasting, and the extent to which extrapolation of past trends is considered warranted.

Extrapolation cannot be the sole forecasting technique employed when there is a likelihood of changes that bear no relationship to the past. Projections may have to be adjusted to allow for one-off events such as implementation of other transport initiatives or development of new industries or residential areas. This requires judgment. When preparing appraisals, provide details about the judgments applied in making forecasts.

For projections based on population, the Australian Bureau of Statistics (ABS) is a useful source of population forecasts (medium series), including at the statistical local area level[3]. Some jurisdictions prefer to use their own population forecasts.

4.5 Make Project Case forecasts - diverted traffic

The ATAP Guidelines define diverted traffic as freight, passengers or vehicles that switch from one mode, route, time of day, origin or destination to another as the result of an initiative.

[3] The central scenario of a CBA should aim to estimate the most likely or 'expected value' CBA results, for which the ABS medium series population forecasts would seem most appropriate. There is a tendency to use the highest population forecasts available, which can be a source of 'optimism bias'. Where ABS's high series population forecasts are employed for the central scenario, sensitivity tests using the medium and low forecasts should be undertaken.

To estimate diverted traffic, obtain an estimate of the maximum volume of traffic that could potentially divert for each market segment. Then estimate the proportion of the potentially divertible traffic likely to divert. Accuracy will be greater the more the market is segmented, because the propensity to divert depends on characteristics such as origin–destination and time-sensitivity.

The simplest way to estimate the proportion of traffic likely to divert is to nominate a percentage using judgment. Preferably, past experience with similar initiatives and market knowledge will inform those judgments.

If a small number of shippers are responsible for a considerable percentage of the divertible freight, ask them directly about their probable responses to the proposed change.

A simple quantitative method is to use the concept of cross elasticity. Where there are quality improvements such as time savings that can impact on the amount of diverting traffic, the price could be expressed as a ‘generalised cost’ (see Box 4 for an explanation). Logit models are a more sophisticated technique for predicting impacts of initiatives on mode or route shares. The logit model splits up the market between modes and routes according to how they compare in terms of price, time taken and other quality attributes.

For rapid CBAs and many detailed CBAs, values for elasticities based on studies by others may need to be assumed, including overseas studies. Since surveys are very expensive to undertake, they are only justified for detailed CBAs of very large initiatives or programs of related initiatives.

Levels of traffic diversion may increase over time as transport users have time to adjust. The literature sometimes distinguishes between short-run and long-run elasticities. If this applies to the initiative, consider allowing for a ‘ramp up’ period during which the level of diversion builds up gradually to the long-run level.

4.6 Make Project Case forecasts - generated traffic

The ATAP Guidelines define generated traffic as altogether new demand resulting from an initiative.[4] If the new traffic comes from a specific source such as a new industrial development or land use change that is expected to occur as a consequence of the initiative, collect information about the source to estimate levels of generated traffic. Where the sources of generated traffic are more diverse, a price elasticity of demand could serve as the basis of estimation. The comment about a ‘ramp up’ period for diverted traffic applies equally to generated traffic. Higher long-run elasticities are a simple way to allow for land-use change caused by an initiative.

[4] Economists usually refer to all additional traffic using the infrastructure in the Project Case, compared with the Base Case, as ‘generated traffic’ regardless of the source. Generated traffic in the economist's use of the term, may be divided into ‘diverted traffic’ and ‘new traffic’ depending on its source. However, transport planners use the terms ‘generated traffic’ to refer to traffic that is new altogether - as in the 'trip generation' phase of transport modelling. Because the ATAP Guidelines are aimed at a broader audience than economists, the transport planners’ terminology has been adopted.

Where there is considerable uncertainty about levels of generated traffic, a sensitivity test can be undertaken by estimating traffic levels with and without the generated traffic. The risk analysis stage is an opportunity to explicitly consider the uncertainty associated with generated traffic.

4.6.1 Induced demand

Induced demand is the sum of generated and diverted traffic. Part T1, Section 3.4 of the ATAP Guidelines discusses the modelling of ‘induced demand’, which it defines as the impacts of transport improvements in terms of the resulting changes in route choice, the time of day travel occurs, mode choice, trip distribution (that is, choice of trip destination), trip generation (that is, the number of trips undertaken), land use changes and the location decisions of both households and businesses. Chapters 7 and 8 below discuss the role of induced demand in user benefit estimation.

4.7 Develop pricing assumptions (if applicable)

Where infrastructure use is charged, make assumptions about prices. Price levels affect levels of demand (existing, diverted and generated). Factors affecting prices include the demand curve, costs and the objective of price setting (profit maximisation, economic efficiency maximisation, revenue target or cost-recovery target). Constraints relating to the forms of charging available also need to be taken into account (such as the extent to which charges can vary with time of day).

Prices may have to be estimated simultaneously with developing demand forecasts because the demand curve is needed to estimate the price, and then the price is needed to estimate the quantity demanded.

Prices are critical for estimating revenues for financial analyses.

5. Step 5: Estimate infrastructure operating costs

Steps

5.1. Identify infrastructure operating costs and classify them into time- and usage-related components

5.2. Make Base Case and Project Case projections and take the difference

5.1 Identify infrastructure operating costs and classify them into time- and usage-related components

The term infrastructure operating costs refers to the costs of continuing to provide the infrastructure after the initiative has commenced operation. The primary infrastructure operating cost is maintenance.

Maintenance costs are typically classified into routine and periodic categories. Routine maintenance costs involve small tasks that are undertaken frequently. Periodic maintenance costs involve more expensive works undertaken at intervals of several years.

For cost estimation purposes, it is useful to split infrastructure operating costs into time-related and usage-related costs. Time-related costs are the same each year, regardless of the level of traffic. Routine maintenance costs tend to be largely time-related (as opposed to usage-related) and reasonably constant from year to year. Usage-related costs vary with the level of traffic and, therefore, are dependent on demand projections. Vehicle or train mix, gross weights and speeds may also be relevant.

Maintenance costs in either the usage- or time-related categories can be affected by the weather and by major accidents leading to random variations from year to year. If impacts of uncertain events are potentially significant, use the techniques for dealing with risk in Section 12.

If unit costs are indexed over the appraisal period for increases in real wages or other input costs, infrastructure operating costs will need to be adjusted accordingly. See the discussion of indexation in Section 7.1 below.

5.2 Make Base Case and Project Case projections and take the difference

Estimate infrastructure operating costs for the Base and Project Cases, projecting them forward over the life of the initiative. If Project Case operating costs are below Base Case operating costs, the difference between them is a benefit or negative cost for the initiative. This could occur if the new infrastructure replaces ageing infrastructure that was costly to maintain. Conversely, if Project Case operating costs exceed Base Case operating costs, the difference between them is a cost or negative benefit to the initiative. This occurs if the new infrastructure generated new maintenance costs on top of those of the existing infrastructure.

If the timing of major periodic maintenance differs between base case and project case infrastructure, there may be large positive and negative spikes in annual maintenance savings benefits.

6. Step 6: Estimate user benefits

Chapters 6 and 7 show how to calculate the user benefits of proposed initiatives. This is done by gradually building up the level of complexity of the transport setting and associated analytical method, as follows:

- Chapter 6 introduces the general concepts and their application to the simpler case where there are no cross-modal or network effects.
- Sections 7.1 and 7.2 extend the concepts and methods to cases where cross-modal and network effects apply. The content can be directly applied to relatively simple cross-modal and network situations.
- Sections 7.3 and 7.4 address the application of the principles and concepts to the complex case of urban transport networks in cities.
- Section 7.5 completes the discussion by addressing the issue of deferred future investments, and its effects on user benefits.

Box 5 introduces some key concepts used throughout Chapters 6 and 7. The detailed foundations underlying these two chapters can be found in NGTSM06 Volume 5, Sections 2.6 and 2.7. Those sections of Volume 5 discuss three methods for benefit estimation: the social welfare approach; the gainers and losers approach; and the consumers' surplus with resource correction approach. The social welfare approach is used here because it is the simplest, together with the consumers' surplus with resource correction approach because it used in some of the mode specific guidance sections. Volume 5 shows the application of these methods to a wider range of settings.

Steps

6.1. Determine methodologies for estimating impacts of the initiative on user costs.

6.2. For existing traffic, take the difference between total social generalised costs for the Base and Project Cases.

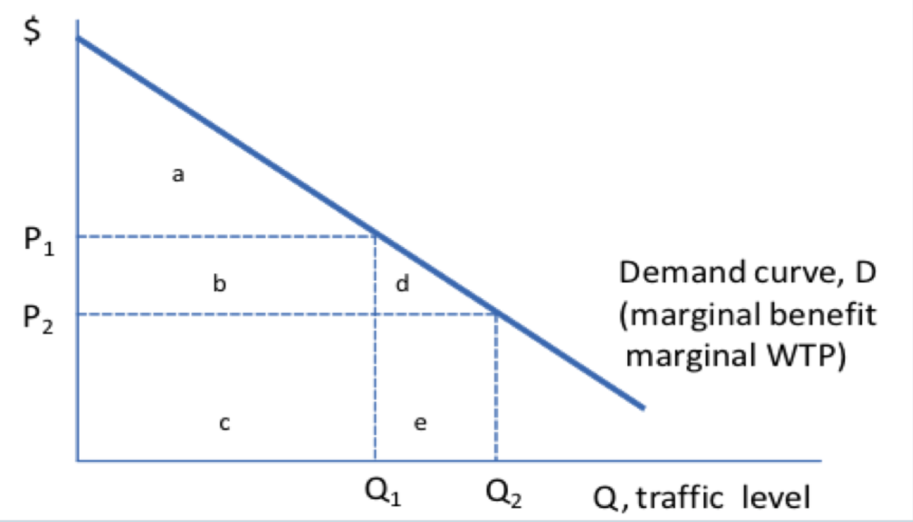
6.3. For induced (diverted and generated) traffic, calculate user benefit as the difference between the increase in willingness-to-pay and the increase in social generalised costs for the Project Case

6.4. If the consumers' surplus method is used to measure user benefits, a resource correction factor may be required.

Table 2 provides a summary of the formulas to be used for calculating user benefits for existing and induced (diverted + generated) traffic

Box 5: User benefit estimation: key concepts

User benefits arise from transport improvements. They are measured by comparing key outcomes in the Base Case versus the Project Case (denoted by subscripts 1 and 2 respectively).

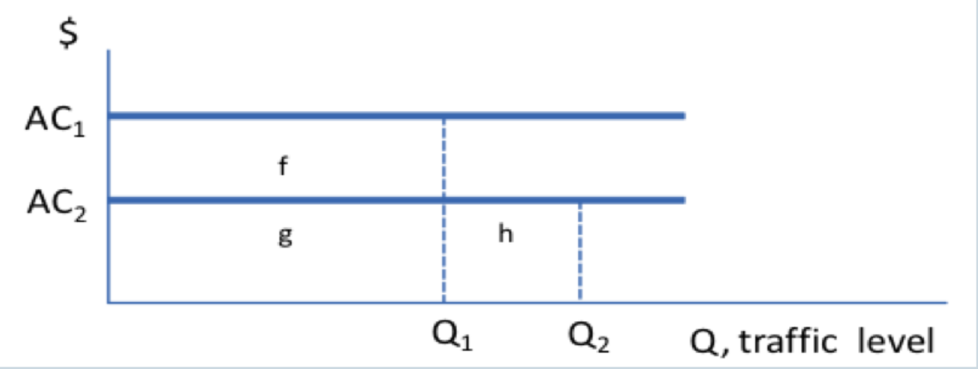


The above figure shows a travel demand curve, where the level of traffic (Q) is a function of the user's perceived cost (P), where perceived cost is the sum of all monetary and non-monetary travel costs that the user considers in making transport decisions, all expressed in equivalent monetary units. A standard assumption is to assume the demand curve is linear, allowing the 'rule of half' to be used (see Section 6.3).

The transport improvement lowers the perceived cost from P_1 to P_2, resulting in an increase in traffic from Q_1 to Q_2 (a move along the demand curve).

At any given traffic level, the marginal benefit of travel is the height of the demand curve, reflecting the marginal willingness-to-pay (WTP) for a given quantity. The area under the demand curve measures the total WTP (TWTP). The word 'total' here means for all units of traffic being considered added together. In the Base Case, TWTP = areas *a* + *b* + *c*. In the Project Case, TWTP = areas *a* + *b* + *c* + *d* + *e*. The increase in TWTP for the project case compared with the base case is areas *d* + *e*.

Consumer surplus (CS) is the TWTP above P. In the Base Case CS = area *a* . In the Project Case CS = areas *a* + *b* + *d*. The increase in consumers' surplus for the project case compared with the base case is areas *b* + *d*.



The above figure shows the resource user cost situation. It shows the average social generalised cost (AC) curve for the Base and Project Cases. The constant AC case is shown here. (NGTSM06 Vol 5 Part 2 also discusses the increasing cost case.) Total social generalised cost (TC) is measured as the product of AC and Q. For the Base Case TC = areas f + g. For the Project Case TC = areas g + h. The increase resource user costs for the project case compared with the base case is areas *h* – *f*.

Sections 6.2, 6.3, 6.4 and Chapter 7 apply these concepts to generate user benefit formulas in various situations.

Table 2 Summary of formulas for calculating user benefits for existing and induced traffic

	Existing Traffic (1)	Induced Traffic (2)	All Traffic Combined (3 = 1+2)
Method 1: Increase in Social Welfare			
a: Increase in willingness-to-pay	0	0.5 (P1 + P2) (Q2 – Q1)	0.5 (P1 + P2) (Q2 – Q1)
b: Increase in social cost	(AC2 – AC1) Q1	AC2 (Q2 – Q1)	AC2Q2 – AC1Q1
c = a – b: User Benefit	(AC1 – AC2) Q1	0.5 (P1 + P2) (Q2 – Q1) – AC2 (Q2 – Q1)	0.5 (P1 + P2) (Q2 – Q1) – (AC2Q2 – AC1Q1)
Method 2: Increase in Consumer Surplus + Resource Correction			
d: Increase in Consumer Surplus	(P1 – P2) Q1	0.5 (P1 – P2) (Q2 – Q1)	0.5 (P1 – P2)(Q2 + Q1)
e: Resource correction	(P2 – AC2) Q1 – (P1 – AC1) Q1	(P2 – AC2)(Q2 – Q1)	(P2 – AC2) Q2 – (P1 – AC1) Q1
f = d + e: User Benefit	(AC1 – AC2) Q1	0.5 (P1 + P2) (Q2 – Q1) – AC2 (Q2 – Q1)	0.5 (P1 + P2)(Q2 – Q1) - (AC2Q2 – AC1Q1)

Note: P is perceived cost; AC is average generalised cost; Q is traffic level; subscript 1 denotes Base Case; subscript 2 denotes Project Case.

6.1 Determine methodologies for estimating impacts of the initiative on user costs

For most transport initiatives, the bulk of the benefits accrue (at least in the first instance) to users of the infrastructure. Trains, trucks and cars save operating costs; passengers and freight save time. There may be other benefits to transport users such as improved reliability or greater comfort for passengers, or less damage to freight. Both reductions in costs and improvements in service quality can lead to increases in usage — diverted demand, sourced from other routes or modes, and generated demand, which is altogether new traffic.

Estimates of vehicle or train operating costs and times taken for the Base and Project Cases for each year of the initiative's life are also needed. For detailed CBAs, use computer models to derive these estimates. The computer models may estimate benefits and costs for selected years, for example, at five- or 10-year intervals, and interpolate for the intervening years. For rapid CBAs, a greater level of interpolation and extrapolation is acceptable.

Computer models require data on the infrastructure and on the vehicles or trains using the infrastructure (quality and quantity). For improvements to road and rail line-haul infrastructure, there is a four-step process:

1. Estimate free speeds (the speeds and times taken in the absence of any interference from other vehicles or trains)
2. Adjust speeds downward and travel times upward to allow for congestion (including time lost at intersections for urban traffic and in passing loops for trains)
3. Estimate levels of consumption of inputs (fuel, time)
4. Multiply input consumption levels by unit costs.

Here, the term ‘unit costs’ refers to the average price, cost or value of inputs; for example, fuel per litre, time per hour, hourly wage rates for drivers and crew, lubricating oil per litre, cost per tyre and so on. For some inputs, private and resource unit costs differ. For example, the resource unit cost of fuel will exclude excise causing it to be less than the private cost, which is the market price. Ensure the correct unit costs for estimating a financial cost or a resource cost are used (see Boxes 2 and 3 for explanations of financial and resource costs).

Calculations may be needed for a number of different categories of user (e.g. for road: private cars, business cars, rigid trucks, articulated trucks, B-doubles, road trains) and for multiple origin–destination pairs.

Since infrastructure utilisation fluctuates by time of day, day of week and season, and costs to users change with the level of infrastructure use when there is congestion, the computer model may have to loop around many times to cover the full range of utilisation levels. A simpler approach is to model only morning peak and apply an expansion factor to obtain whole-year impacts. Unrealistic expansion factors can lead to major errors in benefit estimation. It is better to model at least the peak and a representative off-peak time of day.

It is acceptable to index unit costs over the appraisal period where resource costs or users’ willingness-to-pay are expected to rise over time. For labour costs, value of work time, and human capital-based safety and externality values, use a forecast for real wages growth. For willingness-to-pay values such as non-work time, and willingness-to-pay-based safety and externality values, use a forecast for per capita GDP growth multiplied by an income elasticity of 0.5. Fuel consumption by vehicles and trains may be indexed to fall with time due to technological improvements.

6.2 For existing traffic, calculate user benefit as the difference between total social generalised costs for the Base and Project Cases

The social welfare approach to benefit estimation is used in Sections 7.2 and 7.3. In this method, net user benefit is the increase in the total gross benefit users' gain from travel (as measured by TWTP), less the increase in total resource cost borne by the user from that travel (time, fuel use and so on).

Existing traffic’ is traffic (referring to all units of throughput - people, vehicles, freight) that uses the relevant infrastructure in both the Base and Project Cases (not diverted or generated traffic). The quantity of existing traffic is, by definition, the same in the Base and Project Cases.

For existing traffic, TWTP does not change (see Box 5). So to calculate user benefit, estimate the total social generalised costs (TC) for the Base and Project Cases and take the difference where:

total social generalised cost = level of existing traffic × average social generalised cost

i.e. TC = Q x AC

The user benefit for existing traffic is therefore:

$(AC_1 – AC_2)\ Q_1$ *[formula 1]*

where Q_1 is the level of existing traffic, and AC_1 and AC_2 are the average social generalised costs for the Base and Project Cases respectively.

Note that changes in money and perceived costs are irrelevant for existing traffic (but are relevant for new traffic - see Section 7.3).

6.3 For induced (diverted and generated) traffic, calculate user benefit as the difference between the increase in willingness-to-pay and the increase in social generalised costs for the Project Case

If demand is assumed to be perfectly inelastic (no diverted or generated traffic), skip this section. Note that the term ‘induced traffic’ here refers to traffic not the number of users. Any increase in usage by existing users is treated as generated traffic.

Boxes 5, 6, 7 and 8 provide diagrammatic explanations and a numerical example that will assist readers in understanding the text below. It is suggested they be read concurrently.

The gross benefit to diverted and generated traffic from using the infrastructure affected by the new initiative is given by the increase in TWTP - the area under the demand curve between the Base Case and Project Case traffic levels.

The increase in TWTP can be estimated using the rule-of-a-half[5] as:

increase in TWTP = $(P_1+P_2)(Q_2–Q_1)/2$ *[formula 2]*

where Q_1 and Q_2 are the respective Base Case and Project Case quantities and P_1 and P_2 are the respective Base Case and Project Case perceived costs paid or incurred by users. If there is no diverted or generated traffic, $Q_1 = Q_2$, and there is no WTP benefit (as in section 6.2).

[5] The rule-of-a-half says that if we assume the demand curve to be linear over the relevant traffic range (here between Q1 and Q2), the area d in Box 5 can be estimated as half the rectangular area (Q2 – Q1)(P1 – P2).

To obtain the net user benefit arising from the diverted and generated traffic, deduct from equation (2) the increase in social generalised costs incurred by users.

Hence the net user benefit for diverted and generated traffic is:

$(P_1 + P_2)(Q_2 – Q_1)/2 – AC_2(Q_2 – Q_1)$ *[formula 3]*.

If diverted traffic is present, there may be additional benefits or costs to consider on the mode or route from which the traffic diverts. See Chapter 7.

Combining formulas (1) and (3) above for existing traffic and for diverted and generated traffic, the formula for net user benefit across all traffic is:

$(AC_1 – AC_2)Q_1 + (P_1 + P_2)(Q_2 – Q_1)/2 – AC_2(Q_2 – Q_1)$

which simplifies to

$(P_1 + P_2)(Q_2 – Q_1)/2 – (Q_2\, AC_2 – Q_1\, AC_1)$ *[formula 4].*

6.4 If consumers' surplus is used to estimate user benefits, a resource correction factor may be required

Sections 6.2 and 6.3 calculated user benefits using the social welfare approach based on changes in total willingness-to-pay and total user resources costs. As noted at the start of this chapter, the alternative method is to estimate the user benefit using the gainers and losers approach in which gains and losses to users (consumers) are measured as consumer surplus changes. This approach is widely used in transport economics, including in urban transport assessments using urban travel demand models.

Consumers' surplus is the area under the demand curve above the perceived price (perceived user cost). When there is a change in perceived cost from P_1 to P_2, the change in consumers' surplus is measured as:

$(P_1 – P_2)(Q_2 + Q_1)/2$ *[formula 5]*.

Note that the consumers' surplus formula (5) matches the correct net user benefit result given by formula (3) in Section 6.2 only in the special case where perceived costs and average social generalised costs are equal; that is, $P_1 = AC_1$ and $P_2 = AC_2$. In practice, that may not be the case because:

- Perceived cost may include taxes, charges and subsidies
- Users may fail to perceive some of the resource costs they incur.

An adjustment or 'resource correction' is required whenever $P_1 \neq AC_1$ and $P_2 \neq AC_2$.The resource correction adjusts for the differences between perceived and social generalised costs. Details of the resource correction are discussed below. As in Section 6.3, references to Boxes 5, 6, 7 and 8 will assist readers in understanding the text below. It is suggested the text and the boxes be read concurrently.

For *existing traffic*, the consumer surplus change is $(P_1 – P_2)Q_1$ whereas the true benefit to society is $(AC_1 – AC_2)Q_1$ (see Section 7.2). The required adjustment is to add a resource correction equal to the increase in the gap between perceived price and social generalised cost $(P_2 – AC_2)Q_1 – (P_1 – AC_1)Q_1$. That is

$$(P_1 – P_2)Q_1 + [(P_2 – AC_2)Q_1 – (P_1 – AC_1)Q_1] = (AC_1 – AC_2)Q_1$$

For *diverted and generated traffic*, the resource correction is the difference between perceived and social generalised costs, that is, $(P_2 – AC_2) (Q_2 – Q_1)$.

The resource correction formula for diverted and generated traffic can be expressed as

resource correction = (perceived [average] cost – average social generated cost) ×
quantity of diverted and generated traffic

The total user benefit for diverted and generated traffic is then the consumers’ surplus change $(P_1 – P_2) (Q_2 – Q_1)/2$ plus the resource correction $(P_2 – AC_2) (Q_2 – Q_1)$, which simplifies to

$$(P_1+P_2)(Q_2–Q_1)/2 - AC_2(Q_2–Q_1)$$

the same as formula (3) in Section 6.3.

Note that if social generalised costs exceed perceived costs, the resource correction will be a negative amount.

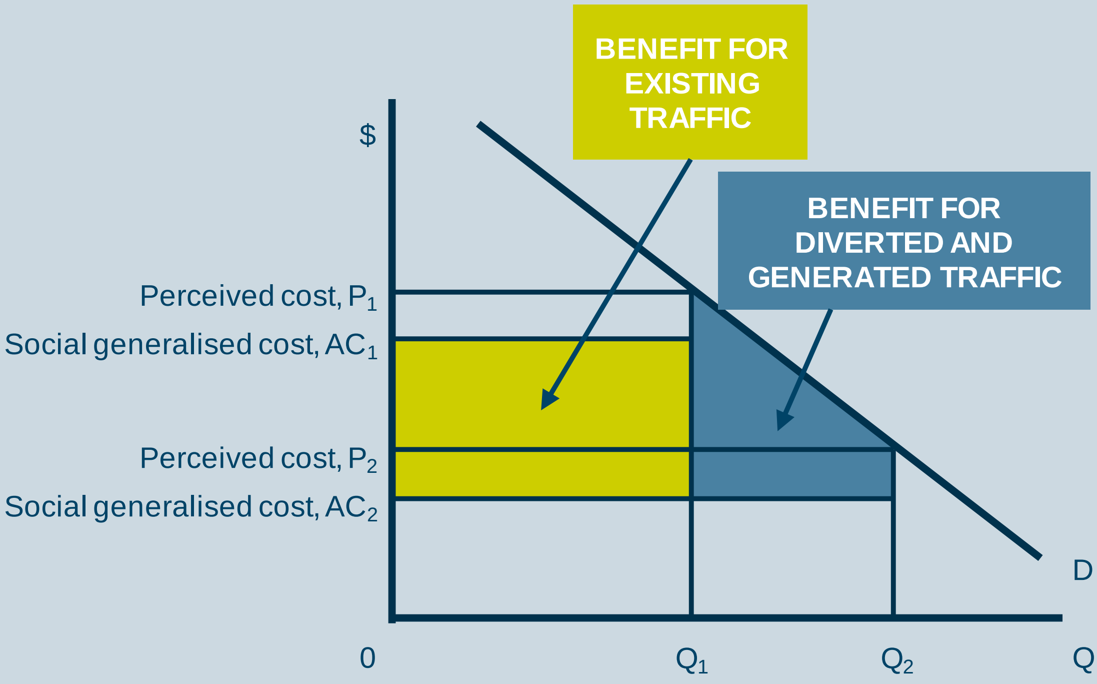
In the case of road infrastructure, where fuel excise causes perceived cost to exceed the resource cost of driving, the resource correction for additional diverted and generated traffic on the initiative infrastructure will equal the gain in fuel excise to the government (assuming all other costs are fully perceived). Even though the fuel excise is a transfer from road users to the government, it is still part of users’ increased WTP and so is a benefit.

Box 6: Diagrammatic explanation of user benefit estimation: price > cost

The diagram shows the case where perceived cost exceeds social generalised cost, for example, due to the fuel excise. The initiative reduces both perceived cost and social generalised cost, with subscript 1 indicating the Base Case and subscript 2 the Project Case. Infrastructure use is determined by the intersection of perceived cost with the demand curve (expressed as a function of perceived cost). The benefit, with respect to existing use, is the area of the rectangle between the Base and Project Case levels of social generalised costs up to the level of existing traffic, Q_1. For diverted and generated traffic (Q_1 to Q_2), the increase in WTP is the area under the demand curve between Q_1 and Q_2, while the benefit for this traffic is the WTP area minus Project Case social generalised costs.

Applying the consumers' surplus with resource correction approach (see Section 6.4), provided $P_1 – AC_1 = P_2 – AC_2$, no resource correction is needed for existing traffic. The resource correction for the diverted and generated traffic, that is, the rectangular area $(P_2 – AC_2) \times (Q_2 – Q_1)$. The total benefit can be measured as the consumers' surplus change $(P_1 – P_2) \times (Q_2 + Q_1) / 2$ plus the resource correction.

Box 7 provides a numerical illustration.



Box 7: Numerical example of user benefit estimation: price > cost

In this numerical example, the initiative results in a reduction in perceived costs from $2.00 to $1.80. Existing traffic is 10 000 units. The fall in perceived costs induces additional diverted and generated traffic of 2000 units. Social generalised costs per user fall from $1.40 to $1.20.

Existing traffic: Total social generalised costs fall from $14 000 = 10 000 × $1.40 to $12 000 = 10 000 × $1.20, leading to a benefit to society of $2000.

Diverted and generated traffic: The gross benefit to users (or the WTP) is $3800 = 2000 × ($2.00 + $1.80)/2. The social generalised cost to society of creating this benefit is $2400 = 2000 × $1.20. The net benefit from the increased WTP is therefore $1400 = $3800 – $2400.

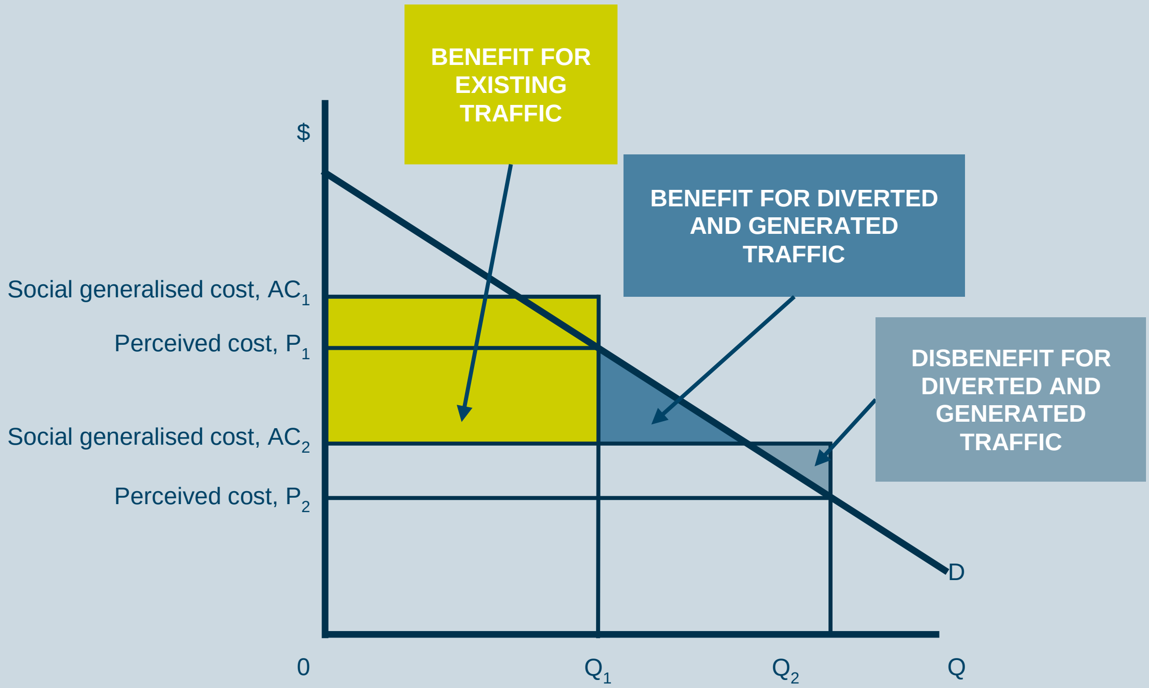
Total benefit: The total benefit to society is the sum of benefits for existing traffic and for diverted and generated traffic, i.e. $3400 = $2000 + $1400.

Consumers' surplus with resource correction approach (see Section 6.4): Since, $P_1 - AC_1 = P_2 - AC_2$, that is, $2.00 – $1.40 = $1.80 – $1.20 = $0.6, no resource correction is needed for existing traffic. The resource correction applies to the diverted and generated traffic: 2 000 × $0.6 = $1200. The total benefit is the consumers’ surplus change ($2.00 – $1.80) × (12 000 units + 10,000 units) / 2 = $2200 plus the resource correction, $2200 + $1200 = $3400.

Box 8: Diagrammatic explanation of user benefit estimation: cost > price

The diagram shows the case where social generalised cost exceeds perceived cost, due to either a subsidy or users failing to perceive some of the costs they incur. The initiative reduces both perceived cost and social generalised cost, subscript 1 indicating the Base Case and subscript the Project Case.

Infrastructure usage is determined by the intersection of perceived cost with the demand curve (expressed as a function of perceived cost). The benefit in respect of existing users is the area of the rectangle between the Base and Project Case levels of social generalised costs up to the level of existing traffic, Q_1. For diverted and generated traffic (Q_1 to Q_2), the increase in WTP is the area under the demand curve between Q_1 and Q_2. The benefit for this traffic is the WTP area minus Project Case social generalised costs. The result is a triangle of positive benefit for traffic for which WTP exceeds social generalised cost, minus a triangle of disbenefit for traffic for which the social generalised cost exceeds WTP. The resource correction (see Section 6.4) for the diverted and generated traffic is the rectangular area ($P_2 – AC_2$) ($Q_2 – Q_1$). With social generalised cost exceeding perceived cost, the resource correction is a negative amount.



7. Step 7: Estimate cross-modal and network effects

Steps

7.1. Determine whether cross-modal and network effects matter.

7.2. Estimate benefits or disbenefits on related infrastructure due to diverted and generated traffic.

7.3. Consider application in complex urban networks

7.4. If the initiative results in changes to land use change, there may be additional benefits

7.5. If future investments in related infrastructure are deferred (brought forward), estimate net benefits (disbenefits)

7.1 Determine whether cross-modal and network effects matter

Refer to this section when undertaking a CBA of an initiative that alters the use of other transport infrastructure (in addition to use of the infrastructure created or improved by the initiative being appraised), regardless of mode.

Determine which of these two categories the effect fits into:

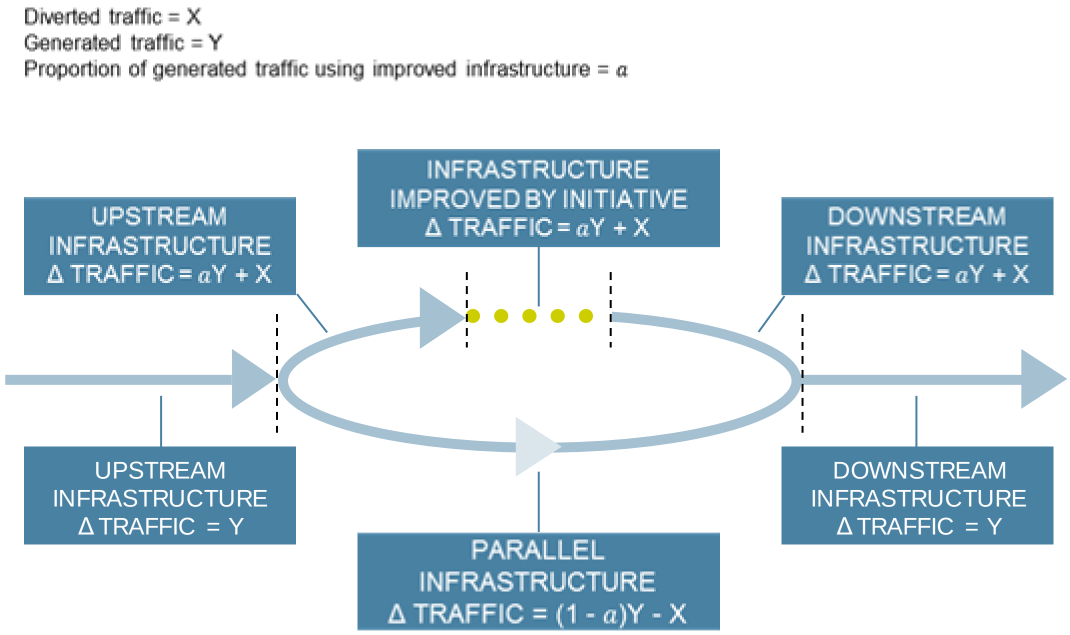
- Diverted demand (substitution) — where passengers or freight switch from parallel infrastructure to the infrastructure created or improved by the initiative being appraised (e.g. a rail upgrade that attracts freight from road, a road improvement that reduces traffic on alternative routes)

- or -

- Upstream/downstream effects (complementarity) — where additional use of infrastructure created or improved by the initiative being appraised also causes increased use of upstream or downstream infrastructure (such as a road or rail upgrade that results in additional usage in other parts of the route or at terminals).

See Figure 1 for an illustration of the concepts defined here.

Figure 1 Related infrastructure and traffic changes



7.2 Estimate benefits or disbenefits on related infrastructure due to diverted and generated traffic

This section discusses benefit estimation on related infrastructure, either parallel infrastructure or upstream/downstream infrastructure. Boxes 9 and 10 provide diagrammatic expositions, and boxes 11 and 12 numerical examples, that will assist readers in understanding the text below. It is suggested the text and the boxes be read concurrently.

Compare the perceived cost incurred by transport users with the marginal social generalised cost for the related infrastructure with altered demand. If they are practically the same, there are no further benefits or costs to consider. Note that where the related infrastructure is a congested road, the absence of congestion pricing may result in the perceived cost being below the social generalised cost.

Where traffic on the related infrastructure is *lower* in the Project Case than the Base Case, and the marginal social generalised cost is *above (below)* the marginal perceived cost, there will be an additional *benefit (disbenefit)*. Normally, for parallel infrastructure, the traffic will be lower in the Project Case because the quantity of traffic diverted away from the parallel infrastructure in the Project Case will outweigh any positive impact of any generated traffic.

Where traffic on the related infrastructure is *higher* in the Project Case than the Base Case, and the marginal social generalised cost is *above (below)* the marginal perceived cost, there will be an additional *disbenefit (benefit)*. This will normally be the case for upstream and downstream infrastructure.

If costs are constant with respect to traffic level (that is, there are no changes in costs as a result of reduced congestion), then:

additional benefit = (perceived [average] cost – average social generalised cost) ×
change in quantity of traffic on the related infrastructure

Whether the result is positive (a benefit) or negative (a disbenefit) depends on the signs of the two terms in the formula. The difference between perceived and social costs is positive if the perceived cost exceeds social cost, as would be the case for a tax. The difference in costs would be negative for a subsidy or if transport users failed to perceive some of the costs they incur.

The change in the quantity of traffic would be positive for an increase and negative for a decrease. Hence, careful application of formula, ensuring the signs of the two terms are correct, will ensure the correct sign for the result.

If costs fall (increase) as a result of reduced (increased) congestion on the related infrastructure, the benefit is still the area between the average perceived cost curve and the social generalised cost curve over the quantity change. For social generalised costs, the marginal social cost curve must be used as it includes the congestion externality. For small changes, linear approximations of the cost curves can be used. For both the perceived (average) cost and marginal social generalised cost, obtain approximations by taking the halfway point between the Base Case and Project Case values[6].

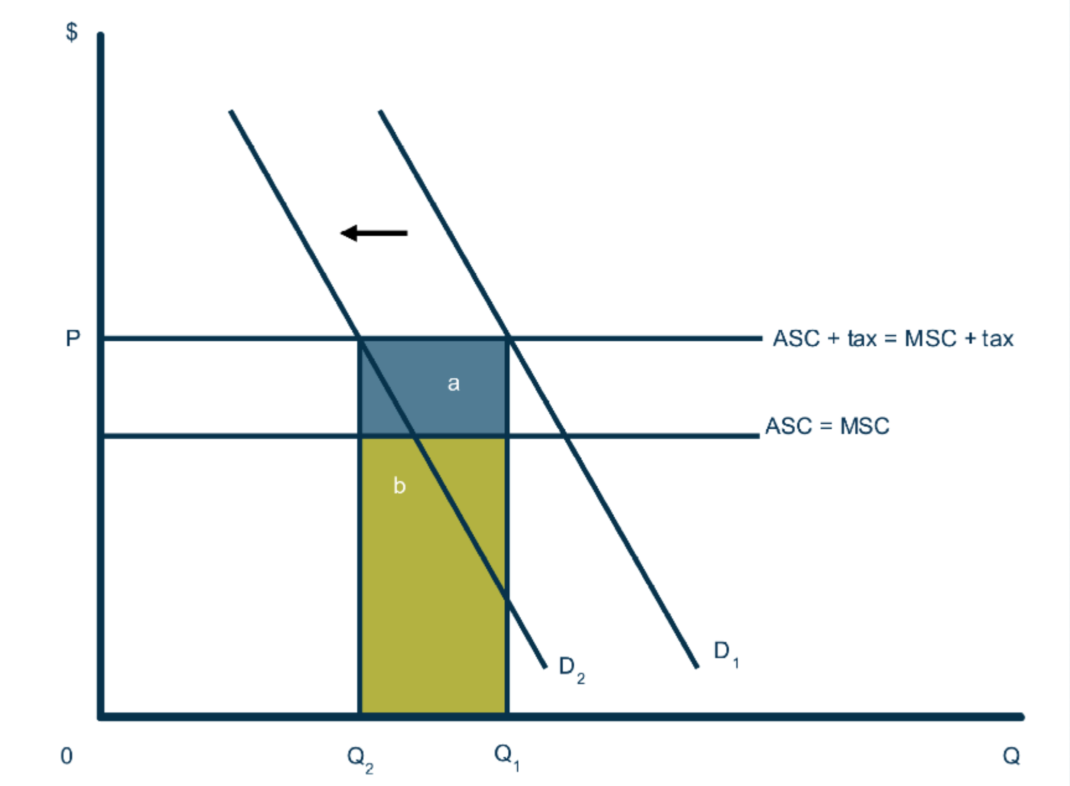
When projecting social and private costs of related infrastructure into the future, adjust them upward for increasing congestion due to traffic growth over time and downward for cost reductions due to likely expansions of, or improvements to, the related infrastructure. Allow for feedback effects on the quantity of diverted traffic.

[6] An alternative measure of the benefit that is often used in practice is: Benefit = $(APC_1 - APC_2)\ (Q_2 + Q_1)/2 + (APC - ASC)(Q_2 - Q_1)$ where APC_1 and APC_2 are average perceived costs in the Base and Project Cases respectively. The second term is a resource correction where $APC = (APC_1 + APC_2)/2$ and $ASC = (ASC_1 + ASC_2)/2$ where ASC is average social cost. Appendix A provides a technical proof.

Box 9: Diagrammatic explanation of benefit estimation on parallel infrastructure: price > cost

The diagram shows the case where perceived cost exceeds social generalised cost on parallel infrastructure - for example, due to the fuel excise. Costs are assumed to be constant, so average social cost (ASC) equals marginal social cost (MSC), and there are no other distortions. The perceived price (P) is average cost plus the tax. The initiative induces a leftward shift in the demand curve from D_1 to D_2 causing the quantity of traffic to fall from Q_1 to Q_2. For each unit of demand, users give up P in WTP and society saves ASC = MSC. Because P > MSC, the loss of WTP exceeds the resource cost saving so there is negative benefit. The full loss of WTP is the sum of the rectangular areas *a* and *b* and the saving in resource costs is area *b*. The net disbenefit is therefore area *a*. The disbenefit is borne by the government in the form of lost tax revenue.

The negative result is consistent with the formula in Section 7.2 because the quantity change is negative. Had the demand curve shifted right, as may occur for upstream or downstream infrastructure, the subscripts, 1 and 2, for the demand curves and quantities would be reversed and area *a* would be a benefit. The government would gain tax revenue equal to area *a*.



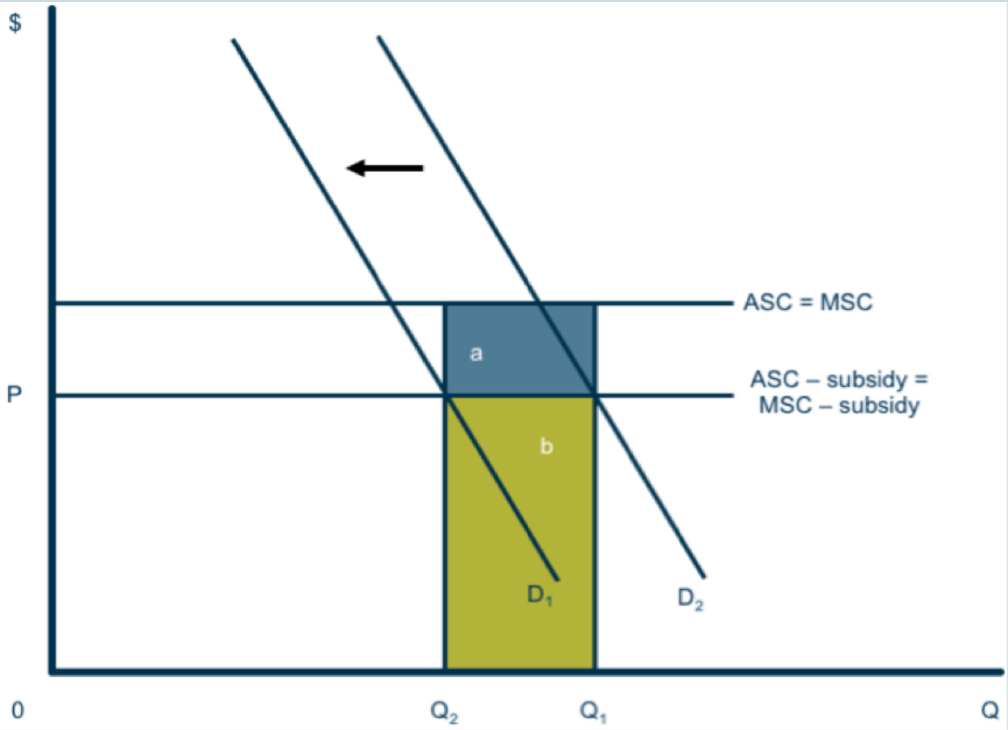
Box 10: Diagrammatic explanation of benefit estimation on parallel infrastructure: cost > price

The diagram shows the case where social generalised cost exceeds perceived cost on parallel infrastructure, for example, due to a subsidy as is often the case for public transport. Costs are assumed to be constant, so average social cost (ASC) equals marginal social cost (MSC), and there are no other distortions. The perceived price (P) is average social minus the subsidy. The initiative induces a leftward shift in the demand curve from D_1 to D_2 causing the quantity of traffic to fall from Q_1 to Q_2. For each unit of demand, users give up P in WTP and society saves ASC = MSC. Because MSC > P, the resource cost saving exceeds the loss of WTP so there is a net benefit. The full resource saving is loss of WTP is the sum areas *a* and *b*. The net benefit is area *a*. The benefit accrues to the government in the form of a saving in the amount of subsidy it has to pay.

In terms of the formula in Section 7.2, both terms are negative, which cancel out to give positive result.

Another reason why social costs could exceed perceived costs is failure of users to perceive part of the costs they incur. In this case, the benefit, area *a*, would accrue to users. For example, if they made travel decisions treating car running costs as a fixed charge per period of time, in the project case, they would find themselves paying less run their vehicles.

Had the demand curve shifted right, as would occur for upstream or downstream infrastructure, the subscripts for the demand curves and quantities would be reversed and area *a* would be a disbenefit. The government would have pay an increased amount of subsidy, or car users failing to perceive car running costs for find themselves having to pay more to run their vehicles.



Boxes 11 and 12 illustrate the above discussion with examples of the estimation of benefits from diverted traffic, and upstream and downstream traffic, respectively.

Box 11: Numerical examples of estimation of benefits from diverted traffic

A rail infrastructure upgrading initiative results in a diversion of 1000 tonnes of freight per annum from road transport to rail.

Without congestion

The perceived cost by road for the door-to-door task is $90 per tonne. The social generalised cost of the door-to-door movement by road over the route is $100 per tonne. There is an annual benefit of ($90 – $100) x –1000 tonnes = $10 000.

If the perceived cost by road is $105 per tonne — above the social generalised cost — the annual benefit is negative: ($105 – $100) x –1000 tonnes = –$5000, a disbenefit of $5000.

With congestion (linear approximation of cost curves)

Say the road is congested. The Base Case perceived cost and marginal social generalised cost are $90 and $100 respectively. Due to reduced congestion on the road following the loss of traffic, the Project Case perceived cost and marginal social generalised cost are $86 and $94 respectively. The average (halfway point) of the Base Case and Project Case perceived costs is ($86 + $90)/2 = $88. The average (halfway point) of the Base Case and Project Case marginal social generalised costs is ($100 + $94)/2 = $97. The benefit from traffic diversion is then ($88 – $97) x –1000 tonnes = $9000.

Note that the same benefit can be calculated as the reduction in average social generalised cost to users who remain on the road plus a benefit for diverting users obtained by applying the rule-of-half. See NGTSM 2006, Volume 5, Section 2.7, Example K for an explanation.

Box 12: Numerical examples of estimation of costs from upstream-downstream effects

A rail infrastructure upgrading initiative results in a diversion of 1000 tonnes of freight per annum from road transport to rail.

Without congestion

The perceived cost of carrying the freight on the feeder road is $9 per tonne. The social generalised cost is $10 per tonne. Using the formula in Section 7.2, there is an annual benefit of ($9 – $10) x 1000 tonnes = $1000, a disbenefit of $1000.

If the perceived cost by road is $11 per tonne — above the social generalised cost — there is an annual benefit: ($11 – $10) x 1000 tonnes = $1000.

With congestion (linear approximation of cost curves)

Say the road is congested. The Base Case perceived cost and marginal social generalised cost are $8 and $10 respectively. Due to increased congestion on the road following the increase in traffic, the Project Case perceived cost and marginal social generalised cost are $12 and $14 respectively. The average of the Base Case and Project Case perceived cost is ($8 + $12)/2 = $10. The average of the Base Case and Project Case marginal social generalised cost is ($10 + $14)/2 = $12. The benefit from traffic diversion is then ($10 – $12) x 1000 tonnes = $2000, a disbenefit of $2000.

7.3 Application in complex urban networks

7.3.1Measuring user benefits

The discussion in Sections 7.1 to 7.2 presented the principles for estimating user benefits when cross-modal and network effects apply. Direct application of the above discussion is feasible in cases where those cross-modal and network effects are relatively simple. When the network and the associated cross-effects are complex, the assessment also becomes much more complex. This is the case for the urban networks of cities.

The complexity of travel patterns is illustrated as follows:

- There are multiple routes throughout the city
- Those routes can be parallel and also cross each other
- There are multiple transport modes that can be chosen: car, car-pooling, public transport (bus, train, tram), cycling, walking
- Activities are scattered across the urban area and also concentrated in centres
- Patterns of localised traffic and through traffic is repeated across many sub-areas within the city.

All these features of cities produce a vast range of travel options and choices for users between many origins and many destinations, dispersed across a metropolitan area. In these complex urban cases, the estimation of travel decisions and user benefits requires the use of more sophisticated analytical methods, namely those available through urban travel demand models[7]. Part T1 of the ATAP Guidelines provides guidance on travel demand models.

The measurement of user benefits using travel demand models still involves use of the same principles discussed in the above sections. Equations (1), (3) and (4) in Sections 6.2 and 6.3 define the user benefit for existing traffic, new traffic and both traffics combined. Section 7.4 produced the same user benefit equations using the alternative method of consumer surplus plus resource correction.

However, the difference with complex urban networks is in how the formulas are applied:

- The user benefit calculations first need to be undertaken within the travel demand model at a disaggregated level: for each origin-destination pair[8], for each mode, for each time period and for each forecast year
- The disaggregated results are then aggregated to yield overall use benefits:

[7] Travel demand models divide an urban area into a large number of smaller zones. Each zone is modelled as both an origin and a destination. Trips are modelled for every pair of origins and destinations across the urban area.

[8] In some practice, the calculations are 'link-based'; that is they are undertaken for each link in the modelled transport network. The origin-destination approach discussed here is generally considered the best practice approach.

- Aggregating across the entire demand matrix (that is, across all origin-destination pairs)
- Repeating the process for all modes and time periods
- Repeating the process for each model forecast year.

With a highly disaggregated base, a wide range of user benefit breakdowns can be summarised to facilitate a good understanding by both the analysts and the decision-maker of how user benefits are expected to vary by time periods, by mode, by geographical location and by forecast year.

7.3.2 Accounting for induced demand

Part T1 Section 3.4 of the ATAP Guidelines discusses induced demand[9]. It states that induced demand refers to the impacts of transport improvements in encouraging some people to switch routes, modes or time of travel to take advantage of the improved travel times and service levels. In addition, induced demand can refer to the tendency of some people to travel more, or travel further, when travel conditions are improved. In the demand model, induced demand can arise from changes in any of the following: route choice, time of day travel occurs, mode choice, trip distribution (that is, choice of trip destination), trip generation (that is, the number of trips undertaken), land use changes and the location decisions of both households and businesses.

In economic terms, the induced (additional) traffic resulting from, say, a road network improvement will perceive a benefit through now being able to travel, taking advantage of the improved conditions. However, this additional traffic will reduce the potential benefits of the improvements for other traffic if the road network is at all congested.

The inclusion of induced demand effects can make a significant difference to user benefit estimates. For example, research a couple of decades ago (Huw et al, 1992) found that failure to account for induced demand overvalued road capacity expansion benefits by 50 per cent or more. Other studies (Abelson and Hensher, 2001 and Litman, 2008) have also found that excluding induced demand can materially overstate the economic benefits of an initiative.

Given the significant potential impact of induced demand, best practice in the assessment of major urban transport initiatives now requires that the outputs from the demand model (both travel estimates and user benefit estimates) take account of induced demand.

For example, in the case of major urban road initiatives, it is not sufficient to assume that the only difference between Base Case and Project Case numbers of peak period users will arise from users switching routes to take advantage of improved speeds on the initiative route. Such an approach ignores the complexity of real-world responses to major transport investments (Bray, 2005).

Induced demand is only expected to be of material significance for large urban transport initiatives. Induced travel demand effects are of greatest importance for the assessment of transport initiatives in networks with:

[9] Note that induced demand is equivalent to generated and diverted traffic, as discussed in earlier sections of Part T2.

- A high degree of congestion (typically in urban areas, especially at peak periods) and/or
- High elasticity of demand (typically in urban areas, especially where alternative modes offer strong competition) and/or
- Relatively large changes in travel costs (typically for larger schemes providing substantially enhanced capacity).

For public transport network improvements, induced demand effects are also most significant when similar conditions apply that is, when demand is elastic and increases in response to improved service, and when the service is already congested or crowded.

For major urban transport initiatives where induced demand is considered to be relevant to the assessment, Part T1 (Section 3.4.3) indicates that the Variable Trip Matrix (VTM) approach must be used in the demand modelling and associated user benefit calculations that accommodate the various sources of induced demand.

Finally, the case of large city-shaping transport initiatives should be specifically mentioned. Part F0.2 of the ATAP Guidelines discusses such initiatives, noting their significant potential impacts on land use and urban structure. Induced demand in such cases is therefore of high importance.

Part F0.2 explores the ideal of using a ‘fully evolved CBA’ of large city-shaping urban transport projects, with full modelling of land use-transport interaction. It notes, however, that there continue to be challenges to implementing such an approach at this point in time[10]. It suggests that a practical alternative approach is the iterative application of CBAs using land-use impact scenario analysis. In this approach, scenario analysis is used to investigate the potential major land-use impacts of strategic transport initiatives. Testing the effect of different land-use impact outcomes on a CBA determines the sensitivity of the CBA results.

[10] Section 3.5 of Part T1 provides an overview of the current state of land use-transport interaction modelling.

7.4 If the initiative results in changes to land use change, there may be additional benefits

If the initiative results in more compact land use so there is less urban sprawl in the base, there may be some additional benefits to consider.

The same principal applies as outlined above in Sections 7.1 and 7.2. If prices (and hence changes in willingness-to-pay) equal marginal social costs, there are no additional net benefits. For example, if the households and businesses that locate on the urban fringes in the base case pay for the full resource cost of the additional land, infrastructure and services they require and the externalities they create, the resource cost is fully offset by the benefits to the land users.

There are only benefits to the extent that prices are below marginal social costs. For example, if the governments meet some of the costs of establishing and maintaining new outer suburbs in the base case, there is a net benefit from not having to create these suburbs in the project case. However, the benefit is limited to the difference between the resource cost and the private cost incurred by people who move to the new outer suburbs in the base case, not the full avoided resource cost of the creating the new suburbs. In other words, the benefit of the saving in the resource costs of creating and maintaining the new outer suburbs has to be reduced by the lost willingness-to-pay of the people who would have lived in those suburbs.

Not creating new outer suburbs in the Project Case may lead to some savings in congestion costs compared with the Base Case. These would be estimated in the usual way by assuming leftward shifts in the demand curves for the infrastructure affected in the Project Case. Lower externalities associated with transport to and from the fringe suburbs could be counted as benefits because they are unpriced. Loss of fuel excise to the government would count as a disbenefit, as the reduction in consumers' willingness-to-pay exceeds the resource cost saving.

Part T1 of the ATAP Guidelines provides guidance on travel demand modelling, including modelling of the interaction between land use and transport.

7.5 If future investments in related infrastructure are deferred (brought forward), estimate net benefits

The preceding sections asked analysts projecting social and private costs of related congested infrastructure into the future, to adjust their projections for cost reductions due to likely expansions of, or improvements to, the related infrastructure. A reduction in demand for use of related infrastructure can cause future expansions or improvements to be deferred, and, conversely, an increase in demand can cause future expansions to be brought forward in time. In discounted present value terms, deferral of future capital expenditure is a benefit and bringing of future capital expenditure is a cost.

If expansion and contraction of infrastructure capacity of related infrastructure was perfectly divisible and occurred in a way such that capacity was always optimal (capacity was adjusted so the marginal benefit of expansion was maintained equal to the marginal cost), there would no net benefits to consider from changes in the timing of future capacity changes on related infrastructure due to the initiative being appraised. The gains or losses from altered timings of future capital expenditures would be exactly offset by gains and losses to users of the infrastructure. Lumpiness in capacity expansion and over- or under-investment mean that changes in the timing of future capital expenditures on related infrastructure can give rise to additional impacts for inclusion in a CBA.

When estimating deferred infrastructure benefits or brought-forward infrastructure disbenefits, it is essential to offset them with any changes to user benefits on the related infrastructure. In some cases, the two offsetting impacts may approximately cancel out.

- If a reduction in demand on related infrastructure leads to a benefit from deferred capacity expansion, there will be an offsetting loss of benefit, during the deferral period, for users who remain on the related infrastructure.
- If an increase in demand on related infrastructure leads to a disbenefit from capacity expansion being brought forward in time, there will be an offsetting benefit, during the period over which the additional capacity has been brought forward, for existing users of the related infrastructure.

Changes in user benefits are estimated in accordance with the other sections in Chapters 6 and 7.

To note only — it does not affect the methodology: the impact on existing users of related infrastructure of a changed timing of capacity expansion will be greater if the planned capacity expansion is later than its optimal time, which would be indicated by a high benefit-cost ratio. Conversely, the impact on existing users of related infrastructure will be lower if the planned capacity expansion is before its optimal time, which would be indicated by a low benefit-cost ratio. In the extreme case, where the planned capacity expansion is not needed at all and creates zero user benefits, there will be no impact on existing users from changing its timing. There is only the change in the discounted cost of deferring or bringing forward the investment.

8. Step 8: Estimate safety benefits

Steps

8.1. Estimate crash rates for each severity level or crash type for each year in the Base and Project Cases.

8.2. Multiply crash numbers by unit costs.

8.3. The benefit is Base Case crash costs minus Project Case crash costs.

8.1 Estimate crash rates for each severity level or crash type for each year in the Base and Project Cases

A ‘crash rate’ is a number of crashes per period of time. Crashes at a location usually vary with ‘exposure’ (the number of opportunities at which crashes can occur). Exposure at a location is usually measured by the amount of traffic passing through the site per period of time. Crash numbers are usually assumed to be proportional to exposure or traffic. Hence, the relevant crash rate for forecasting future crash numbers in the Base and Project Cases is a number of crashes per year to unit of traffic (vehicles, trains, cyclists, pedestrians) or traffic-kilometre. Typically for roads, crash rates are expressed per 100 million vehicle kilometres travelled (VKT).

Depending on data availability, crashes may be considered at different categorisations and levels of aggregation:

- Severity level: fatal, serious injury, other injury, property damage only, or ‘casualty’ which groups together fatal and all injury crashes
- Crash type: for example, in the case of roads, head-on, run-off road, pedestrian, etc.
- Location: rural, urban, urban freeway.

There may be a choice of using default crash rates for the type of infrastructure and the actual crash rate for the base case infrastructure estimated over a period of time. As crashes tend to be infrequent for a given piece of infrastructure, data over a number of years is needed to obtain a statistically reliable estimate for the crash rate. Statistical significance can be improved by estimating a more aggregated crash rate, such as, the rate for casualty crashes instead of fatal and different injury severity levels.

Numbers of crashes in each year for the Base Case can be forecast by multiplying crash rates by forecast traffic.

When forecasting the crash rate for the Project Case, be wary of using default values for the Project Case infrastructure when the Base Case forecasts are based on actual crash rates from past data. The Base Case infrastructure may have particular characteristics that differ from that assumed for the default values, or the estimated crash rate might be unduly affected by random fluctuations. It may be better to use default values for both Base and Project Cases or to calculate a ‘crash reduction factor’ (proportional reduction in crashes) from the default values and apply it to the forecast Base Case crash numbers. Crash reduction factors are available for a range of blackspot treatment types. Note that these factors apply to casualty crashes, not total crashes, which would include property damage only crashes.

8.2 Multiply crash numbers by unit costs

Unit crash costs need to be obtained for the particular crash severity levels or types and locations distinguished in the forecasts of crash numbers. The ATAP Guidelines publishes default values for both the willingness-to-pay and hybrid human capital approaches.

8.3 The benefit is Base Case crash costs minus Project Case crash costs.

No further explanation is required.

9. Step 9: Estimate externality benefits and costs

Steps

9.1. Apply default values.

9.2. Estimate externalities specific to the initiative (if required).

9.3. The benefit (or disbenefit if negative) is the Base Case externality costs minus the Project Case externality costs.

Externalities can be thought of as side effects of an initiative on third parties. Examples include noise, atmospheric and water pollution, climate change caused by greenhouse gas emissions, and severance (barrier effects). Since these effects are outside the price system, they are difficult to value in monetary terms. Nevertheless, significant progress has been made in recent years in the development of statistical and survey techniques to elicit people's valuations of environmental externalities (hedonic pricing, contingent valuation methods). However, these techniques are far from perfect and are resource intensive.

9.1 Apply default values

In rapid CBAs and in detailed CBAs where particular externality costs are not critical (that is, small in relation to total benefits and costs), use default values.

Default values are standard unit costs that can be applied across the board to obtain an estimate of externality costs. The level of approximation can be reduced if default values vary with population density (for example, rural and urban locations) and for different intensities of the externality. Although only a rough guide, employing a default value for an externality is usually preferable to the alternative of giving it a zero value.

The default values represent broad average values applicable to initiatives in all Australian jurisdictions. The list is not complete due to data inadequacies. The valuation of externalities is an evolving area of expertise, and the values should therefore be treated with caution. If these values are considered to be inappropriate for the initiative being appraised, use other values, providing a justification for their use and a sensitivity test using the Guidelines values.

The default values are expressed in common units of monetary value per vehicle-kilometre (vkm) travelled (cents/vkm) or per net tonne-kilometre (cents/ntk). Values are disaggregated for private cars, light trucks, medium trucks, heavy trucks and buses, and some are further disaggregated by location (urban and rural).

In order to employ default values in a CBA, use estimates of vkm for each vehicle type and location for the Base Case and Project Case for each year of the initiative's life. Multiply these by the default externality values.

9.2 Estimate externalities specific to the initiative (if required)

If, after using the default values, some externalities are of sufficient magnitude to make a significant difference to the summary results of the CBA, then - as part of a detailed CBA - consider undertaking modelling or survey work to identify externalities specific to the impacts of the initiative being appraised.

The first step will be to estimate the quantities of the externalities in physical terms for the Base and Project Cases.

The second step is to value the externalities. When valuing an externality, the aim is to find out how much the affected people are willing to pay to avoid the externality, or how much they are willing to accept to put up with it. Techniques to do this include hedonic pricing, stated preference surveys, and estimation of mitigation costs or damage and avoidance costs.

9.3 The benefit (or disbenefit if negative) is the Base Case externality costs minus the Project Case externality costs

If it is not possible to value an externality with default values or site-specific research, then describe the nature, size and impacts of the externality quantitatively in physical units, where applicable, and then qualitatively.

10. Step 10: Discount benefits and costs, calculate summary results

Steps

10.1. Choose a discount rate.

10.2. Assemble benefits and costs by time period.

10.3. Calculate the NPV.

10.4. Calculate the BCR.

10.5. Calculate the NPVI (if required).

10.6. Calculate the incremental BCR (if applicable).

10.7. Calculate the internal rate of return (IRR) (if required).

10.8. Calculate the first-year rate of return (FYRR).

10.1 Choose a discount rate

Discounting is necessary because a dollar of benefit in the future is worth less than a dollar of benefit today. There is a variety of views and approaches to selecting the social discount rate. The technical literature is large and complex. There is no definitive answer on which experts will agree. For a background discussion on discount rates see NGTSM 2006 Volume 5, Section 2.10.1.

In practice, use the discount rate nominated by the funding jurisdiction. For example, at the time of publication: Infrastructure Australia requires the use of a real rate of 7 per cent with 4 per cent and 10 per cent used for sensitivity testing; the Commonwealth Department of Transport and Regional Development requires the use of real rates of both 4 per cent and 7 per cent.

10.2 Assemble benefits and costs by time period

Adopt an end-of-year convention for discounting purposes, where all benefits and costs are assumed to occur at the end of the year in which they occur.

Set ‘year zero’ at the time of the commencement of construction. Any costs occurring in year zero are not discounted. Costs incurred during year one will be discounted by one year. Discount forward any costs (e.g. avoidable planning and design costs[11]) incurred prior to the commencement of year zero (years minus one, minus two and so on) by multiplying by $(1+r)^t$.

[11] Leave out any planning and design costs already occurred at the time of undertaking the CBA because they will not be affected by any decision to proceed with the initiative.

With the life of the initiative assumed to commence at completion of construction, the number of years over which discounting occurs will be larger than the initiative's life. For example, if an initiative takes two full years to construct and has a 30-year life, there will be 32 years of benefits and costs to discount - the final year's net benefits being discounted by 32 years.

10.3 Calculate the NPV

The summation of all annual discounted present values of a stream of benefits or costs is called the 'present value' of that stream. The net present value (NPV) of an initiative is the difference between the discounted stream of benefits and the discounted stream of costs. The NPV is given by:

$$NPV = \sum_{t=0}^{n} \frac{B_t - OC_t - IC_t}{(1+r)^t}$$

where:

- t is time in years
- n is number of years during which benefits and costs occur
- r is the discount rate
- B_t is benefits in year t
- OC_t is infrastructure operating costs in year t
- IC_t is investment costs in year t.

A positive NPV means that the initiative represents an improvement in economic efficiency compared with the Base Case.

Use the NPV to compare:

- Mutually exclusive options for the same initiative
- Alternative combinations of related initiatives (where implementation of one affects the benefits and/or costs of another)
- Alternative implementation timings for the same initiative.

The Incremental BCR in Section 11.6 below is an alternative tool for these situations.

10.4 Calculate the BCR

The BCR is the present value of benefits minus operating costs divided by the present value of costs. There are two alternative definitions depending on whether one puts infrastructure operating costs in the numerator or the denominator.

$$BCR1 = \frac{PV(B)}{PV(OC + IC)}$$

$$BCR2 = \frac{PV(B - OC)}{PV(IC)}$$

where $PV(x) = \sum_{t=0}^{n} \frac{x_t}{(1+r)^t}$

BCR1 puts costs and (savings in costs) that impact on government budgets in the denominator and everything else in the numerator. BCR2 puts costs that occur *before* completion of the initiative in the denominator and benefits and savings in costs that occur *after* completion of the initiative in the numerator. Benefits of deferred capital expenditure and costs of capital expenditure brought forward, discussed in Section 8.6, belong the denominator in BCR1 and the numerator in BCR2.

A BCR greater than one implies a positive NPV.

The BCR measure is used:

- As a convenient way to express the economic worth of an initiative
- To rank initiatives from an economic efficiency perspective where there is a budget constraint. BCR2 is the theoretically correct measure to use for this purpose because it is short-term funds being allocated. As long as operating and maintenance costs are small in relation to benefits and investment costs, BCR1 and BCR2 will be close and ranking by BCR1 should not lead to significant errors.

Never use BCRs to choose between mutually exclusive options for the same initiative, because they remove the effects of different scales of the initiatives.

10.5 Calculate net present value per dollar invested if required

The net present value per dollar invested is defined as

$$NPVI = \frac{NPV}{PV(IC)}$$

The NPVI is exactly equal to BCR2 minus one. If BCR2 has been provided, there is no value added by providing the NPVI. However, if only BCR1 has been provided, the NPVI can be used for ranking initiatives subject to a budget constraint.

10.6 Calculate the incremental BCR (if applicable)

The incremental BCR (IBCR) can be used instead of the NPV in the three comparative situations listed in Section 11.3 above. The IBCR is defined as

$$IBCR = \frac{PV(B_2 - OC_2) - PV(B_1 - OC_1)}{PV(IC_2) - PV(IC_1)}$$

where the subscripts represent options 1 and 2, and option 2 has the greater investment cost. The IBCR is well-suited for comparing options involving different scales of initiative. Increases in the scale of initiative are worthwhile as long as the IBCR for each scale exceeds one.

IBCR comparisons can take account of budget constraints, unlike simple NPV comparisons.

- Posit a cut-off BCR at the level of the lowest acceptable BCR for initiatives competing for funds out the same budget. A cut-off BCR of 2 implies that each dollar of funds used to pay of the increment has an opportunity cost of funds of $2 of forgone benefit from other investment opportunities not taken.
- List the options in ascending order of investment cost and calculate the IBCR for each adjacent pair.
- An IBCR above the cut-off implies the increment is worth accepting. If the IBCR for a pair of options is below the cut-off, reject the higher cost option. Remove it from the list and use the lower cost option as the basis for the next increment.
- The economically best option is that with the highest investment cost which has an IBCR greater than or equal to the cut-off BCR[12]. (UK DFT 2006).

10.7 Calculate the internal rate of return (IRR) (if required)

Central agencies sometimes require reporting of the internal rate of return (IRR).

The IRR is defined as the value of the discount rate at which the NPV equals zero. It represents the minimum discount rate at which the initiative is viable in economic terms. There is no formula for the IRR. It needs to be found by iteration. Excel has a function to do this.

The IRR can be used in the same way as the NPV to indicate whether or not an initiative will be of benefit to society as a whole. It provides an indication of the economic worth of an initiative without requiring specification of a discount rate.

The IRR has no other uses. Never use the IRR to rank initiatives or to choose between mutually exclusive options as this amounts to comparing initiatives using different discount rates.

[12] Testing whether an option has an IBCR greater than a cut-off BCR, μ, is the same as comparing the NPVs for the two options with investment costs grossed up by the cut-off BCR to account for the opportunity cost of scarce investment funds. $IBCR = \frac{PV(B_2 - OC_2) - PV(B_1 - OC_1)}{PV(IC_2) - PV(IC_1)} > \mu$ is the same a $PV(B_2 - OC_2) - \mu PV(IC_2) > PV(B_1 - OC_1) - \mu PV(IC_1)$s

10.8 Calculate the first-year rate of return (FYRR)

The first-year rate of return (FYRR) is the level of benefits minus operating costs in the first year of operation of the initiative discounted to year zero, divided by the present value of investment costs. That is:

$$FYRR = \frac{B_{t_f}}{(1+r)^{t_f}} \Big/ \sum_{t=0}^{t_f} \frac{IC_t}{(1+r)^t}$$

where t_f is the first year of operation of the initiative.

The FYRR can indicate whether an initiative's optimal implementation time is in the past or future, and hence whether deferral is warranted. Provided the assumptions underlying the criterion are met (see NGTSM 2006 Volume 5 for details), the optimal implementation time is the first year in which the FYRR is greater than the discount rate.

All initiatives should be subjected to the FYRR test and the result reported in the Business Case.

11. Step 11: Assess risk and uncertainty

Steps

11.1. Undertake simple sensitivity analyses.

11.2. Decide on the level of detail for a risk analysis.

11.3. Identify risky variables and sources of risk.

11.4. Assign alternative values to risky variables.

11.5. Assign probabilities to events.

11.6. Identify states of nature and associated probabilities.

11.7. Calculate expected values of CBA results.

11.8. Calculate probability-based values of investment costs if required.

11.9. Use a computer program if the analysis becomes too complicated.

11.10. Consider risk management strategies.

All benefits and costs that go into a CBA are forecasts of the future. Risk and uncertainty arise from the possibility that a forecast will prove to be wrong.

Distinguish between downside risk and pure risk. Downside risk arises because people usually do not to consider what can go wrong, causing assessments to be biased in favour of the initiative. If downside risk has been eliminated from projections, the remaining variation about the expected value is called pure risk. In most cases, pure risk can be ignored in CBAs. See NGTSM Volume 5, Section 2.11 or BTRE (2005) for an explanation.

For financial analyses, the weighted average cost of capital will include a risk premium. It compensates lenders and shareholders for bearing the risk that the firm will go bankrupt. It is not a mechanism to offset optimism bias in financial calculations.

It is not good practice to add a risk premium to the discount rate for CBAs. It can distort ranking of initiatives. See NGTSM 2006 Volume 5, Section 2.11 or BTRE (2005) for an explanation.

11.1 Undertake simple sensitivity analyses

Sensitivity analysis is a simple way to analyse the uncertainty surrounding CBA results, but it is a limited tool. In its most basic form, it involves changing one variable at a time by a standard percentage, say, +10 per cent followed by –10 per cent, or by an absolute amount to gauge how much NPV changes. If the NPV changes by only a small amount (e.g. ±10 per cent change causes a ±3 per cent change in NPV), it implies that the uncertainty surrounding the variable is not very important and is not critical to decision-making. Conversely, if the effect on NPV is large in percentage terms, the robustness of the CBA can be called into question. It may be worthwhile to expend more resources to obtain a better estimate of the variable, though this will do nothing to reduce risk arising from inherent volatility of the variable.

Choose the percentage variations used for sensitivity tests, bearing in mind the range of plausible values that a variable can take. The amounts the variables change by do not have to be symmetrical.

As an example, Table 3 shows the sensitivity ranges for road initiatives recommended by Austroads.

Table 3 Sensitivity variables and ranges recommended by Austroads

VARIABLE	SUGGESTED MINIMUM VALUE	SUGGESTED MAXIMUM VALUE
Capital cost[a] Concept estimate Detailed costing Final costing	–20% of estimate –15% of estimate –10% of estimate	+20% to 35% of estimate[b] +15% to 25% of estimate[b] +10% to 20% of estimate[b]
Road-agency operating and maintenance costs	–10% of estimate	+10% of estimate
Traffic Total traffic volume (AADT) Proportion heavy vehicles Average car occupancy Traffic growth rate Traffic generated by specific (uncertain) developments Traffic diverted or generated by the initiative Traffic speed changes Changes in crash rates	–10% to –20% of estimate –5 percentage points –0.3 from estimate –2% pa (absolute) from the forecast rate Zero – 50% of estimate –25% of estimated change in speed –50% of estimated change	+10% to +20% of estimate +5 percentage points +0.3 from estimate +2% pa (absolute) to the forecast rate As forecast +50% of estimate +25% of estimated change in speed +50% of estimated change

a. The appropriate range for capital costs depends on the detail of investigations, designs and costing.The concept estimate relates to initial pre-feasibility or sketch-planning estimates. The final costing relates to estimates after the final design stages.

b. The range of values relates to different types of initiative. Costing for more routine initiatives (e.g. road shape correction, resealing) are generally more accurate than those for larger initiatives (e.g. new motorway construction). Source: Austroads 1996, p. 28; and 2005a, p. 27.

Spreadsheets are ideally suited to conducting sensitivity tests. Group the list of parameters likely to be tested in an easily accessed part of the spreadsheet (for example, the upper left corner). Present the results in terms of percentage and/or absolute deviations in NPV and BCR in a table.

11.2 Decide on the level of detail for a risk analysis

The SMT and rapid CBA template (see Part F3 of the ATAP Guidelines) requires proponents to address a series of questions about the risks of their proposed initiatives. Some of these relate to risks that the initiative will be delayed. There is a question about describing the major risks on the cost side (e.g. excess costs) and benefit side (e.g. where benefits are not realised). For the SMT and rapid CBA, it is not necessary to go further by conducting a state-contingent assessment as described here.

For detailed CBAs of larger initiatives, governments may insist on a probabilistic analysis, at least for investment costs, which may require the use of computer software. The larger the initiative, the greater the level of detail warranted. Discuss the level of detail required with the government agency assessing the proposal.

The remainder of this section is concerned with the probabilistic approach. This approach helps to minimise downside risk or optimism bias, that is, to ensure that the results of CBAs are expected values (the means of probability distributions). It provides a thought process that disciplines the analyst to ask a complete set of 'what if?' questions.

11.3 Identify risky variables and sources of risk

The main sources of risk for investment initiatives are:

- Construction costs that differ from the expected because of changes in input costs or unforeseen technical factors
- Operating costs that differ from the expected because of changes in input costs or unforeseen technical factors
- Demand forecasts that differ from the expected, a risk that rises the further into the future the projections are made
- Environmental impacts that differ from the expected or are unforeseen
- Network effects, where an asset is part of the network (for example, an individual length of road or rail track) and decisions made elsewhere in the network impact on the initiative in question.

11.4 Assign alternative values to risky variables

Identify the possible values, or ranges of values, that risky benefits and costs (or variables affecting them) can take. Technically, each value (or range of values) that a variable can take is called an event. Wherever possible, identify circumstances associated with each event (such as equipment breakdowns, adverse weather, technical difficulties, unanticipated environmental or planning requirements, industrial disputes and population levels).

Be wary of simply assuming a symmetrical probability distribution around the estimated value of a variable. This presupposes that the estimate is the central value and may not lead to proper consideration of sources of optimism bias.

It may help to prepare checklists based on experience, examine similar current or previous initiatives, hold a brainstorming session or compile historical information. An Environmental Impact Statement (EIS) should identify environmental risks. Exclude events with very small probabilities of occurring, taking into account the size of the probability and the impact on benefits or costs.

11.5 Assign probabilities to events

In most cases, it is necessary to make subjective judgments about probabilities. In some cases, historical data or engineering models can assist. For each risky variable, the probabilities of all possible events must sum to one.

11.6 Identify states of nature and associated probabilities

Next, identify all combinations of events that can occur (technically called 'states of nature'). Compiling an event tree can be a useful tool for this task (see Box 13). Then calculate the probability of each state of nature. The probability of a state of nature is the product of the probabilities of all the constituent events. The probabilities of all possible states of nature must sum to one.

11.7 Calculate expected values of CBA results

Each state of nature will be associated with a unique stream of year-by-year benefits and costs. Note that both the Base and Project Cases can vary in different states of nature because external factors such as the weather and economic conditions can affect both. Calculate CBA results (NPV, BCR, IRR and FYRR) for each state of nature. Multiply each result by the probability of the associated state of nature and sum to obtain expected values (see Box 13).

11.8 Calculate probability-based values of investment costs if required

Calculate probability-based values of investment costs if the funding jurisdiction requires it. Investment costs are typically reported at P50 and P90 levels. P50 and P90 are the costs with sufficient contingency to provide a 50 per cent and 90 per cent likelihood respectively that these costs will not be exceeded. With half of the area of the probability distribution on either side, P50 is the median of the probability distribution.

The central CBA scenario should have results at 'expected values', that is, the results should be the means of the probability distributions for the NPV and BCR. These can be obtained by ensuring that all the individual cost and benefit estimates going into the CBA are expected values. For investment costs, the P50 value or median will equal the mean or expected value of investment costs if the probability distribution is symmetrical. If the distribution is reasonably symmetrical, the P50 value can be used as an approximation of the mean for the central scenario for a CBA. The P90 value could then be used as a sensitivity test to gauge the impact of investment costs being higher than expected. It is understood that some state treasuries use the P90 estimate for budget funding purposes on the grounds that, due to optimism bias, the P90 value may be closer to the expected value than the P50 value.

For rapid CBAs and small initiatives, the 'deterministic approach' to costing may suffice. It involves applying a percentage contingency allowance to base estimates for either individual cost elements or to the aggregate project cost. Using the deterministic approach, the amount of the percentage contingency allowance would be quite small to approximate a P50 estimate, and relatively larger to approximate a P90 estimate (Evans and Peck, 2008, p.32). To be useful, deterministic costing requires access to reliable benchmark data, particularly at the whole-of-project level, in order to estimate the contingency allowance. Both the probabilistic and deterministic approaches to costing require input from experienced practitioners.

11.9 Use a computer program if the analysis becomes too complicated

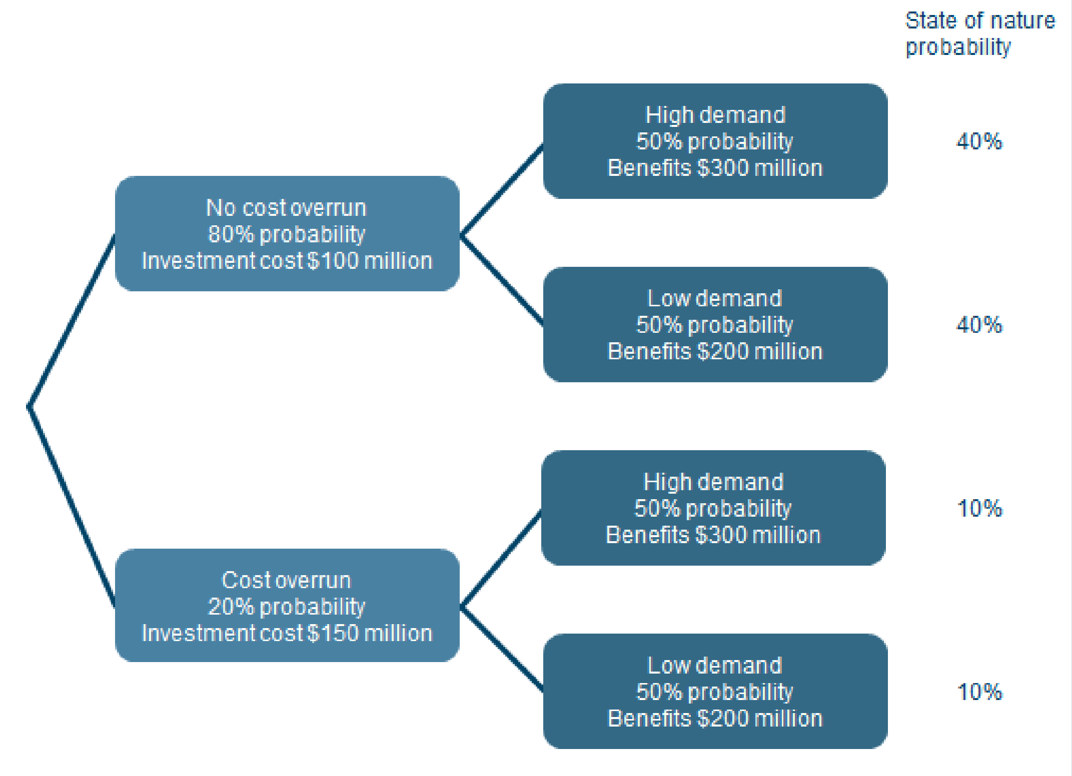
Where the number of states of nature or the number of uncertain variables is large, the combinations of input values can become extremely large. To facilitate the process, use computer software packages such as @RISK. This software links with Excel. The program allows probability distributions for continuous variables to be specified. See Austroads (2002) for guidance.

If computer software is used to estimate expected values of CBA results, the software will also provide estimates of the variances. For public sector initiatives, variances are, in most cases, not relevant to decisions about whether initiatives should proceed or about ranking initiatives. See

BTRE (2005) or NGTSM 2006 Volume 5, Section 2.11 for an explanation.

Box 13: Example of calculation of expected NPV and BCR

The present value of **investment** costs for a new initiative is $100 million with an 80 per cent probability, and $150 million with a 20 per cent probability if major cost overruns occur. The present value of benefits is $300 million with high demand and $200 million with low demand with a 50:50 chance of either. The diagram shows the event tree and probabilities for the four states of nature.



The table shows calculation of the expected NPV and BCR.

Investment cost event	Cost ($m)	Demand event	Benefit (m)	Prob	NPV ($m)	Prob × NPV	BCR	Prob × BCR
No overrun	-100	High	300	0.4	200	80	3.0	1.2
No overrun	-100	Low	200	0.4	100	40	2.0	0.8
Overrun	-150	High	300	0.1	150	15	2.0	0.2
Overrun	-150	Low	200	0.1	50	5	1.3	0.1
Expected value						**140**		**2.3**

11.10 Consider risk management strategies

Consider changes to proposals that can increase expected NPVs by reducing either the probabilities or the costs of adverse events. Often, these changes will involve expending additional resources with certainty (for example, building a stronger bridge). Use the probabilistic approach to assess the economic viability of each option and to compare options.

The ‘real options’ approach involves consideration of options for waiting and staged flexibility. A ‘real option’ is a decision taken today that makes it possible for policy makers to take a particular action in the future. Real options are similar to financial options but are exercised over real assets rather than financial assets (PC 2012, pp.12 and 97). Under the ‘wait and see’ approach’ options are explored that involve deferring investment until a major uncertainty is resolved or lessened and the initiative is more clearly going to be successful. Staged flexibility involves incurring additional short-term costs in exchange for lower costs later when uncertainties are resolved or lessened and decisions can be made to withdraw, proceed as planned or proceed in a different way.

The decision criterion is to choose the option that maximises the expected value of the NPV obtained from a probabilistic assessment.

12. Adjusted cost-benefit analysis

Steps

12.1. Determine whether an adjusted CBA is required.

12.2. Determine which adjustments to make.

12.3. Replace values for certain parameters with nominated values.

12.4. Multiply specified benefits or costs by a weighting factor >1 to give the benefit or cost greater weight and <1 for less weight.

12.5. Insert subjectively determined monetary values for particular non-monetised benefits or costs.

12.6. Make percentage estimates of how the benefits are distributed among nominated groups.

12.7. Calculate the distributional multiplier and adjust the benefits accordingly.

12.8. Calculate adjusted NPV and BCR and report results.

12.1 Determine whether an adjusted CBA is required

The ATAP Guidelines provide an optional appraisal technique, adjusted CBA, for jurisdictions to use where they consider it appropriate.

CBA aims to maximise the economic efficiency objective. It recognises a number of other objectives such as safety and environment, but only as far as they are consistent with economic efficiency. Equity is not taken into account at all. The adjusted CBA methodology is a formal way to re-weight or incorporate non-efficiency objectives.

Adjusted CBA is a hybrid of multi-criteria analysis and CBA, retaining the monetary measuring rod of CBA. Adjusted CBA is not an essential component of the methodology established by the Guidelines, but it is included as an option. The decision to use adjusted CBA should be made by the government agency responsible for developing the investment program, not by proponents of initiatives.

All initiatives being compared must be subjected to the same adjustments. Therefore, it is the agency's responsibility to decide which adjustments should be made and to decide the weights. Any subjectively determined monetary values for impacts omitted from a CBA because they cannot be valued in dollar terms should be agreed between the government agency and a proponent after gaining a good understanding of the impact through consultation and expert opinion.

The government agency may decide to make the adjusted CBA assessment purely an internal process. Alternatively, it could provide the weights to proponents of initiatives and let them undertake the task.

12.2 Determine which adjustments to make

Adjustments will fall into one or more of the categories set out in Sections 13.3 to 13.6.

12.3 Replace values for certain parameters with nominated values

Some market-based parameter values might be replaced with nominated values (such as a lower or zero value of time for non-work travel, higher unit costs for crashes). The government agency to which the proposal is submitted will supply the adjusted parameter values.

12.4 Multiply specified benefits or costs by a weighting factor >1 to give the benefit or cost greater weight and <1 for less weight

Multiply some benefits and costs by weights (such as 2.0 for crash costs, 1.5 for cost savings for freight transport or environmental benefits and costs). The government agency to which the proposal is submitted will supply the weighting factors.

12.5 Insert subjectively determined monetary values for particular non- monetised benefits or costs

Subjectively determined money amounts may be set for one-off, non-monetised benefits or costs such as aesthetic impacts or effects on flora or fauna. Consult with the government agency to which the proposal is submitted to agree on the values. Obtain a thorough understanding of the impacts through consultation with other stakeholders and experts.

12.6 Make percentage estimates of how the benefits are distributed among nominated groups

When considering equity implications, it can be difficult to estimate how the benefits and costs of initiatives are distributed. The ATAP Guidelines propose a simple and practical approach. A small number of groups of people within society can be identified and judgments made about the percentage of benefits that accrue to each group. Distribution of investment costs and infrastructure operating costs are ignored in this simple approach, because investment costs are paid for by governments and private investors and infrastructure operating costs are usually small in comparison to benefits.

The government should assign a weight to each identified group. The weight is multiplied by the proportion of benefits received and the results summed to arrive at a distributional multiplier. Total benefits from the initiative are multiplied by the distributional multiplier. The multiplier will be greater than one for initiatives with favourable distributional effects, and less than one for initiatives with unfavourable distributional effects. A simple numerical example is provided the next section.

If the funding agency decides to use a distributional multiplier, the first step is to estimate how the benefits are likely to be distributed among the nominated groups. Estimate the percentage of total benefits accruing to each group. Note that benefits can accrue well outside the geographical area of the initiative. The origins and destinations and composition of people or freight benefiting from a transport improvement could be important indicators of how benefits are distributed. Because of the difficulty in forecasting distributional impacts of initiatives, the estimation process will inevitably involve judgement, more so in the rapid adjusted CBA stage. Consult with the funding agency about the calculations and judgements made in estimating distributions of benefits. See Part T5 Distributional (Equity) Impacts of the ATAP Guidelines.

12.7 Calculate the distributional multiplier and adjust the benefits accordingly

Obtain from the funding agency the weights to be used for the nominated groups. For each group, multiply the weight by the estimated proportion of benefits accruing to the group, and sum the results. This is the distributional multiplier. See Box 14 for a simple worked example. Note that the distributional multiplier is applied to benefits only, not to benefits less infrastructure operating costs.

Box 14: Numerical example showing calculation of distributional multiplier for an adjusted CBA

In this example, benefits are split three ways. The distributional multiplier is 1.1.

	Share of benefits	Weight	Share × weight
Metropolitan	30	0.5	0.15
Regional	50	1.5	0.75
National	20	1.0	0.2
Total	**100**		**1.1**

12.8 Calculate adjusted NPV and BCR and report results

Having adjusted individual benefits and costs according to Sections 12.3 and 12.4, sum the benefits less operating costs for each year, including any subjectively determined money values under Section 12.5. Do the same for investment costs. Multiply the benefits by the distributional multiplier if applicable (if the steps in Sections 12.6 and 12.7 were performed).

Finally, calculate the adjusted NPV and BCR.

Adjusted net present values (NPV) can be used to compare options as wells to rank initiatives.

Adjusted BCRs can produce an alternative set of initiative rankings that could be useful in choosing between initiatives in order to develop a program.

A criticism of adjusted CBA is that it 'distorts' the results of CBAs in such a way that it can favour less economically efficient initiatives over more efficient initiatives. As a safeguard, the Guidelines recommend that adjusted CBA results never be reported separately from the results of the corresponding unadjusted CBA.

Appendix A Benefit where the related market is a congested road – technical proof

This appendix provides a technical proof of the alternative measure of benefit on related infrastructure referred to in footnote in section 7.2.

The exact benefit area is negative the gap between the marginal social cost (MSC) and average perceived cost (APC) curves between Q1 and Q2,

$$\text{Benefit} = \int_{Q_1}^{Q_2} (\text{APC} - \text{MSC})\text{dQ},$$

which is consistent with the formula in the text of section 7.2 except for replacing average social cost (assumed constant in the formula in section 7.2) with marginal social cost. (See Harberger 1972, pp. 262-3)

$$\text{Benefit} = \int_{Q_1}^{Q_2} (\text{APC}-\text{ASC})\text{dQ} + \int_{Q_1}^{Q_2} \text{ASCdQ} - \int_{Q_1}^{Q_2} \frac{\text{dTSC}}{\text{dQ}}\text{dQ}$$

$$\text{Benefit} = \int_{Q_1}^{Q_2} \text{ASCdQ} \ - \text{TSC}_2 + \text{TSC}_1 + \int_{Q_1}^{Q_2} (\text{APC}-\text{ASC})\text{dQ}$$

where TSC is total social cost.

Since $\text{TSC} = ASC \times \text{Q}$, the total cost terms, can be written as $-\text{ASC}_2\text{Q}_2 + \text{ASC}_1\text{Q}_1$.

The term $\int_{Q_1}^{Q_2} \text{ASCdQ}$ is the area under the average cost curve between Q1 and Q2. It can be approximated by $(\text{ASC}_2 + \text{ASC}_1)(\text{Q}_2 - \text{Q}_1)/2$.

The last term, the resource correction, can be approximated as $(\text{APC}-\text{ASC})(\text{Q}_2 - \text{Q}_1)$ where $\text{APC} = (\text{APC}_1 + \text{APC}_2)/2$ and $\text{ASC} = (\text{ASC}_1 + \text{ASC}_2)/2$.

Combining the terms:

$$\text{Benefit} = (\text{ASC}_2 + \text{ASC}_1)(\text{Q}_2 - \text{Q}_1)/2 + -\text{ASC}_2\text{Q}_2 + \text{ASC}_1\text{Q}_1 + (\text{APC}-\text{ASC})(\text{Q}_2 - \text{Q}_1)$$

which simplifies to $(\text{ASC}_1 - \text{ASC}_2)(\text{Q}_2 + \text{Q}_1)/2 \ + (\text{APC}-\text{ASC})(\text{Q}_2 - \text{Q}_1)$.

Assuming $\text{ASC}_1 - \text{ASC}_2 = \text{APC}_1 - \text{APC}_2$, the benefit can be expressed as:

$$\text{Benefit} = (\text{APC}_1 - \text{APC}_2)(\text{Q}_2 + \text{Q}_1)/2 \ + (\text{APC}-\text{ASC})(\text{Q}_2 - \text{Q}_1)$$

(Neuberger 1971, p. 56 has this formula without the resource correction.)

Note that if the cost change is positive, as would occur on an upstream or downstream road where the demand curve shifts rightward, $\text{APC}_1 - \text{APC}_2 < 0$, the formula will give a negative result, reflecting the increase in net social cost due to greater congestion.

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