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TRANSPORT MINISTERS

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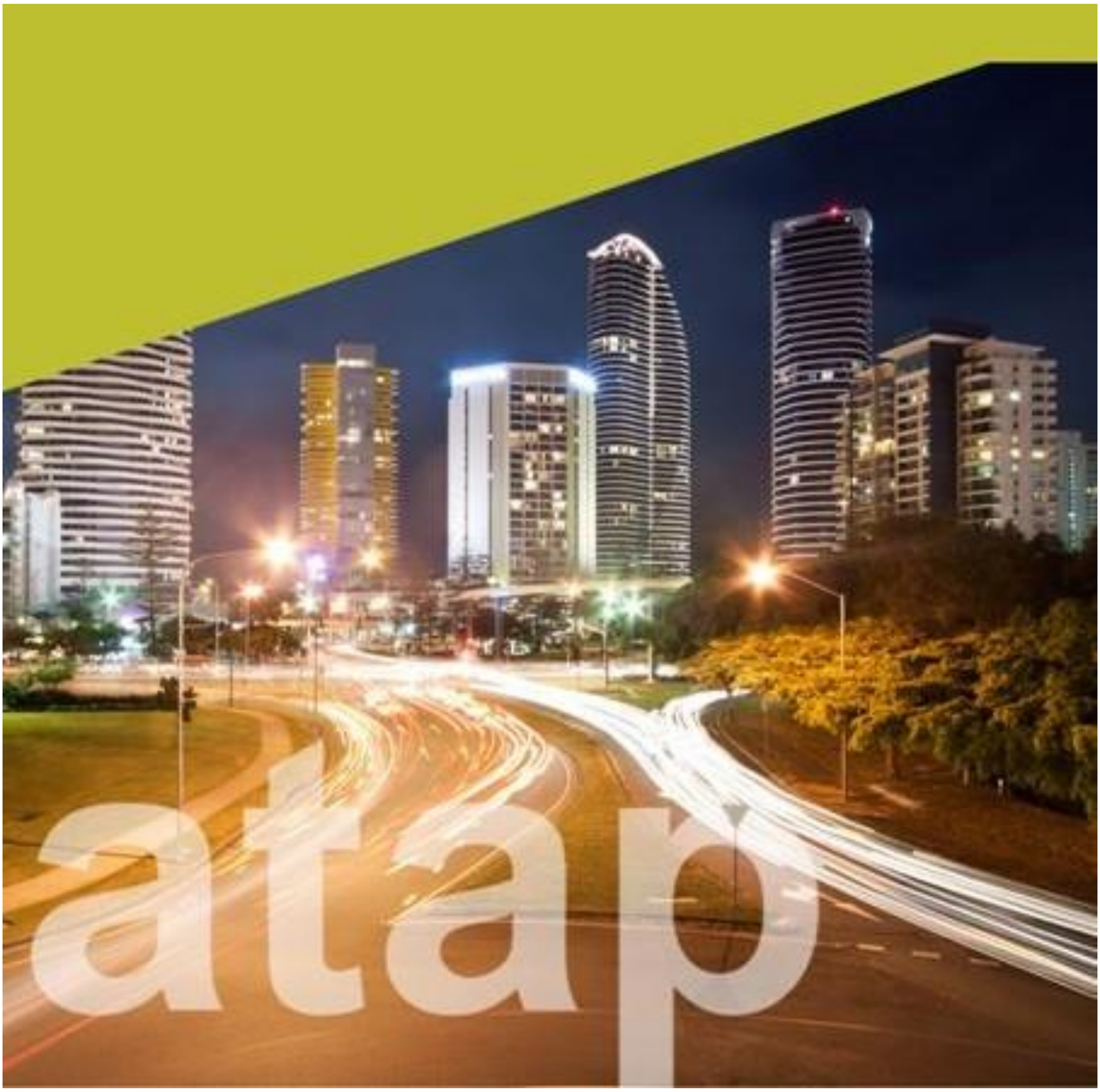
T2 Cost Benefit Analysis

April 2022



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At a glance

Cost–benefit analysis (CBA) is the core appraisal tool in ATAP Guidelines framework. This part of the Guidelines, 'T2', sets out the general approach to undertaking CBAs, which is elaborated on in the mode-specific (M) parts.

In the ATAP Framework, CBA is undertaken in step 3, where options are assessed and filtered to arrive at a single preferred option (ATAP Part F3 Options generation and assessment). CBA can be undertaken at a 'rapid' level to determine whether further assessment of an option is justified, and at a 'detailed' level.

CBA aims to identify and express, in monetary terms, all the gains and losses (benefits and costs) created by an option or 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 (NPV), is positive — that is, total benefits exceed total costs — implementation of the option will be an economically efficient use of resources. Benefits and costs are estimated by comparing changes between the Base Case (without the option or initiative) and the Project Case (with the option or initiative).

The method for undertaking CBA is presented as a series of steps, starting with specifying the options, including the Base Case, followed by listing the various benefits and costs. Each of these is monetised as far as possible in the subsequent steps: capital investment costs, infrastructure operating costs (including maintenance), user benefits (principally time and money cost savings) both for the infrastructure improved by the initiative and, if required, for related infrastructure, safety benefits and externalities. Demand forecasts play a critical role in estimating future benefits. Benefits and costs estimated for each year of the appraisal period are discounted and combined into summary results that can be used to make decisions. Techniques are presented to assess and adjust for risk and uncertainty.

The final chapter proposes techniques to 'adjust' CBAs where the analyst wants to give particular government objectives greater prominence in relation to the economic efficiency objective.

Introduction

This Part of the ATAP Guidelines, T2, provides general guidance for undertaking cost–benefit analysis (CBA) of transport initiatives and their associated options[1]. CBA plays a central role in the ATAP assessment approach.

Links to other parts of the Guidelines

The most closely related other parts of the Guidelines are:

- F3 Options generation and assessment — which presents the ATAP assessment model, which includes CBA
- Mode-specific guidance — M1 Public transport, M2 Roads, M3 Rail freight, M4 Active travel, M5 Travel behaviour change. Mode-specific guidance applies the CBA guidance in T2
- Other parts of the Tools and techniques category
- All the Other Guidance category
- The Parameter Values (PV) category of the Guidelines, which provides parameter values for public transport, road, rail and active travel and for environmental externalities for use in CBAs.

ATAP assessment framework summary

The ATAP assessment framework is presented in Section 3.3 of ATAP Part F3. It consists of:

- Clarification of relevant jurisdictional goals, transport system objectives and targets (see ATAP Part F1 Goals, objectives, targets) — It is important to be clear from early on which of these are relevant to the given assessment
- Clarification of policy choices that have already been made and are part of the context for the assessment (see ATAP Part F0.1 Policy choices and system planning)
- Being clear about the problem or opportunity that is being addressed (see ATAP Part F2 Problem identification and assessment)
- Generation of a wide range of options for addressing the problem or opportunity (see ATAP F3). Note that IA (2018) requires that at least two Project Cases, plus the Base Case, be presented in business cases submitted to them
- A three stage assessment process:
  - Strategic merit test — consideration of the degree of strategic alignment of the option being assessed with goals, transport system objectives, targets, policies and strategies
  - Rapid appraisal — consisting of the rapid application of CBA, distributional impact

[1] In the Guidelines, the preferred option is referred to as an ‘initiative’. The term ‘initiative’ is intended to cover non-infrastructure proposals such as regulatory and pricing solutions in additional physical infrastructure projects.

assessment (DIA) and the Appraisal summary table (AST)

  – Detailed appraisal — consisting of the detailed application of CBA, DIA and AST.

- The AST provides the mechanism for summarising all appraisal results — monetised and non-monetised — side-by-side in a single location. This approach recognises that all benefits and costs — monetised and non-monetised — are relevant to the appraisal of an option. The AST also includes quantitative and qualitative impact descriptions — these are necessary inputs to calculating monetised and non-monetised benefits, costs and impacts. Presentation of these inputs can also be of assistance to the decision-maker. Non-monetised impacts that are non-quantifiable can only be described in qualitative terms. (See ATAP Part F3 Options generation and assessment)
- The assessment of all options should include an assessment of risk and uncertainty, in order to ensure that the recommended option is robust (see this guideline ATAP Part T2 Chapter 11, and ATAP Part T7 Risk and Uncertainty)
- Bringing together all aspects of the assessment into a Business Case (see ATAP Part F4 Business cases).

What is cost–benefit analysis?

A cost–benefit analysis (CBA) is a form of economic analysis that assesses the benefits and costs of a proposed option that can be expressed in money units. It expresses them in terms of today's money ('present values'), providing a common metric for comparing options. Benefits and costs for use in the CBA are estimated by comparing changes between the Base Case (without the option) and the Project Case (with the option improvement).

CBA aims to identify and express, in monetary terms, all the gains and losses (benefits and costs) created by an option 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 option 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 standard technique used all over the world and can be applied to a wide range of options and initiatives in a defensible, comprehensive, transparent and rigorous way. It permits options to be compared and initiatives to be ranked, 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-capital options such as the introduction of new technology, pricing or changed management practices (see ATAP Part T7 for the assessment of non-capital options).

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.

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 and well established. If correctly followed, a CBA can result in comprehensive coverage of benefits and costs, without double-counting.

CBA is not a financial analysis. 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. In contrast, a CBA is from the perspective of the whole of society. 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 introduced into the analysis.

The CBA methodology set out in the ATAP Guidelines is tailored to suit the assessment of transport improvements in a multi-modal context and where a wide range of options is explored.

CBA is the primary appraisal tool at the options assessment, business case development and initiative prioritisation stages of the appraisal process (ATAP Framework stages 3, 4 and 5).

Table 1 summarises the process. The rest of this guidance provides supporting details.

Table 1 CBA steps

Step	Description	T2 chapter
Specify the Base Case and Project Case	Identify and describe the Base Case and Project Case (the option being assessed).	1
Identify the benefits and costs	List and describe the benefits and costs associated with the option. The benefit and cost in each year is the change in the relevant outcome between the Base Case and the Project Case.	2
Estimate capital investment costs	Estimate the capital investment cost of the Base Case and the Project Case.	3
Make demand forecasts	Estimate demand in each year of the appraisal period for the Base Case and the Project Case.	4
Estimate infrastructure operating costs	Estimate the recurring costs (operating and maintenance) for each year of the appraisal period for the Base Case and the Project Case.	5
Estimate benefits	• Benefits will include: user benefits, improved safety, and reduced externality costs. • When monetising benefits, ensure that cross-modal and network effects have also been accounted for. • Use the demand forecasts to estimate travel times, reliability, crash and externality levels for the Base Case and the Project Case for each year of the appraisal period • Monetise as many benefits and disbenefits as appropriate using relevant parameter values. • Estimate the monetised benefits for every year of the appraisal period.	6 to 9
Discount the benefits and costs and present the results	• Discount all benefits and costs over the appraisal period. • Present the key result indicators of the analysis (net present value, benefit–cost ratio, etc).	10
Assess risk and uncertainty	Assess how the results will change as key inputs are varied to reflect their associated level of risk and uncertainty.	11
Adjusted cost-benefit analysis	An optional assessment is to undertake an adjusted cost–benefit analysis where selected benefits and costs may be adjusted to give greater emphasis to particular government objectives.	12

Structure of ATAP Part T2 CBA guidance

The chapters of this guideline match the steps of the CBA process, with a chapter for each step:

- Step 1: Specify the initiative and options
- Step 2: Identify the benefits and costs
- Step 3: Estimate capital 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.
- Step 12: Adjusted CBA (an optional step).

T2 provides sufficient detail for the application of CBA. Further, more detailed discussion is also provided in NGTSM (2006) Volume 5, Part 2. For ease of use, NGTSM (2006) Volume 5, Part 2 and T2 both have the same chapter and section headings as the steps.

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 of an initiative 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 2 in ATAP Part F3).

The appendices cover topics on benefit estimation and documentation and quality control for CBAs.

Rapid and detailed appraisal

As discussed above, options are assessed in a three-stage assessment process, with rapid and detailed appraisal as the second and third stages of assessment. This multi-stage process, beginning with the strategic merit test, recognises the fact that the appraisal of options is not costless. To limit the cost of assessing a large number of options in the early stages, the staged process is used to filter out the least meritorious options without expending too many scarce assessment resources. 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 option is likely to pass a detailed appraisal. The resources required for a detailed appraisal can then be expended only on options that have a good chance of succeeding.

The methodology used in a rapid appraisal is the same as for a detailed appraisal, however, the estimates of benefits, costs and impacts are less precise.

A rapid appraisal should consider as many benefits and costs as necessary to establish whether an option is worth developing further. Benefit and cost items that are small, or difficult to estimate, can be omitted altogether. Non-monetised benefits and costs should also be explored at an indicative level.

Rapid appraisal assists with considering or rejecting options by assessing their net benefit, indicating their net economic worth.

For small initiatives where the costs of a wrong decision are small, it is appropriate to undertake a rapid appraisal as the only form of CBA. 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 or technology solutions should be treated in the same way. Intelligent transport systems initiatives will often fall into the small-scale initiative category.

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, an indicative expected margin for error in rapid CBAs for investment costs would be ±40%.

Where any of the following benefits (or costs) amount to more than 10% 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% 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 an option 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 option-specific unit values for externalities. For the most part, other parameter values are well-established; hence, the same values can be 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 options and Base Case

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.	Consider pricing assumptions (where applicable).

1.1 Describe the option

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

1.2 List the objectives the option will achieve

It is important to show that the option 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 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 an option 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 ATAP Part F3 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. The significance of synergies between initiatives can be tested. 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 funding easier by spreading funding needs over time, and can reduce risks by providing opportunities to delay or cancel later initiative stages. (See Section 11.11 below and ATAP Parts T7 and T8.)

1.5 Identify constraints that could inhibit an option from proceeding

The next step is to identify any major constraints and show that the option 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, regulatory 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). Box 1 provides supporting background discussion on the Base Case.

Box 1: The Base Case

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

- Base Case — without the proposed option, and
- Project Case — with the option (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 2018)
- What would happen if the current arrangements were to continue (DoFA 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 2018).

Choice of ‘do nothing or ‘do-minimum’’ 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 (DoFA 2006, Productivity Commission 2014, IA 2018). 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.

The Base Case consists of a ‘real world assessment’ (IA 2018) of what would be done in the absence of the Project Case being implemented. A ‘do-minimum’ rather than a ‘do-nothing’ 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 initiatives 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 option being appraised but can affect benefits and costs of the latter and CBA results. The benefits of the option being assessed can be increased as well as decreased by the implementation of other initiatives elsewhere in the network. See ATAP Part F3 Options generation and assessment, Appendix A for a discussion of inter-relationships between initiatives.

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 intervention in each case to address the problem under investigation. The Project Case involves implementing the project option. The Base Case involves a do–minimum treatment.

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

1. The committed expenditure approach: Whereby only future initiatives that are committed and funded are included in the Base Case and Project Case. Submissions to Infrastructure Australia require this approach (IA 2018)
2. The planning reference case approach: Whereby a ‘planning reference case’ of initiatives across the transport network for the entire appraisal period — reflecting strategic planning — are included in the Base Case and Project Case. The planning reference case should reflect realistic future funding. This will require liaison with treasury departments on future funding envelopes.

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

- Undertake the core 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.

See ATAP Part O8 Land-use benefits of transport initiatives, Section 3.3 on developing assumptions for in the Base Case where other initiatives impact in the network affect land use.

One-off events

One-off events such as Olympic or Commonwealth Games can affect benefits and costs of options. 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).

1.7 Consider pricing assumptions (where applicable)

Specify any assumptions about charging for infrastructure usage. See Section 4.7 on developing pricing assumptions.

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.	Specify the perspective (or standing) 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 option or options 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 2 is a checklist that covers most of the benefits and costs associated with transport initiatives, with Boxes 2, 3 and 4 providing supporting definitions and advice.

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 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 2, 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 option commences operation (e.g. 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 2 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 • Construction externalities 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. ATAP Part T3 Wider economic benefits, ATAP Part O8 Land-use benefits of transport initiatives and ATAP Part M4 Active travel (for health benefits) cover additional benefits that can be monetised.

* The values of some of these benefits can be negative and so 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, unpriced externalities 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 cost 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 uses 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 options 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.

Box 5: Treatment of Goods and Services Tax (GST)

CBAs can be carried out using either the factor cost (gross of indirect tax) or market price (net of indirect tax) unit of account. Which is used will not affect the benefit–cost ratio or change the sign of a net present value as long as it is applied consistently. Businesses and government, which do not pay indirect tax, perceive costs in the factor cost unit of account while consumers perceive market prices. UK CBA guidance uses market prices. An indirect tax correction factor of 1.19 is applied to costs and benefits where they are measured net of tax. (UK DfT 2018, pp. 5, 16) For example, in the Data Book, the perceived value of work time based on earnings is converted to market price by multiplying by 1.19. For non-work time, based on willingness-to-pay the market price equals the perceived cost.

In Australia, where the 10% GST rate is half the 20% value added tax rate in the UK, ensuring a consistent unit of account is less important. The usual practice is consistent with the factor cost approach. Cost and time savings to businesses are valued at factor cost. To continue this consistency, costs and benefits should be valued net of GST. Willingness-to-pay values should be factored down by multiplying by 1/1.1. This is because stated preference surveys use the market price unit of account. When a person says that they would be willing to pay up to (say) $x to save one extra hour of travelling time, they mean that, in order to save an hour, they are willing to forgo consumption goods that are worth $x at market prices. The same information could equally well be expressed by saying that they would be willing to forgo consumption goods which are worth $x/1.1 at factor cost (UK DfT 2018, p. 16).

2.2 Leave out depreciation

Because the full cost of the asset to society is taken into account when the resources are consumed to create the asset, it is incorrect to include depreciation of capital assets in a CBA. Including 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.[2]

2.3 Specify the perspective (or standing) of the CBA

The standing of a CBA should be made explicit in all cases. The standing or perspective of a CBA can be national, state/territory, regional or local. Consideration needs to be given to treatment of benefits and costs accruing to visitors from outside the area of the standing.

CBAs aims to encompass benefits and costs for all members of society, but there are different ways to define 'society'. The default position is a national perspective (Australian residents) based on prevailing social norms and preferences and legal rights (Dobes et al. 2016, p. 75).

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[2] For financial analysis, depreciation is excluded 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.

The national perspective excludes foreign nationals. Transfers between Australians and foreigners outside of Australia in the form of investments, borrowing, profits, dividends, interest payments and changes in the prices of exports and imports are valued solely on the basis of their impact on the welfare of Australians.

For land transport initiatives, it is usually impractical to distinguish between Australians and foreign visitors. Some benefits accruing in the first instance to foreign visitors will be passed on to residents. There is an ethical argument that Australians have a duty as hosts to give equal treatment to visitors as to residents. It is therefore recommended that costs and benefits accruing to foreign visitors be treated the same as for Australian residents.

A CBA can be undertaken from with a narrower standing such as people living in a particular state, territory, region or local area.

CBAs from a narrower point of view than the whole country can be more difficult to carry out in practice because of the need to distinguish between benefits that accrue to people within the area and benefits that accrue to people outside the area. A regional or local 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. In the case of an initiative involving multiple assets, the appraisal period should be set at the expected life of the primary asset. It is typical to assume a 30-year life for road construction 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.

Typically, the year in which construction commences is designated as year zero or the 'base year'. Discounted present value calculations (see Chapter 10) will discount future benefits and costs to the base year.

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, $A = PV \cdot \frac{r}{1-(1+r)^{-n}}$, 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 asset life or, in the case of multiple asset initiatives where some assets will last longer than the primary asset, add a residual value to allow for net benefits beyond the end of the appraisal period (see Section 3.3 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. For analyses in real terms, specify the ‘price year’, that is, the year of the dollar values in which all monetary amounts will be expressed.

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 over the appraisal period, allow the nominal discount rate to vary accordingly.

3. Step 3: Estimate capital investment costs

Steps	
3.1.	Develop a timeline 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 timeline 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[3]
- Will be incurred before the initiative commences operation
- Are paid for by the investors.[4]

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.

Contractor profit margins should be included where they represent a reasonable return on capital costs. Developer contributions paid to fund supply of public infrastructure needs generated by the

[3] 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.

[4] 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).

initiative should also be included but if public infrastructure costs are over- or under-recovered there may be additional benefits or disbenefits to count. See ATAP Part O8 Land use benefits of transport initiatives, Chapter 7.

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.

Include land costs where appropriate. See Section 3.4 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. 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. 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, excluding fuel excise, goods and services tax (GST) and subsidies (see Boxes 3 and 5 for details).

Estimate the amount of time required for each phase of implementation of the initiative and total the costs for each year. An 'escalation factor' will be used for each year to adjust for both inflation and increases in real terms of input prices (see ATAP Part O1 Cost estimation). The forecast annual amounts after escalation will represent the actual costs expected to be incurred in nominal terms. They have to be converted into real terms by inflating them or deflating them to 'price year' dollars (see Section 2.5 for details).

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, aim for investment costs to be estimated within ±40% of the actual amount. For detailed CBA, the expected level of accuracy is ±10%.

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 both the CBA and financial results. Refer to Chapter 12 on risk analysis and ATAP Guidelines Parts O1 Cost estimation, O2 Optimism bias and T7 Risk and uncertainty assessment.

Investment costs may need to be estimated for the Base Case as well as for the Project Case.

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. These usually involve valuing the depreciated asset or extrapolating benefits. The approaches recommended here are based on straight-line depreciation of capital costs.

Under the straight-line depreciation (SLD) method

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

All capital costs incurred are depreciated at a constant rate during the estimated asset life for the whole initiative without discounting such that the residual value 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*).

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

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 core 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 the market's valuation of 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 (except in cases where the land becomes contaminated). If land costs are included with investment costs, except in cases where repurposing of the land at the end of the initiative's life is impossible (for example, if the land is required for access purposes or is too narrow reuse), it is appropriate to include the value of the land as a residual at the end of the appraisal period. This applies even where the land is most likely to continue to be used for the same purpose. In that case, its ongoing rental cost would be counted in the economic appraisal of the replacement asset.

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 in real terms, adjust the end-of-appraisal-period land value accordingly.[5]

The present value of land rental costs (with a negative sign to indicate it is a cost) over the appraisal period, is

$$-L_0 + \frac{L_n}{(1+r)^n}$$

where L_0 is the value of the land in year zero, L_n is the value in year n, the end of the appraisal period, and r is the discount rate.

If the asset lasts longer than the appraisal period, land rental costs in the residual value can be calculated similarly as

$$-L_n + \frac{L_m}{(1+r)^{m-n}}$$

where L_m is the value of the land at the end of the asset's life in year m. Due to the level of uncertainty, it is recommended the land value not be assumed to increase after the end of the appraisal period, that is, set L_m equal to L_n.

[5] The forecast growth rate in land value should never exceed the discount rate because it would result in a negative present value for the land rental cost over the time the land is occupied by the project. If the real value of the land is expected to rise considerably during the appraisal period, it might be worth considering an option where the project is constructed with less durable/costly assets and the appraisal period commensurately shortened. The project could finish occupying the land sooner, making the land available for a higher value use compared with the net benefits forgone by shortening the project's life.

The net effect of counting L_n as a benefit at the end of the appraisal period (the value of the land released), together with $-L_n + L_m/(1+r)^{m-n}$ (the rental cost for the *m* – *n* years following the appraisal period, discounted to year *n*) as part of the residual value, is to increase the residual value by $L_m/(1+r)^{m-n}$.

If there are land clean-up or infrastructure demolition costs at the end of the asset's 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. Hence, 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:

- Numbers of passengers, walkers, cyclists, vehicles or trains
- Freight tonnes or containers
- Kilometres travelled by passengers, walkers, cyclists, vehicles, trains or freight tonnes.

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 tends to produce optimistic forecasts in good economic times and pessimistic forecasts in bad economic times by assuming the good or bad times will continue into the future indefinitely. Qualitative judgement is needed to decide whether the historical trend is likely to continue in the forecast horizon (BITRE 2018, p. 2). 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.

For projections based on population, the Australian Bureau of Statistics (ABS) is a useful source of population forecasts (medium series[6]), including at the statistical local area level. Some jurisdictions prefer to use their own population forecasts. When preparing appraisals, provide details about the judgments applied in making forecasts.[7]

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[6] The core 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 core scenario, sensitivity tests using the medium and low forecasts should be undertaken.

[7] The ex-post CBA case studies in BITRE (2018) identified traffic forecasting as an area requiring significant improvement. For non-urban national highways, trend extrapolation has been the primary traffic forecasting methodology. BITRE (2018) also found that forecasting errors arose from not allowing for change in vehicle mix over time. Changes in traffic composition can have an important bearing on appraisal results.

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.

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 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). The relevant cross-elasticity is the percentage change quantity demanded in the source of the diverted demand (mode, service, route) from a one percent change in the perceived cost, money price or a service attribute such as reliability or frequency at the destination of the diverted demand (the mode, service or route changed by the initiative being appraised). The value of the cross-elasticity would be taken from experience elsewhere in broadly comparable situations.

For new modes, the 'diversion rate' approach might be used. The diversion rate is the proportion of the demand for the destination mode that would otherwise use the source mode. There is good degree of consistency in diversion rates across project types and countries. Further detail is available in ATAP Parts M1 Public Transport and M3 Freight rail.

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. See Appendix C for a discussion.

For rapid CBAs and many detailed CBAs, values for elasticities, diversion rates and logit model parameters based on studies by others may need to be assumed, including values from 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.[8] 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. ATAP Part O8 Land-use benefits of transport initiatives, discusses land-use change forecasting and 'second-round' effects on transport demand caused by land-use change stimulated by the initiative being appraised. Where the sources of generated traffic are more diverse, a price elasticity of demand could serve as the basis of estimation. As with diverted traffic forecasting 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.

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. ATAP Part T1, Section 3.4 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. Chapter 7 below discusses the role of induced demand in user benefit estimation.

4.7 Develop pricing assumptions (if applicable)

Where infrastructure use is charged for, make assumptions about prices. Price levels affect levels of demand (existing, diverted and generated). Factors affecting pricing assumptions include costs, the objective of price setting (profit maximisation, economic efficiency maximisation, revenue target or cost-recovery target) and what the market will bear (price elasticity of demand). 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).

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[8] 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 term '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.

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 usually 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 and gross weights 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 Chapter 11.

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 6.1.

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 disbenefit or cost to the initiative. This occurs if the new infrastructure generates new maintenance costs on top of those for 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.

Steps

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

6.2. Calculate user benefit for existing traffic.

6.3. Calculate user benefit for induced traffic.

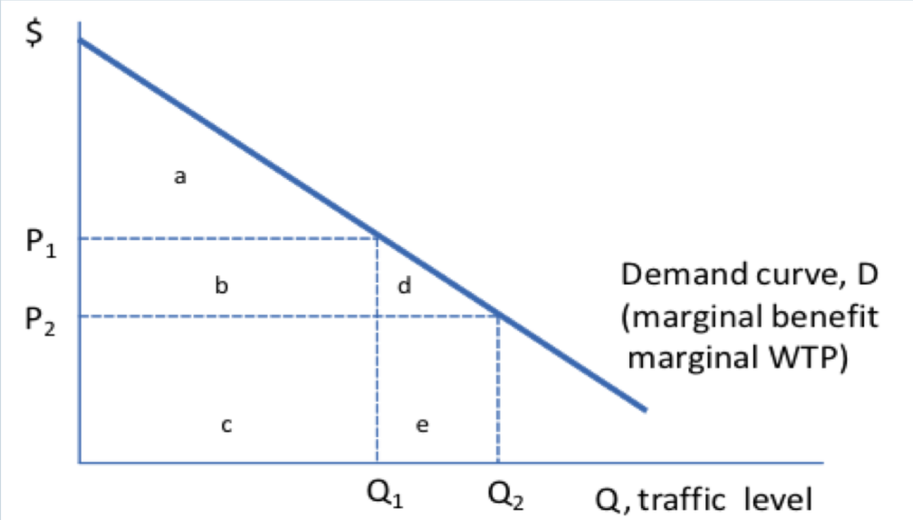
6.4. For a new mode, service or route, the area under the demand curve from zero to the quantity consumed is relevant.

Box 6 introduces some key concepts used throughout Chapters 6 and 7. The detailed foundations underlying these two chapters can be found in NGTSM (2006) 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 (or beneficiaries) approach; and the consumers' surplus with resource correction approach. NGTSM (2006) Volume 5 shows the application of these methods to a wider range of settings.[9]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.

[9] UK DfT (2018, pp 3 and 14) terms the social welfare approach the 'calculus of social costs and benefits' and the gainers and losers (or beneficiaries) approach, the 'calculus of willingness-to-pay'. UK DfT recommends the latter because it allows different impacts on different groups to be identified. It is not used in T2 Chapters 6 and 7 because the simple examples have only two types of beneficiary, users and governments for taxes and subsidies. In these simple cases, the resource correction is the gain or loss to the government. For application to freight rail where gains and losses to users, producers, the road provider and third parties (externalities) are separated out, see ATAP Part M3, Section 7.5.

Box 6: 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).

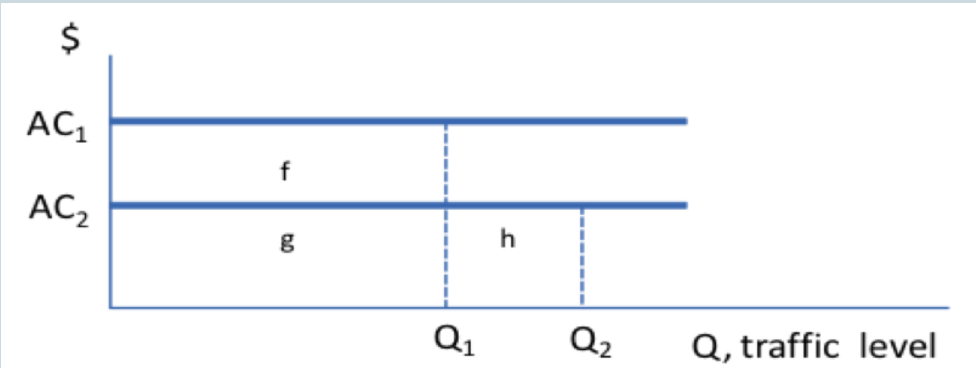


The above figure shows a travel demand curve, where the level of traffic (*Q*) is a function of the user's perceived cost (*P*), where perceived cost is the sum of all monetary and non-monetary travel costs that the user considers in making transport decisions, all expressed in equivalent monetary units. 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*.

Consumers' 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. (NGTSM 2006 Volume 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.

Used in conjunction with Box 6, Table 3 summarises the formulas to be used for calculating user benefits for existing and induced (diverted + generated) traffic under the two approaches for the more general case where perceived and resource user costs differ. Such differences can be caused by taxes and subsidies and users not perceiving all the costs they incur. Examples include the fuel excise and vehicle repair and maintenance and tyre costs. The social welfare approach measures net benefits as the change in total willingness-to-pay (TWTP) minus the change in resource costs. Since the TWTP is measured using perceived costs, changes in TWTP that are transferred to the government, as occurs with taxes, are accounted for. Resource costs include unperceived costs. So, differences in perceived and resource costs are fully taken into account. Under the consumers' surplus with resource correction approach, consumers' surplus changes only measure impacts consumers perceive. The 'resource correction' is required to adjust for the unperceived impacts.

Table 3 Summary of formulas for calculating user benefits for existing and induced traffic

Method 1: Increase in social welfare

	Existing traffic (1)	Induced traffic (2)	All traffic combined (3 = 1+2)
a: Increase in willingness-to-pay	*0*	$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1)$	$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1)$
b: Increase in social cost	$(AC_2 - AC_1)\,Q_1$	$AC_2\,(Q_2 - Q_1)$	$AC_2Q_2 - AC_1Q_1$
c = a – b: User Benefit	$(AC_1 - AC_2)\,Q_1$	$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2\,(Q_2 - Q_1)$	$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - (AC_2Q_2 - AC_1Q_1)$

Method 2: Increase in consumers' surplus + resource correction

	Existing traffic (1)	Induced traffic (2)	All traffic combined (3 = 1+2)
d: Increase in Consumers' surplus	$(P_1 - P_2)\,Q_1$	$\frac{1}{2}(P_1 - P_2)(Q_2 - Q_1)$	$\frac{1}{2}(P_1 - P_2)(Q_2 + Q_1)$
e: Resource correction	$(P_2 - AC_2)\,Q_1 - (P_1 - AC_1)\,Q_1$	$(P_2 - AC_2)(Q_2 - Q_1)$	$(P_2 - AC_2)\,Q_2 - (P_1 - AC_1)\,Q_1$
f = d + e: User Benefit	$(AC_1 - AC_2)\,Q_1$	$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2\,(Q_2 - Q_1)$	$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1)$ - $(AC_2Q_2 - AC_1Q_1)$

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

For a cost reduction, $AC_2 < AC_1$, so that the 'increase in social cost', $AC_2 - AC_1$, is negative.

If it is assumed that $P_2 - AC_2 = P_1 - AC_1$, that is, the gap between perceived and average social generalised cost is the same in the base and project cases, then the resource correction for existing traffic is zero and the benefit formula becomes $0.5\,(P_1 - P_2)(Q_2 + Q_1) + (P_2 - AC_2)(Q_2 - Q_1)$. This formula is derived in Appendix A and presented in ATAP Part M2 for estimating benefits in a network with unpriced congestion.

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 also 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, cost of 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. The ATAP Parameter Values (PV) series provides recommended values for unit 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 that has been taken is to model only morning peak and apply an expansion factor to obtain whole-year impacts. However, unrealistic expansion factors can lead to major errors in benefit estimation (BITRE 2018). It is thus 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 Calculate user benefit for existing traffic

The social welfare approach to benefit estimation (see Table 3) is used in Sections 6.2 and 6.3 . Under this method, net user benefit is the increase in the total gross benefit users' gain from travel, as measured by total willingness-to-pay (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 4). 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. $TC = Q \times AC$

The user benefit for existing traffic is therefore:

$$(AC_1 - AC_2)Q_1 \qquad \text{Equation 1}$$

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 6.3).

6.3 Calculate user benefit for induced traffic

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 6, 7, 8 and 9 provide diagrammatic explanations and numerical examples 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[10] as:

$$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) \qquad \text{Equation 2}$$

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).

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:

$$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2(Q_2 - Q_1) \qquad \text{Equation 3}$$

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

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

$$(AC_1 - AC_2)Q_1 + \frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2(Q_2 - Q_1)$$

which simplifies to:

$$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - (Q_2 AC_2 - Q_1 AC_1) \qquad \text{Equation 4}$$

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[10] The rule-of-a-half says that if we assume the demand curve to be linear over the relevant traffic range (here between Q_1 and Q_2), the area *d* in Box 6 can be estimated as half the rectangular area $(P_1 - P_2)(Q_2 - Q_1)$.

6.4 If consumers' surplus is used to estimate user benefits, a resource correction 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, an alternative method to estimate consumers' surplus changes and apply a resource correction to adjust for differences between perceived and resource costs. 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 for existing, generated and diverted traffic together is measured as:

$$\frac{1}{2}(P_1 - P_2)(Q_1 + Q_2) \qquad \text{Equation 5}$$

Note that in the special case where perceived costs and average social generalised costs are equal; that is, $P_1 = AC_1$ and $P_2 = AC_2$, the net user benefit result given by equation (4) in Section 6.2 reduces to the consumers' surplus benefit in equation (5).

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. As in Section 6.3, references to Boxes 6, 7, 8 and 9 will assist readers in understanding the discussion below about the resource correction. It is suggested the text and the boxes be read concurrently.

For *existing traffic*, the consumers' surplus change is $(P_1 - P_2)Q_1$ whereas the true benefit to society is $(AC_1 - AC_2)Q_1$ (see Section 6.2). The required adjustment is to add a resource correction equal to the increase in the gap between perceived price and social generalised cost $(P_2 - AC_2)Q_1 - (P_1 - AC_1)Q_1$. Equation 6 shows the benefit to existing traffic, which is identical to equation 1.

$$(P_1 - P_2)Q_1 + [(P_2 - AC_2)Q_1 - (P_1 - AC_1)Q_1] = (AC_1 - AC_2)Q_1 \qquad \text{Equation 6}$$

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 $\frac{1}{2}(P_1 - P_2)(Q_2 - Q_1)$ plus the resource correction $(P_2 - AC_2)(Q_2 - Q_1)$, which simplifies to

$$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2(Q_2 - Q_1) \qquad \text{Equation 7}$$

the same as equation (3) in Section 6.3 for the net user benefit for diverted and generated traffic.

The total benefit for all traffic combined is then equation (7) plus the benefit for existing traffic given in equation (6).

$$(AC_1 - AC_2)Q_1 + \frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2(Q_2 - Q_1) =$$
$$\frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - (Q_2 AC_2 - Q_1 AC_1) \qquad \text{Equation 8}$$

The result, equation 8, is identical to equation (4) above.

If it can be assumed that the change in perceived cost is the same as the change in average cost, $P_1 - P_2 = AC_1 - AC_2$, then the benefit for existing traffic is the same as the consumers' surplus change for existing traffic. Equation (8) then becomes

$$(P_1 - P_2)Q_1 + \frac{1}{2}(P_1 + P_2)(Q_2 - Q_1) - AC_2(Q_2 - Q_1) =$$
$$\frac{1}{2}(P_1 - P_2)(Q_1 + Q_2) + (P_2 - AC_2)(Q_2 - Q_1) = \qquad \text{Equation 9}$$

consumers' surplus change + resource correction for diverted and generated traffic

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

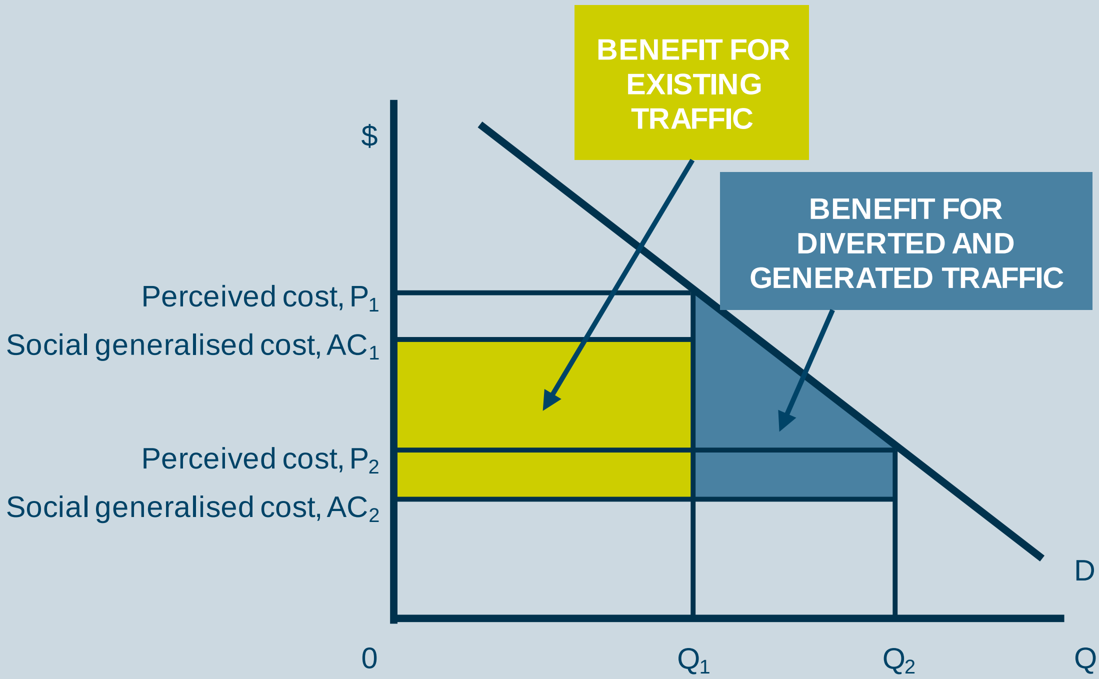
In the case of road infrastructure, where fuel excise causes perceived cost to exceed the resource cost of driving, the resource correction for additional diverted and generated traffic on the initiative infrastructure will equal the gain in fuel excise to the government (assuming all other costs are 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 7: 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, $(P_2 - AC_2)(Q_2 - Q_1)$. The total benefit can be measured as the consumers' surplus change, $\frac{1}{2}(P_1 - P_2)(Q_2 + Q_1)$ plus the resource correction.

Box 8 provides a numerical illustration.



Box 8: 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.

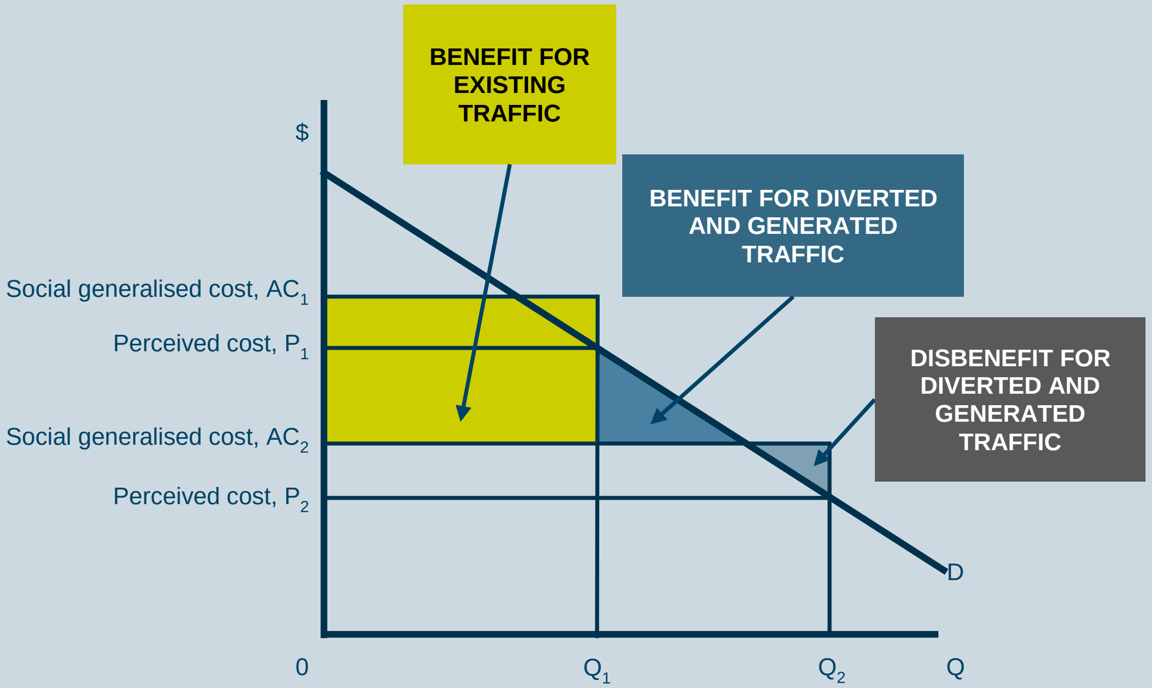
Total benefit: The total benefit to society is the sum of benefits for existing traffic and for diverted and generated traffic, i.e. $3400 = $2000 + $1400.

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 9: 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 2 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.



6.5 For a new mode, service or route, the area under the demand curve from zero to the quantity consumed is relevant

It is particularly difficult to estimate user benefits for initiatives that introduce an entirely new transport mode, service or route that does not exist in the base case. A new demand curve is created. The benefit is the entire consumers' surplus area under the new demand curve from a quantity of zero to the quantity consumed in the project case, as shown in the left part of Figure 4 in Appendix B Section B1. Assumptions have to be made about the height and shape of the demand curve over a large part of its length and the assumptions chosen have a major impact on the size of the benefit.

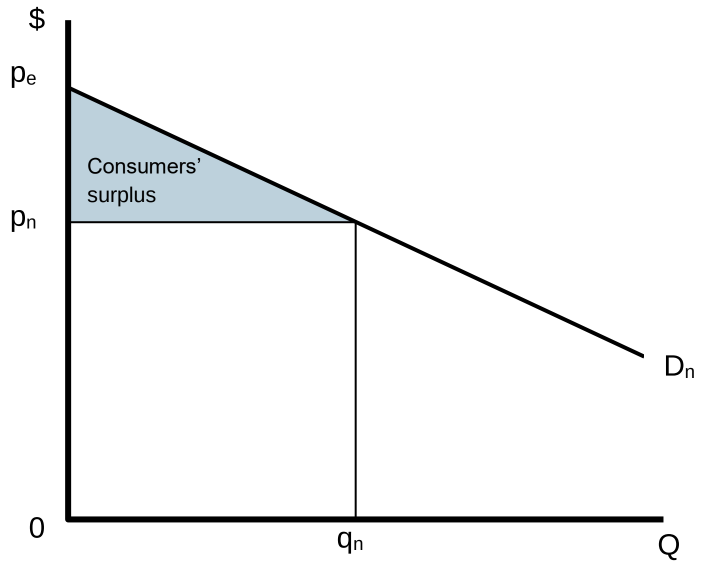
If a logit model has been used to forecast demand, as discussed in appendices B and C, the logsum approach to measuring consumers' surplus benefits handles new demands very conveniently, as shown in Appendix C Section C7.

In the absence of a logit model, market research or market sounding could include questions designed to gauge the maximum perceived costs potential users would be willing to pay to make use of the new mode, service or route. Such information could be used to construct a demand curve over a range of perceived costs and quantities.

The following is a simple, approximate approach to estimating the consumers' surplus benefit from a new service from Harvey (2002), which can be applied in certain cases where logit modelling and market research information are lacking. For brevity, the term 'service' is employed to cover mode and route.

If much of the demand for the new service is diverted from an existing service with a higher money price and shorter travel time (for example, from car to public transport or from road to rail), the money price for the existing service can be taken to indicate the price which the demand curve for the new service intersects the price axis. Leaving behind the random utility assumption of the logit model whereby users' choices are affected by unobserved factors, if the new service is slower and charges the same money price as the existing faster service, no one will switch to the new service. As the money price for the new service, p_n, falls below that for the existing service, p_e, users switch services starting with those users having the lowest individual values of time. Each user *i* shifting modes, gains the price difference minus the cost to them of the slower travel time, $p_e - p_n - v_i\ \Delta t$ where v_i is user *i*'s individual value of time and Δt is the travel time difference. The first user to change services must have a value of time of practically zero, and therefore gains a benefit equal to the full price difference, $p_e - p_n$. The last user to shift is indifferent and between the two services and so must have a value of time of $(p_e - p_n)/\Delta t$ to make a zero net gain. Applying the rule-of-a-half, the average benefit across all users who shift to the new service (q_n) is half way between $p_e - p_n$ and zero. The total consumers' surplus benefit is then $(p_e - p_n)q_n/2$, as illustrated in Figure 1.

Figure 1 Consumers' surplus for a new service



In one way, the approach is more sophisticated than the simple logit model described in appendices B and C because the latter assumes all users have identical values of time. However, the assumption of a linear demand curve implied by the rule-of-a-half is a strong assumption if applied over a large range of quantities and prices. If it is considered that demand curve could be convex, a sensitivity test might be undertaken using a rule-of-a-quarter, $(p_e - p_n)q/4$.

Unfortunately, the method is not applicable where the new service offers a better service quality for a higher money price compared with existing services.

Where the new service represents a major improvement on the existing service, such that virtually all users will switch to the new service, the new and existing services can be treated as it they are the same transport activity with a single demand curve for the activity. The demand curve would be defined as being for the quantity transported from origin A to destination B as a function of perceived cost without specifying a mode, service or route. The consumers' surplus benefit for existing users who switch to the new service is simply the reduction in perceived costs times the quantity. There may be some generated demand necessitating application of the rule-of-a-half.

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. Estimate benefits or disbenefits in other related markets if relevant.

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

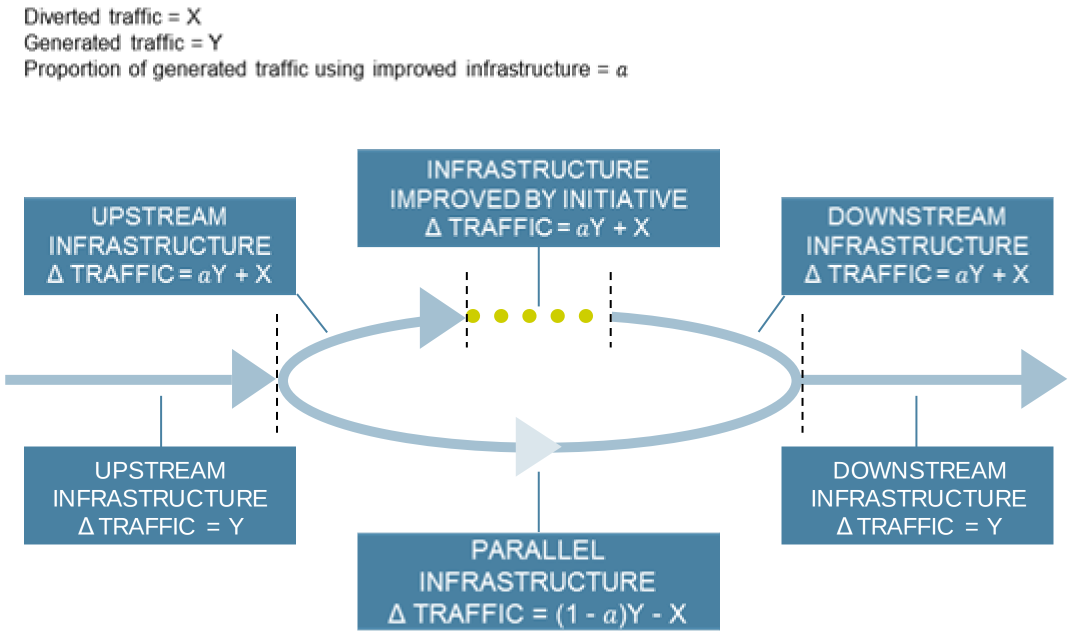
Refer to this section when undertaking a CBA of an initiative that alters the use of other transport infrastructure (in addition to use of the infrastructure created or improved by the initiative being appraised), regardless of mode.

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 2 for an illustration of the concepts defined here.

Figure 2 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 10 and 11 provide diagrammatic expositions, and Boxes 12 and 13 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. This is case of an unpriced externality.[11]

[11] It is a well-established theoretical result that, when measuring welfare changes, the only markets that need to be considered in addition to the market directly affected by a project or policy change are those with distortions (Dinwiddy and Teal 1996; Kanemoto 2011). 'Distortions' here refers to prices being different from marginal social costs. Sources of distortions include taxes, subsidies, quantitative restrictions, unpriced externalities, imperfect competition and non-constant returns to scale.

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.

ATAP Parts M1 Public transport and M3 Freight rail discuss the case where a public transport or freight rail initiative causes a leftward shift in the demand curve for road transport leading to decongestion benefits. 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 the related infrastructure. 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[12].

Note that the benefit from diverted users on their new modes or routes is calculated using the rule-of-half or other method as discussed in Chapter 6, regardless of whether any additional benefit or disbenefit has arisen on their old modes or routes as discussed in this chapter.

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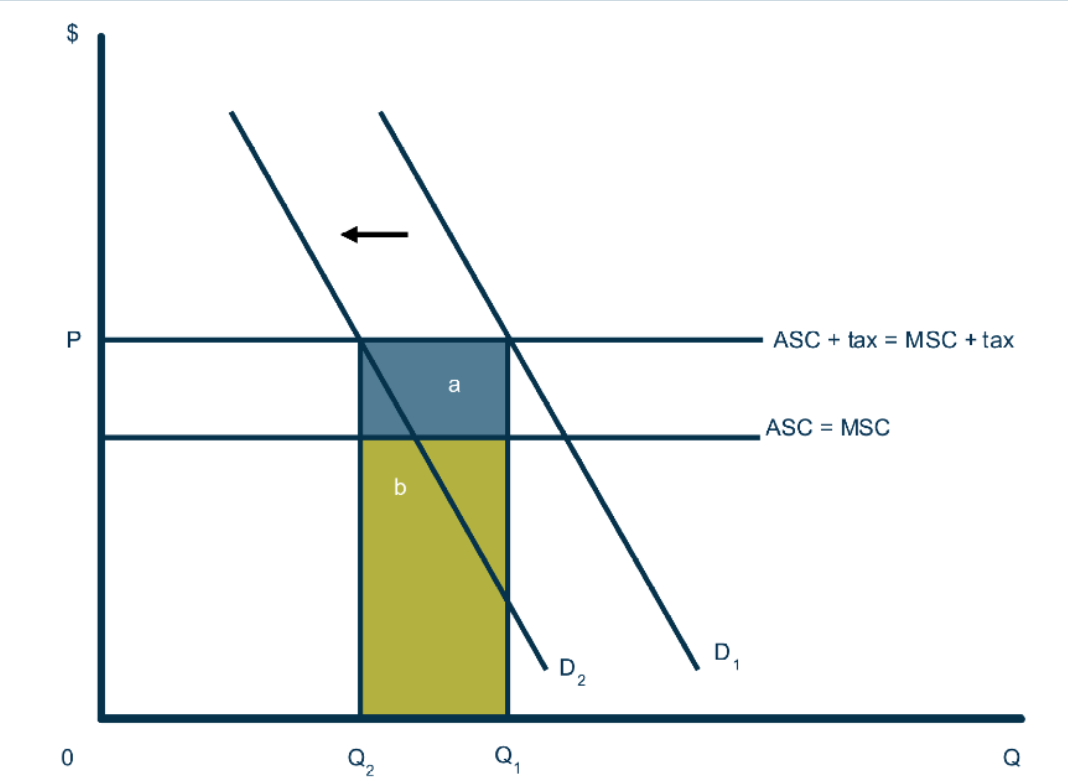
[12] An alternative measure of the benefit that is often used in practice is: $Benefit = \frac{1}{2}(APC_1 - APC_2)(Q_1 + Q_2) + (APC - ASC)(Q_2 - Q_1)$ where APC_1 and APC_2 are average perceived costs in the Base and Project Cases respectively. The second term is a resource correction where $APC = \frac{1}{2}(APC_1 + APC_2)$ and $ASC = \frac{1}{2}(ASC_1 + ASC_2)$ where *ASC* is average social cost. Appendix A provides a technical proof. This approach is recommended in ATAP Part M2, Section 7.4.

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.

Box 10: 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 a 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*.



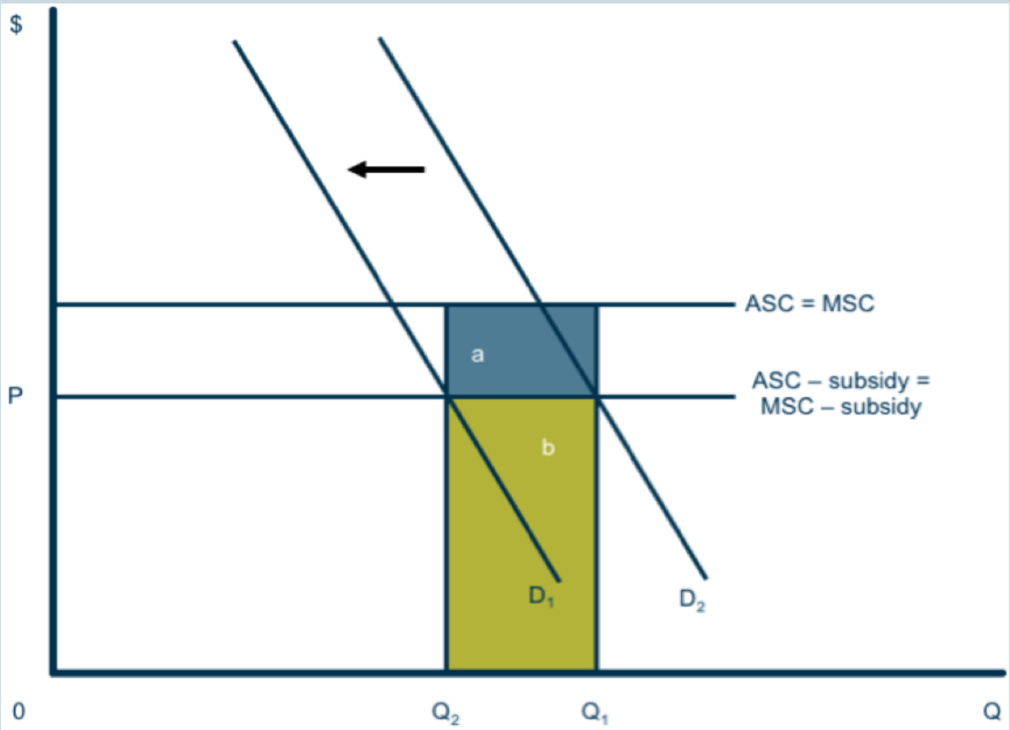
Box 11: Diagrammatic explanation of benefit estimation on parallel infrastructure: cost > price

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 cost 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 a loss of WTP equal to 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 a 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 maintenance and tyre costs as a fixed charge per period of time, in the Project Case, they would pay less than they anticipate in the Project Case.

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 maintenance and tyre costs would pay more than anticipated in the Project Case.



Boxes 12 and 13 contain numerical examples of estimation of benefits from diverted traffic, and upstream/ downstream traffic, respectively.

Box 12: 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 for a particular origin–destination pair.

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 cost curves)

Say the road is congested. Users perceive the average cost but not marginal social cost of congestion, which includes the externality imposed on other road users. The average cost curve expressed in tonnes transported is $AC = 80 + 0.002 \times Q$, implying a total social cost curve of $TSC = 80 \times Q + 0.002 \times Q^2$ and a marginal social curve $MSC = 80 + 0.004 \times Q$. The quantity transported falls from 5000 to 4000 tonnes, which reduces congestion on the road. Substituting these quantities into the relevant equations, the average social cost falls from $90 to $88 per tonne, and the marginal social cost falls from $100 to $96 per tonne. The average social cost is also the perceived cost. Taking the halfway points to average the Base Case and Project Costs, the perceived cost can be taken as $89 = ($90 + $88)/2 and the marginal social cost as $98 = ($100 + $96)/2. Applying the formula in Section 7.2: the 'decongestion' benefit is the gap between perceived and social costs times the quantity: ($89 – $98) x –1000 tonnes = $9000.

The same benefit can be calculated in the manner described in footnote 11 as the reduction in average perceived cost on the road times the average quantity applying the rule-of-half. ($90 – $88) x (5000 tonnes + 4000 tonnes)/2 = $9000. Appendix A explains why the two methods give the same result.

Box 13: Numerical examples of estimation of costs from upstream/downstream effects

A rail infrastructure upgrading initiative results in an additional 2000 tonnes of freight travelling on a feeder road to the rail terminal.

Without congestion

The perceived cost of carrying the freight on the feeder road is $10 per tonne. The social generalised cost is $11 per tonne. Using the formula in Section 7.2, there is an annual benefit of ($10 – $11) x 2000 tonnes = –$2000, a disbenefit of $2000.

If the perceived cost by road is $12 per tonne — above the social generalised cost — there is an annual benefit: ($12 – $10) x 1000 tonnes = $2000.

With congestion (linear cost curves)

Say the feeder road is congested. The average cost curve expressed in tonnes transported is $AC = 8 + 0.0005 \times Q$, and marginal social curve $MSC = 80 + 0.001 \times Q$. The number of tonnes transported on the road is 4000 in the Base Case and 6000 in the project case. The Base Case perceived and marginal social generalised costs are $10 and $12 respectively. Due to increased congestion on the road following the increase in traffic, the Project Case perceived cost and marginal social generalised cost rise to $11 and $14 respectively. The average of the Base Case and Project Case perceived cost is ($10 + $11)/2 = $10.5. The average of the Base Case and Project Case marginal social generalised cost is ($12 + $14)/2 = $13. The benefit from traffic diversion is then ($10.5 – $13) x 2000 tonnes = –$5000, a disbenefit of $5000.

Using the alternative method of footnote 11, the benefit is ($10 – $11) x (4000 tonnes + 6000 tonnes) = –5000.

7.3 Application in complex urban networks

7.3.1 Measuring user benefits

The discussion in Sections 7.1 and 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 are 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.[13] ATAP Part T1 contains guidance on travel demand models.

[13] 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.

The measurement of user benefits using travel demand models involves 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 6.4 produced the same user benefit equations using the alternative method of consumers' 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,[14] for each mode, route, time period and forecast year
- The disaggregated results are then aggregated to yield overall use benefits:
  - 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 model, 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

Section 3.4 of the ATAP Part T1 discusses induced demand.[15] 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.

Other things held equal, the induced (additional) traffic resulting from, say, a road network improvement will give rise to a benefit from greater trip numbers on the improved road. However, this additional traffic will reduce the potential benefits of the improvements for other traffic if the road network is at all congested.

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[14] The benefit calculations could be undertaken for each link instead of origin–destination pair in the modelled transport network and should give an identical total benefit result. However, the origin–destination approach *must* be taken for demand modelling because transport users base their decisions on the whole-of-trip attributes — money cost, time, reliability. Calculation of benefits of reliability improvements must be undertaken using standard deviations of trip times between origin–destination pairs because transport users experience travel time variability for entire trips. The standard deviations of travel times for the links that comprise a trip between an origin–destination pair need to be combined to obtain a route standard deviation using the standard formula $\sigma_r^2 = \sum_{i=1}^{n} \sigma_i^2 + 2\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \rho_{i,j}\sigma_i\sigma_j$, $i < j$, which takes account correlations in travel times between links.

[15]Note that induced demand is equivalent to generated and diverted traffic, as discussed above in Section 4.6.

The inclusion of induced demand effects can make a significant difference to user benefit estimates. Research has shown that failure to account for induced demand can lead to material overstatement of the economic benefits of an initiative (Williams and Yamashita, 1992; Abelson and Hensher, 2001 and Litman, 2008).

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 route improved by the initiative. 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:

- 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.

Large city-shaping transport initiatives, as discussed in ATAP Part F0.2 Integrated transport and land-use planning, have significant potential impacts on land use and urban structure. Induced demand in such cases is of high importance.

Part F0.2 explores the ideal of undertaking a 'fully evolved CBA' of a large city-shaping urban transport project, with full modelling of land use-transport interaction. It notes, however, that there are challenges in implementing such an approach at this point in time.[16] It suggests that a practical alternative approach is iterative application of CBAs with land-use impact scenario analysis. Under this approach, scenario analysis is used to investigate the potential major land-use impacts of major transport initiatives. Testing the effect of different land-use impact outcomes on a CBA determines the sensitivity of the CBA results.

ATAP Part 08, Land-use benefits of transport initiatives, discusses induced demand caused by land-use change induced by transport initiatives under the heading 'second-round transport impacts'. Because of the higher level of uncertainty surrounding land-use change benefit estimates compared with usual benefits estimated in conventional transport CBAs and the potential large size of land-use change benefits, the ATAP Part 08 recommends that land-use benefits, including second-round transport benefits (or disbenefits), be presented in core the CBA results table in a way that highlights their effects on overall results.[17]

7.4 Application to other impacts in related markets

The principle applied in Section 7.2 can be summed up as: where an initiative causes changes in outputs in related markets, additional benefits or disbenefits can arise where prices differ from marginal costs in those markets, and not otherwise. The size of the benefit is the gap between the price and the marginal social cost times the change in output with the sign depending on whether price is above or below marginal social cost and whether the output change is positive or negative. Applications of this principle can be found in other parts of the Guidelines.

ATAP Part T3 Wider economic benefits addresses benefits from transport initiatives in product and labour markets due to external economies from agglomeration, labour market taxes and imperfect competition that will not be captured by conventional benefit estimation methods. Where a transport initiative leads to increased labour supply and income and payroll taxes cause the social value of the additional production (the cost to employers) to exceed the private value (the take-home pay of employees net of commuting costs), there will be an additional productivity benefit that accrues to the government. Where a transport cost saving causes a firm in an imperfectly competitive market to increase output, there is benefit in the form of higher profits to the firm where the price of the product (marginal willingness-to-pay) exceeds the production cost.

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

[17] The same applies to wider economic benefits. See ATAP Part T3 Wider Economic Benefits.

ATAP Part O8 Land-use benefits of transport initiatives covers two further situations where prices not equal to marginal social costs give rise to additional benefits or disbenefits. Where a supply constraint such as regulatory restrictions on land use causes the market price of additional floorspace to exceed the cost of supplying it, and a transport initiative unlocks additional constrained supply, the WTP for newly created floor space less the development cost can be counted as benefit. Where public infrastructure costs are under-recovered from the beneficiaries and land-use changes arising from a transport initiative lead to increased public infrastructure provision, there is a disbenefit equal to the subsidy. If the initiative leads to more dense development, saving public infrastructure costs, there will be benefit equal to the subsidy saved. Note that the benefit is not the amount of the public infrastructure cost avoided, only the subsidy saved, that is, the gap between the private and social cost.

ATAP Part M3 Freight rail discusses the case where a freight rail initiative leads to mode shift from road to rail, and the trucks taken off the roads in the project case are not fully paying for the pavement damage they cause to roads. The savings in road maintenance costs minus the loss of revenue to the government as road provider can be counted as a benefit.

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

Section 4.4 noted that Base Case demand projections may have to be adjusted to allow for implementation of other transport initiatives. In the Project Case, implementation of the initiative being appraised can affect the benefits and costs of related initiatives altering their economically optimum timing. A reduction in demand for use of related infrastructure can cause future expansions or improvements to be deferred. 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 forward of future capital expenditure is a disbenefit.

If expansion and contraction of the 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 be no net benefits to consider from changes in the timing of future capacity changes for 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. However, 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 for the capacity-expanding infrastructure project. 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 numbers in the Base and Project Cases.

8.2. Multiply crash numbers by unit costs.

8.3. Calculate the crash benefit.

8.1 Estimate crash numbers in the Base and Project Cases

A 'crash rate' is the number of crashes per period of time. Crashes at a location vary with 'exposure' (the number of opportunities at which crashes can occur). Exposure at a location is measured by the amount of traffic passing through the site for a given 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 per 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/major injury, other/minor 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 either

- Default crash rates for the type of infrastructure in the base and project cases, or
- The actual crash rate for the Base Case infrastructure estimated over a period of time, with a crash reduction factor applied to obtain the Project Case crash rate.

For the latter method, 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 those assumed for the default values, or the estimated crash rate might be unduly affected by random fluctuations. For these reasons, it is possible for a Base Case crash rate, forecast using recent crash history, to be below the default rate for the Project Case infrastructure despite the latter being clearly safer. It may be better to use default values for both Base and Project Cases.

An alternative is to calculate a 'crash reduction factor' (proportional reduction in crashes) from the default values ((default crash rate for Project Case infrastructure / default crash rate for Base Case infrastructure rate) minus one) and apply it to the Base Case crash rate forecast using recent crash history to obtain the Project Case crash rate.

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. ATAP Part PV2 Road transport publishes default unit crash costs for roads.

8.3 Calculate the crash benefit

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

9. Step 9: Estimate externality benefits and costs

Steps

9.1. Apply default externality values.

9.2. Estimate any externalities specific to the initiative if required.

9.3. Calculate the externality benefit or disbenefit.

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 externality 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 from ATAP Part PV5 Environmental parameter values. These default values are standard unit costs that can be applied across the board to obtain an estimate of externality costs.

The default values are expressed in common units of monetary value per vehicle-kilometre (vkm), passenger-kilometre (pkm)), tonne-kilometre (tkm) or per net tonne-kilometre (ntk). Values are disaggregated for urban and rural locations and within each of these, passenger car, bus and rail and freight light commercial vehicle, heavy commercial vehicle and rail.

In order to employ default values in a CBA, use the appropriate unit (vkm, pkm, tkm, ntkm) and location for the Base Case and Project Case for each year of the initiative's life. Multiply these by the default externality values.

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 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.

9.2 Estimate any 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 revealed preference methods (hedonic pricing, the travel cost method), stated preference methods (contingent valuation and discrete choice surveys), and estimation of mitigation costs or damage and avoidance costs.

9.3 Calculate the externality benefit or disbenefit

The benefit (or disbenefit if negative) is calculated as the base case externality costs less 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.

10.6. Calculate the incremental BCR if required.

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 approaches to selecting the discount rate. The main approaches are:

- The social time preference (STP) rate — the rate at which society is willing to defer current consumption in exchange for future consumption
- The social opportunity cost of capital (SOC) rate — the rate of return on the marginal dollar of private investment that would be crowded out by additional public sector investment
- A weighted average of the STP and SOC rates — recognising that part of the resources invested come from deferred consumption, part from crowded-out private sector investment. Weighted average discount rates typically allow for a third source of capital, overseas borrowing
- Discounting at the STP rate while using 'shadow price' factors to adjust upwards costs sourced from crowded-out private sector investment and benefits that are reinvested in the private sector earning returns above the STP rate. This approach is considered the most theoretically correct but impractical to implement.

In Australia, there appears to be widespread support for the SOC approach on the grounds that resources invested in public sector projects should earn a return at least what they would if invested by the private sector (DoFA 2006; Harrison 2010; New South Wales Treasury 2017; Abelson and Dalton 2018; Terrill and Batrouney 2018).[18]

[18] The view that the SOC should be used as the social discount rate is not without critics, for example, Feldstein (1972,

Then there are different ways to implement each approach. The technical literature is large and complex. There is no definitive answer on which experts agree. Having accepted the SOC approach, there is a further set of issues about whether the discount rate should include a risk premium and if so whether the premium should be specific to the project being appraised or an average of returns for the bundle of the private sector investments displaced.[19]

A large part of project-specific risk for public sector projects is diversified away through being spread over a large number of taxpayers (Arrow and Lind 1970).[20] There remains non-diversifiable or systematic risk arising from project benefits being correlated with consumers' income or consumption. There are arguments against adding a premium to the discount rate for non-diversifiable project-specific risk. Boardman et al. (2018, p. 248) argue that such an approach might only be appropriate if the goal were to maximise net cash flow to the government, not allocative efficiency. Quiggan (2005) argues that the correlation between project benefits in total and per capita consumption and the variation in per capita consumption over time are so low that the size of the risk premium, calculated using the consumption capital asset pricing model, is practically negligible. In any case, the information is not available to quantify the parameters in the capital asset pricing model to undertake calculation of project-specific discount rates (Harrison 2010, p. 57; Abelson and Dalton 2018, p. 10.)

There is a consensus that it is bad practice to adjust the discount rate upward to offset optimism bias (BTRE 2005; Harrison 2010 p. 41; Abelson and Dalton 2018 p. 11) (see Chapter 11 and ATAP Part O2 Optimism bias). Adding a risk premium to the discount rate engenders little or no increase in construction costs and reduces benefits at an increasing rate with time. It would be an unlikely coincidence if the pattern of reductions in benefits arising from a risk premium corresponded with the adjustments necessary to correct for optimism bias.

The ATAP Guidelines therefore recommends against adding a premium for project-specific risk to the discount rate. Risk and uncertainty should be addressed directly when estimating benefits and costs using the techniques in Chapter 11 rather than adding a risk premium to the discount rate. The SOC rate may include the risk premium in the return earned by the bundle of private sector projects crowded out.

For practical application, 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% with 4% and 10% for sensitivity testing; the Commonwealth Department of Infrastructure, Transport, Regional Development and Communications requires CBA results to be estimated using real rates of both 4% and 7%.

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p. 320) pointed out that the advocates of the pure SOC approach fail to distinguish between what the ideal opportunity cost (what *could* be done with the resources) and the predictive opportunity (what *would* be done with them). See also Boardman et al. (2018, pp 248-250).

[19] An additional public sector project cannot be assumed to crowd out a private sector project with similar risk characteristics. Rather, it can be expected to crowd out a bundle of private sector projects covering the full range of risks, from low to high. The weighted average risk for the bundle of private sector projects displaced will therefore not vary between different public sector projects with different risk levels (Boardman et al. 2018, pp. 247-8).

[20] For a simple explanation, see De Rus (2010), pp. 158-9.

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.

With 'year zero' set at the year in which construction commences, (see Section 2.4), any costs occurring in year zero are not discounted. Costs incurred during year one are be discounted by one year. Discount forward any costs (e.g. avoidable planning and design costs[21]) incurred prior to the commencement of year zero (years minus one, minus two and so on) by multiplying by $(1+r)^t$.

With the life of the initiative assumed to commence at completion of construction, the number of years over which discounting occurs (the analysis period) 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 the number of years of the appraisal period
- r is the discount rate
- B_t is benefits in year t
- OC_t is infrastructure operating costs including maintenance and asset replacement costs in year t
- IC_t is investment (or capital) costs in year t.

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

[21] 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.

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 discussed 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 operating and investment costs incurred by governments in the denominator and the consequences of incurring these costs (the benefits), in the numerator. BCR2 puts only the initial capital investment cost in the denominator and all other impacts in the numerator. In most cases, impacts that occur *before* completion of the initiative go in the denominator, and benefits and savings in costs that occur *after* completion of the initiative in the numerator. There are exceptions to the before–after rule such as construction externalities (e.g. traffic delays, diversion costs, noise, dust), which belong in the numerator because they are not paid out of budget-constrained funds.

Benefits of deferred capital expenditure and costs of capital expenditure brought forward for related projects, (see Section 7.5), belong in the denominator for BCR1 and the numerator for BCR2, because they occur well in the future. It is recommended that revenue from public transport fares and road tolls go in the numerator for both BCR definitions regardless of whether the revenue accrues to the public or private sector.[22]

[22] Fare and toll revenue, being part of willingness-to-pay, will not appear as a separate benefit in a social welfare presentation of benefits so there is no question of putting them in the denominator on the grounds that they accrue to

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 funds out of budgets in the near future being allocated. For an explanation, see Box 14. 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.

BCR2 cannot be calculated for initiatives with zero investment costs such as regulatory changes and actions that increase operating costs in exchange for, say, a service quality benefit. BCR1 must be used. However, initiatives without investments will not be competing with other projects for funds.

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

Box 14 BCR definitions

Two BCR definitions are given, BCR1 with operating and maintenance costs in the denominator and BCR2 with them in the numerator. BCR2 is the correct one to use for ranking projects competing for funds from a constrained budget. BCR2 gives the value of benefits less operating costs the initiative contributes per dollar of investment cost. Selecting initiatives in descending order or BCR2 until the point is reached where the budget is exhausted results in the optimal combination of initiatives, which maximises total NPV subject to the budget constraint.

Operating costs including maintenance and asset replacement costs are paid out of government budgets well into the future. They do not take funds away from initiatives under consideration at present. As current initiatives compete for funds out the current budgets, only the benefit per dollar taken from budgets in the near future is relevant for ranking projects, not dollars coming out of later budgets. So only investment costs should go in the denominator in a BCR used to rank projects (i.e. BCR2).

To properly consider the impacts of future operating costs on future projects competing for funds would require solving a complex optimisation problem with assumptions made about the size of future budgets and the benefits and costs of future initiatives. A simple approach to allow for future operating costs reducing funds available to invest in future initiatives is to assume values for future cut-off BCRs. If the cut-off BCR is assumed to have a constant value of μ over time, an additional dollar of operating cost incurred reduces future investment spending by one dollar forgoing $$\mu$ of benefit. A present value operating costs, PVOC, would have an opportunity cost of $\mu \times$ PV(OC). Initiatives could be ranked by $BCR = \frac{PV(B) - \mu \cdot PV(OC)}{PV(IC)}$.

BCR2 is sometimes called the 'net benefit investment ratio' (NBIR).

governments. The reason for recommending they go in the numerator regardless of the BCR definition is to ensure consistency between a presentation of benefits under social welfare and gainers and losers (or beneficiary) approaches.

10.5 Calculate net present value per dollar invested

The net present value per dollar invested is defined as

$$NPVI = \sum_{t=0}^{n} \frac{NPV}{PV(IC)}$$

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 calculated, the NPVI can be used for ranking initiatives subject to a budget constraint.

10.6 Calculate the incremental BCR if required

The incremental BCR (IBCR) can be used as an alternative to the NPV for the following three comparative scenarios:

- 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 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 also take account of budget constraints, unlike simple NPV comparisons. To take account of budget constraints:

- 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 BCR implies the increment is worth accepting. If the IBCR for a pair of options is below the cut-off BCR, 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.[23] (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.

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.

There is no formula for the IRR. It needs to be found by iteration. Excel has a function to do this.

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. Box 15 explains the FYRR further. Provided the assumptions underlying the criterion are met, 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.

[23] 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, μ, 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 as $PV(B_2 - OC_2) - \mu PV(IC_2) > PV(B_1 - OC_1) - \mu PV(IC_1)$.

Box 15 First-year rate of return (FYRR) criterion

If implementation of an initiative is delayed by one year, society forgoes the benefits in the first year of operation, B_f. There is an offsetting gain of the saving in the time value of the capital invested for one year. The time value of one year of delay is the investment cost multiplied by the discount rate, $r \times IC$. The net gain from delaying the project by a year is $r \times IC - B_f$. This amount will be positive if $r \times IC > B_f$ or $r > B_f/IC$, that is, if the FYRR is below the discount rate. As the project is delayed and demand grows, the first-year benefit rises. The optimal time is the first year in which the FYRR exceeds the discount rate. If the FYRR is significantly above the discount rate, it means the optimal implementation time was in the past.

The validity of FYRR criterion depends on two critical assumptions. First, benefits must be consistently rising over the life the project. Second, changing the year of implementation must not alter the benefits in any years. For example, benefits in the year 2035 should be the same regardless of whether the project is implemented in 2025 or 2030.

If these assumptions are not met, the optimal time can be found the by comparing NPVs with different implementation times all discounted to the same year. For example, if comparing implementation times of 2030 and 2035, in both cases NPV should be estimated with 2030 as year zero, not changing year zero to 2035 for the delayed implementation.

The FYRR criterion can be particularly important for initiatives for which high demand growth over a long period of time causes very large levels of congestion in the Base Case. In such cases, forecast benefits in the later years of the initiative’s life can become extremely large leading to high BCRs suggesting that the initiative is urgently needed. However, going without the project during the early years when Base Case congestion levels are low can be the economically efficient choice.

See NGTSM 2006 Volume 5 for more detail.

10.9 Reporting core results

An approach used when presenting the results of a CBA is to categorise the benefit components as being ‘core’ or ‘non-core’ results. The distinction relates to the reliability of the various benefit components in CBA results, in terms of the confidence one can assign to the methodologies and parameter values used in their estimation, and therefore the result. Core benefits are those for which the methodology and parameter values are well established, agreed in practice, and not controversial. Non-core benefits are those where the methodology or parameter values are new, or uncertain, have not been widely tested or accepted in practice, and are likely to be controversial.

Use of the core vs non-core distinction signals to decision makers which parts of an appraisal contribute a greater level of risk in their decisions. Distinguishing between core and non-core benefits, reporting the impact of this distinction on CBA results, and undertaking sensitivity testing on key input parameters, are critical in an appraisal.

The core vs non-core distinction is sometimes referred to as core results being ‘above the line’ (ATL), and non-core results being ‘below the line’ (BTL).

In the Guidelines, this distinction has been specifically made in:

- T3 Wider economic benefits (section 1.5.4 Presentation of WEBs)

- O8 Land use benefits of transport initiatives (section 4.3 Presentation of land-use change benefits)
- M2 Roads (section 8.3.15. Reliability benefits).

Recommendations in the Guidelines on individual benefits being core or non-core provides a consistent national approach for presenting benefits, however individual state and territory jurisdictions may use alternative results as the decision criteria for projects fully funded within their jurisdiction. It is recommended that reasons for using alternative results be clearly explained in application reports for consideration by state / territory treasury departments and centralised Infrastructure Agencies.

11. Step 11: Assess risk and uncertainty

Steps

11.1.	Undertake 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.

There is a need to 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. It is part of a broader problem called ‘optimism bias’, which is addressed in ATAP Part O2 Optimism bias. If, following a comprehensive risk assessment process, downside risk has been eliminated from projections, the remaining variation about the expected value (the mean of the probability distribution) is called pure risk. In most cases, pure risk can be ignored in CBAs. Governments invest in a large number of initiatives and their benefits and costs are spread over many individuals. Just as for a diversified share portfolio, initiatives that do worse than expected are likely to be approximately offset by initiatives that do better. The undiversifiable component of pure risk in public sector initiatives arises from benefits being correlated with movements in the economy as a whole. The volatility of benefits from transport initiatives caused by changes in the general level of economic activity is not great, and the size of the benefit amounts to only a small proportion of households’ total consumption. There are exceptions where an initiative has a large effect on the welfare of affected individuals so the risk is not diversified away by other public sector initiatives. Examples include initiatives that improve access for isolated communities.

As noted above in Section 10.1, it is not recommended to adjust for project risk, downside or pure, by increasing the discount rate as it can distort the ranking of initiatives.

The purposes for addressing risk and uncertainty using the methods outlined in this chapter are to:

- Reduce optimism bias to push CBA results closer to expected values (the means of probability distributions), and
- Obtain information about and reduce the variances of probability distributions of CBA results.

More detail on the methods here are provided in ATAP Part O1 Cost estimation and ATAP Part T7 Risk and uncertainty assessment.

11.1 Undertake sensitivity analyses

Sensitivity analysis is a simple way to analyse the uncertainty surrounding CBA results, but it is a limited tool. It is therefore an attractive form of quantitative risk assessment, especially for smaller, less complex assessments.

In its most basic form, it involves changing one variable at a time by a standard percentage, say, +10% followed by –10%, or by an absolute amount to gauge how much NPV changes. If the NPV changes by only a small amount (e.g. ±10% change causes a ±3% 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 by which the variables are changed do not have to be symmetrical. Table 4 shows the sensitivity ranges for road initiatives recommended by Austroads.

Changing a list of variables by standard amounts risks reducing sensitivity testing to a mechanical exercise. It is therefore recommended that, as far as possible, sensitivity analysis be tailored or targeted to the specific assessment being undertaken. The testing should focus on the most risky input variables, which would be those that are simultaneously of high impact and most uncertain (Austroads 2012; IA 2018). Such critical interrogations of major ‘risky’ variables, assessed and interpreted by way of more focused sensitivity testing, would enhance the quality of most assessments.

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.

11.2Decide on the level of detail for a risk analysis

The SMT and rapid CBA template (see ATAP Part F3 Options generation and assessment, Appendix B) requires proponents to address a series of questions about the risks of their proposed initiatives. One of the questions asks proponents to describe 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 probabilistic 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. It provides a thought process that disciplines the analyst to ask a complete set of 'what if?' questions.

Table 4 Sensitivity variables and ranges recommended by Austroads

Variable	Suggested minimum value	Suggested maximum value
Capital cost[a]		
Concept estimate	–20% of estimate	+20% to 35% of estimate[b]
Detailed costing	–15% of estimate	+15% to 25% of estimate[b]
Final costing	–10% of estimate	+10% to 20% of estimate[b]
Road-agency operating and maintenance costs	–10% of estimate	+10% of estimate
Traffic		
Total traffic volume (AADT)	–10% to –20% of estimate	+10% to +20% of estimate
Proportion heavy vehicles	–5% of estimate	+5% of estimate
Average car occupancy	–0.3 from estimate	+0.3 from estimate
Traffic growth rate	–2% pa (absolute) from the forecast rate	+2% pa (absolute) to the forecast rate
Traffic generated by specific (uncertain) developments	Zero	As forecast
Traffic diverted or generated by the initiative	– 50% of estimate	+50% of estimate
Traffic speed changes	–25% of estimated change in speed	+25% of estimated change in speed
Changes in crash rates	–50% of estimated change	+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 2005, p. 27.

11.3Identify risky variables and sources of risk

The main sources of risk for investment initiatives are:

- Investment cost risks created by unforeseen construction, technical or other project scope issues
- Operating cost risks (including maintenance) created by unforeseen market impacts/changes and technical issues
- Demand forecast risks driven by changes in factors such as unforeseen population growth or cost of living
- Environmental impacts driven by unforeseen circumstances
- Network effects caused by unexpected and inter-related network projects/changes
- Technological risk related to changes in technology. The impacts of changes in technology are difficult to predict but can be significant, including: making existing products and assets obsolete or less competitive; creating 'lock-in' effects; and changing the relative prices of existing and new technologies, e.g. relative prices of transport modes. (BTRE 2005, pp. 3-4)

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 and/or small impacts 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 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 16).

11.8 Calculate probability-based values of investment costs if required

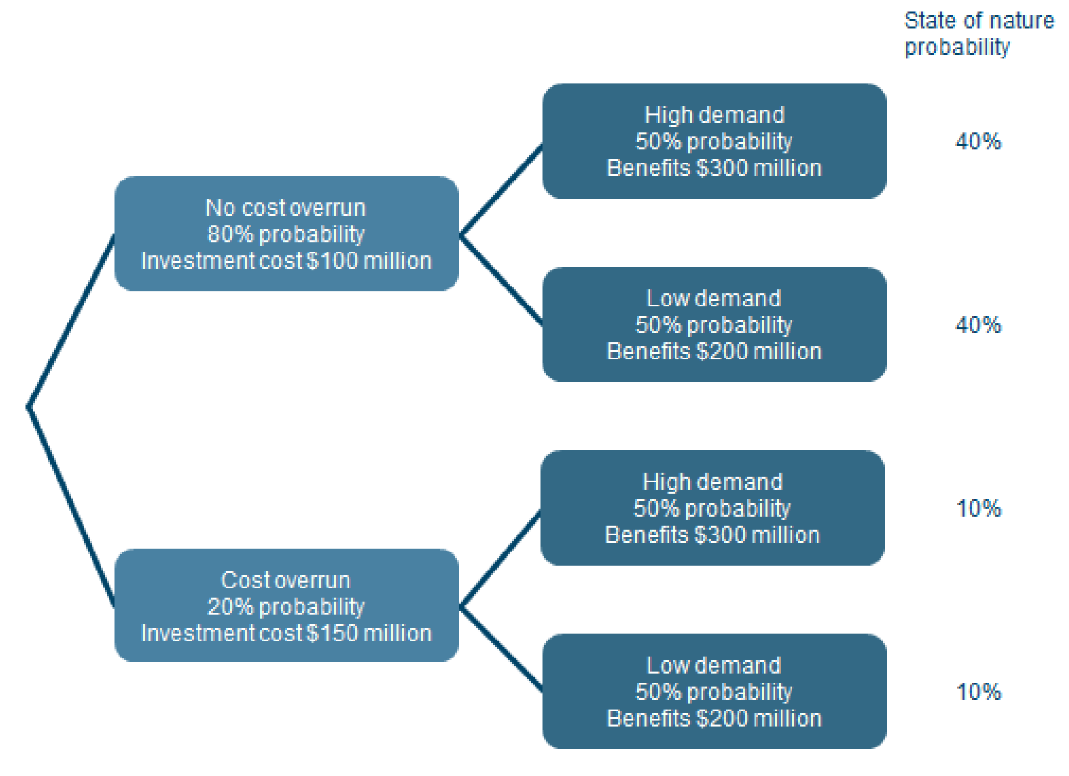
Calculate probability-based values of investment costs if the funding jurisdiction requires it. See ATAP Part O1 Cost estimation for guidance. Investment costs are typically reported at P50 and P90 levels. P50 and P90 are the costs with sufficient contingency to provide a 50% and 90% likelihood respectively that these costs will not be exceeded (ATAP Part O1, p. 6). With half of the area of the probability distribution on either side, P50 is the median of the probability distribution.

The core 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. However, if the modelling has been undertaken properly, the distribution is likely to be skewed to the right causing the mean to lie above the median and the mode. The reason is that costs to supply and install inputs and delivery and installation times will have logical minimums but no theoretical ceiling. The combined effects of right skews in cost components will be magnified if positive correlations are allowed for in the modelling. The mean is therefore likely lie between the P50 and P90 values. Optimism bias, if present, will pull down the estimated P50 and P90 values shifting the actual expected value of project cost towards the P90 estimate and beyond.

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.

Box 16 Example of calculation of expected NPV and BCR

The present value of investment costs for a new initiative is $100 million with an 80% probability, and $150 million with a 20% 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**

11.9 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. ATAP Part T7 Risk and uncertainty assessment discusses choice of probability distributions.

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 because risks are diversified across numerous beneficiaries. An exception is where an initiative has a large effect on the welfare of affected individuals.

11.10 Undertake scenario analysis

Where probabilities are completely unknown, that is, there is uncertainty, scenario analysis offers a way forward. It involves describing plausible future scenarios, usually a small set, and assessing how an option or initiative performs under each of those futures. See ATAP Part T7 Risk and uncertainty assessment, Chapter 7 for further discussion.

11.11 Consider risk management strategies

Consider changes to proposals that can increase expected NPVs by reducing either the probabilities or the costs of adverse events.

Risk mitigation options involve changes to proposals that reduce either the probabilities or the costs of adverse events. Often, these changes will involve expending additional resources with certainty. Building a stronger bridge should reduce the probability of future collapse. Constructing safety barriers to absorb crash impacts should reduce future crash costs. See ATAP Part T7 Risk and uncertainty assessment, Chapter 8 for further discussion.

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 (BITRE 2014). Real options are similar to financial options but are exercised over real assets rather than financial assets (Productivity Commission 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. See ATAP Part T8 Real options assessment for a detailed treatment.

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. Adjust for distributional impacts

12.7. 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 12.3 to 12.6.

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

Multiplying specified benefits or costs by a weighting factor results in some benefits or costs being prioritised over others. If the benefit or cost is multiplied by a number greater than 1 it is given greater weight and if it is multiplied by a number less than 1 it us given 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.

Box 17 presents an approach to adjust CBAs to highlight the productivity effects of transport initiatives.

Box 17 An approach to highlight productivity impacts

Improving productivity is often a declared objective of governments. The benefits that lead to productivity gains are those that affect Gross Domestic Product (GDP). They lead to higher wages for workers, higher profits for businesses, lower prices for consumers and higher tax receipts for governments. Where they improve international competitiveness, they lead to a higher exchange rate, which improves the purchasing power of Australians to buy foreign goods and services.

Benefits that affect productivity and would be included (given a weight of one) in the productivity adjusted CBA are savings in travel time and vehicle operating costs, and improvements in reliability accruing to business travellers and freight. Wider economic benefits (WEBs), if estimated, should be included. Time, vehicle operating cost and reliability impacts for non-business travellers, including journeys to and from work, should be excluded (given a weight of zero).

There would be some productivity related elements in safety benefits, environmental health benefits and the health benefits of active travel. These include costs of running of the health system, availability of people to work, employee morale, and traffic delays from crashes. However, these can be excluded because of the difficulty in separating out the productivity components, and the likelihood that they will be quantitatively small compared with the main productivity benefits.

The ratio of the present value of adjusted benefits to the present value of unadjusted (all) benefits (including WEBs), expressed as percentage, can be presented as an indicator of the ‘productivity intensity’ of an initiative.

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 Adjust for distributional impacts

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 estimates made of 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, greater than one for groups it considers most desirable to benefit, one for neutral, and below one for groups least desirable to benefit. 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 in Box 18.

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. Computable general equilibrium models can provide useful information about distributional impacts of transport initiatives (see ATAP Part T4).

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 18 for a simple worked example. Note that the distributional multiplier is applied to benefits only, not to benefits less infrastructure operating costs.

Box 18 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**

12.7 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 were performed).

Finally, calculate the adjusted NPV and BCR.

Adjusted NPVs can be used to compare options as well as 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.

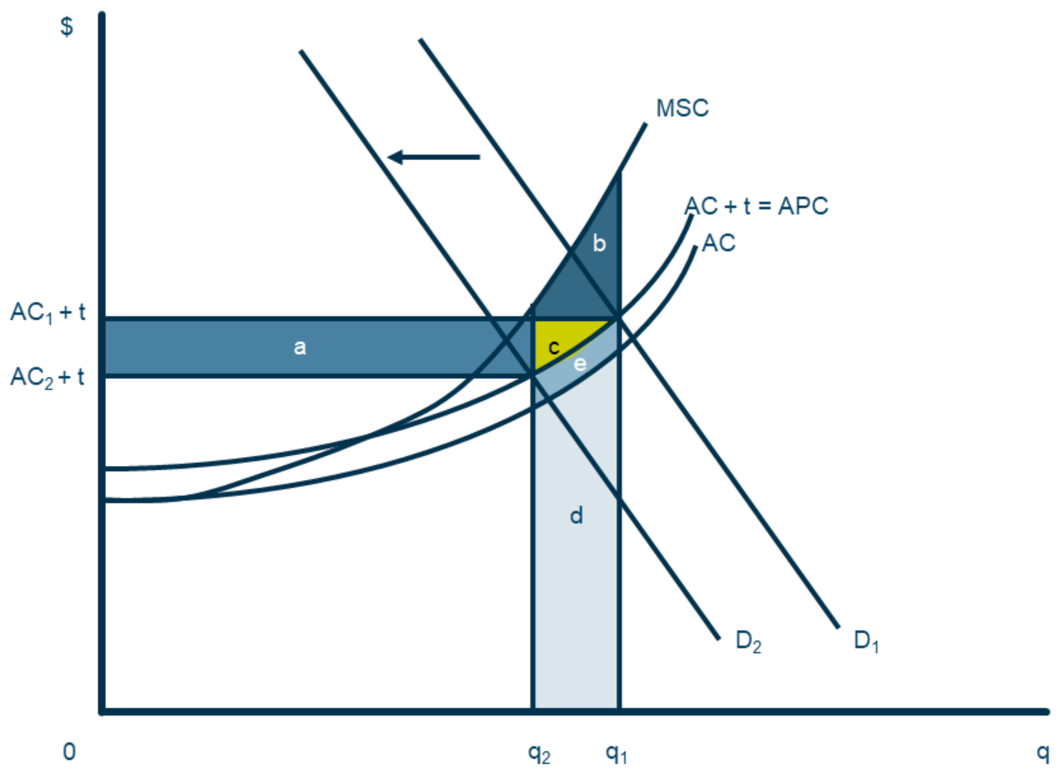
A criticism of adjusted CBA is that it ‘distorts’ the results of CBAs in such a way that it can favour less economically efficient initiatives over more efficient initiatives. As a safeguard, the Guidelines recommend that adjusted CBA results never be reported separately from the results of the corresponding unadjusted CBA. If decision-makers select options or prioritise initiatives on the basis of adjusted CBA results, it is important that they are aware of the trade-offs, that is, the amount of economic efficiency gains forgone in order to promote other objectives.

Appendix A Benefit where the related market is a congested road

This appendix provides a technical proof of the alternative measure of benefit on related infrastructure referred to in footnote 11 in section 7.2. Figure 3 shows the demand and cost curves for a length of congested road similar to those commonly featured in textbook explanations of optimal congestion charging. In these diagrams, there is a rising average cost (AC) curve and a marginal social cost curve (MSC) above it. The mathematical relationship between two curves that $MSC - AC = \frac{dAC}{dq}q$, that is, the amount MSC exceeds AC (the congestion externality) is the increase in AC (incurred by all users) caused by the marginal road user times the quantity of intra-marginal uses who experience in the increase in AC.

There are some major differences between Figure 3 and the textbook congestion pricing diagrams. First, there is no congestion pricing. Second, the demand curve shifts leftward from D_1 in the Base Case to D_2 in the Project Case, representing the situation where traffic is diverted from a road due to a transport initiative that improves the service level on parallel infrastructure in a network. Third, there are two average cost curves shown, one labelled AC representing the resource costs of road use and $AC + t = APC$, which adds the fuel excise to average resource cost to obtain the average perceived cost (APC). Note that if road users were failing to perceive some the costs they incur, there would also be a negative adjustment, which could offset part or all of the fuel excise. Figure 3 is simpler if perceived cost exceeds resource cost, but the mathematical result still applies for the converse case.

Figure 3 Benefit on related road with congestion



Since road users base their decisions on perceived costs, the intersection between the APC curve and demand curve determines the equilibrium quantity. From the Base to the Project Case, quantity falls from q_1 to q_2 and average cost from AC_1 to AC_2.

As discussed in Section 7.2, the benefit is area between the average perceived cost curve and the marginal social generalised cost curve over the quantity change for the related infrastructure, that is areas $b + c$.

$$\boldsymbol{Benefit = \int_{q_1}^{q_2} (APC - MSC)\, dq}$$

Since the $q_2 < q_1$ and $APC < MSC$, the benefit is a positive amount. Note that if the demand curve shifted rightward, as would occur on an upstream or downstream road, $q_2 > q_1$, the formula will give a negative result being a disbenefit due to greater congestion. The relationship derived below applies equally to increased demand but the signs of the results are changed.

Considering the components of the benefit:

$\int_{q_1}^{q_2} (APC)\, dq$ is areas $d + e$, which can be approximated by $\frac{1}{2}(AC_1 + AC_2)(q_1 - q_2) + t(q_1 - q_2)$.

$\int_{q_1}^{q_2} (MSC)\, dq$ is areas $b + c + e + d$, and equals the saving in total social costs, $TSC_1 - TSC_2$.

Since total social cost is average resource cost times quantity, $TSC_1 = AC_1 \cdot q_1$ and $TSC_2 = AC_2 \cdot q_2$.

Combining all these

$$\boldsymbol{Benefit = \int_{q_1}^{q_2} (APC - MSC)\, dq = areas\ (b + c + e + d) - (d + e) \approx}$$

$$\boldsymbol{(TSC_1 - TSC_2) - \frac{1}{2}(AC_1 + AC_2)\left(q_1 - q_2\right) - t\left(q_1 - q_2\right) =}$$

$$\boldsymbol{AC_1 \cdot q_1 - AC_2 \cdot q_2 - \frac{AC_1 \cdot q_1}{2} - \frac{AC_2 \cdot q_1}{2} + \frac{AC_1 \cdot q_2}{2} + \frac{AC_2 \cdot q_2}{2} - t\left(q_1 - q_2\right) =}$$

$$\boldsymbol{\frac{AC_1 \cdot q_1}{2} - \frac{AC_2 \cdot q_1}{2} + \frac{AC_1 \cdot q_2}{2} - \frac{AC_2 \cdot q_2}{2} - t(q_1 - q_2) =}$$

$$\boldsymbol{\frac{1}{2}(AC_1 - AC_2)\left(q_1 + q_2\right) - t\left(q_1 - q_2\right) =}$$

$$\boldsymbol{\frac{1}{2}(APC_1 - APC_2)\left(q_1 + q_2\right) - t\left(q_1 - q_2\right) \approx}$$

$$\boldsymbol{areas\ (a + c - e)}$$

The term $t(q_1 - q_2)$ is the resource correction, being the difference between perceived and resource cost over the quantity change, $(APC - AC)(q_2 - q_1)$. It translates into fuel excise revenue lost to the government. If road users failed to perceive some of their costs, it would also represent a gain in welfare to road users because they save some unperceived costs.

The approach that measures the benefit as the area between the marginal social cost and average costs curves (areas *b* + *c*) can be found in Harberger (1972, pp. 262-3). The approach that measures the benefit as the area between Base Case and Project Case average costs (area *a*) plus the triangle (area *c*) for diverted traffic can be found in Neuberger (1971, p. 56). Neither of them show the resource correction required where perceived and resource costs differ (area *e*).

The Neuberger approach as the practical advantage that the benefit formula for roads from which or to which traffic is diverted is identical to the formula for the road with the transport initiative where the benefit is the consumers' surplus gain given by the area between the Base and Project Case average cost curves plus the triangle for diverted and generated trips. The same formula can be applied across an entire network to roads altered by transport initiative (shifting cost curves) and to roads with shifting demand curves due to network effects. See ATAP Part M2, Section 7.4.

Appendix B Methods for estimating changes in consumers' surplus

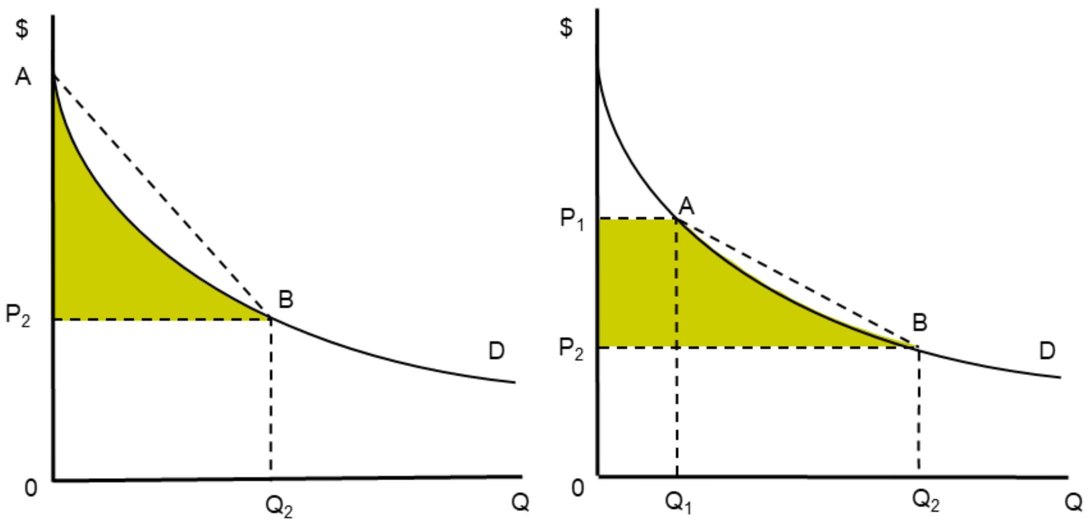
B.1 Method 1 — Rule-of-a-half

The first method is to calculate the change in consumers' surplus in the usual manner, with the change in consumers' surplus for generated and diverted trips based on the rule-of-a-half. Typically this is done in a spreadsheet outside the demand model, the demand model software can be extended to undertake the calculations within the model.

The 'rule-of-a-half' makes the simplifying assumption that the demand curve is a straight line over the region of the generalised cost change associated with the initiative. This is a reasonable assumption only for relatively modest changes in demand. When an initiative results in relatively large changes in travel demand, the associated curvature of the demand curve over the range may be significant so the rule-of-a-half calculation is no longer a good approximation to the change in consumers' surplus.

Figure 4 shows two such cases. The left side shows the case where a new mode is introduced. The right side shows the case for an existing mode with a large demand change (Q_1 to Q_2) due to a reduction in perceived cost from P_1 to P_2. The magnitudes of the coloured areas are the consumers' surplus changes. The rule-of-a-half gives the consumers' surplus benefit as the area P_2AB for the new mode on the left side of Figure 4 and the area P_2P_1AB for the reduction in perceived cost for the existing mode on the right side. The next two sections offer ways to address the error from applying the rule-of-a-half to a non-linear demand curve.

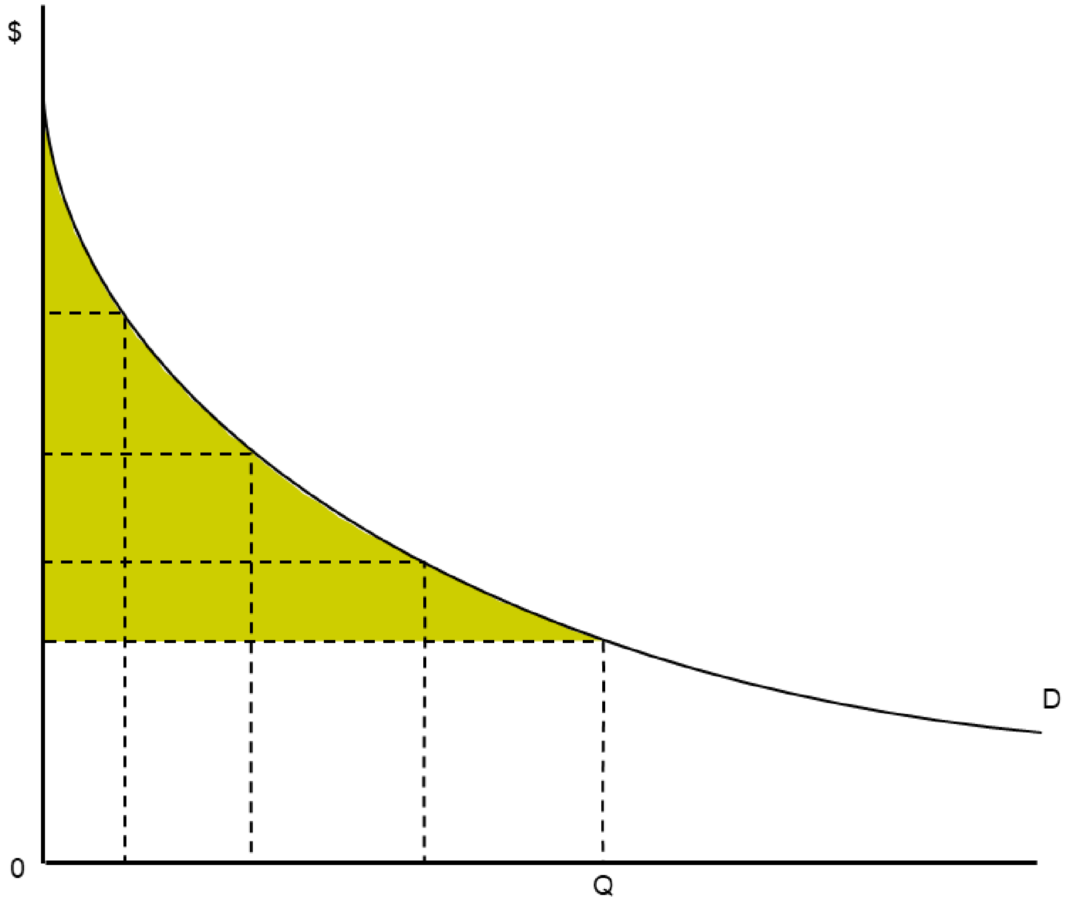
Figure 4 Consumers' surplus areas



B.2 Method 2 — Numerical integration — modified rule-of-a-half

There is variety of numerical integration techniques that can be used to measure consumers' surplus areas for non-linear demand curves. A simple method that would appeal to analysts accustomed to the rule-of-a-half is to break the demand changes into a number of smaller parts (TfNSW 2016, Nellthorpe et al. 2001) and apply the rule-of-half to each part of the demand change. In Figure 5, that would mean application of the rule-of-a-half to each for the four slices and summing the areas.

Figure 5 Numerical integration method



B.3 Method 3 — Logsum method derived directly from a multi-modal demand model

When using a discrete choice (also called logit) travel demand model, a more direct and more accurate, method of estimation of the change in consumers' surplus is using the logsum measure within the demand model. Technical details are in Appendix C.

The logsum method has several advantages over the other methods:

- It is theoretically the most correct method to estimate changes in consumers' surplus where demand has been forecast using a logit model

- It draws more directly on information in logit travel demand models
- It calculates benefits by integrating demand curves for each mode between the base case and project case generalised cost. It is therefore more accurate than any application of the rule-of-a-half or numerical integration methods.
- It provides a curved demand relationship where the change in demand on an existing mode is sufficiently large that the demand curve is likely to significantly deviate from a straight line
- It provides a good estimate of total consumers' surplus where an initiative involves introduction of a new mode that currently does not exist and hence where the demand curve extends over a significant level of demand and is likely to be curved (see Section 6.5 above).

The logsum method can be employed only where a logit travel demand model has been used to estimate demand. To confirm that the logsum approach has been correctly applied, it is advisable to check the result by making an estimate of the consumers' surplus gain using the rule-of-a-half or a numerical integration method. The consumers' surplus estimate obtained by assuming linear demand curves should differ from the logsum estimate, but not by a large amount, depending on the sizes of the price changes and type of numerical integration technique.

The logsum method first calculates the change in utility (as represented in the travel demand model) for each assigned traveller, then aggregates the changes for groups of travellers and finally requires conversion of utility into a monetary value. More specifically, it measures traveller utility by calculating the natural log (ln) of the denominator of the logit mode choice model. The complexity of the calculation depends on the level of detail included in the travel demand model for the factors that affect travel decisions. The method also requires careful use of parameters to convert utility, which is the driver of travel choice in travel demand models and the initial measure of user benefits, to monetary values. The use of the approach becomes more complex when the marginal utility of money is not taken to be constant.

The logsum method has several disadvantages:

- Because the calculation is undertaken entirely within the travel demand model, there is reduced transparency in the calculation of benefits
- The theoretical complexity of the methodology is likely to make it less easily understood by non-modelling specialists
- The accuracy of the estimate of benefits will depend on the quality of the transport model and the parameters used to calibrate it (which is the case for other methods as well). At present, the logsum method requires users who have excellent knowledge of travel demand models and economics to ensure its proper use.

The logsum method will become more valuable as travel demand models continue to become more complex, for example, to include income effects, changes in departure times and more flexibility with regard to destination choice. Appendix C is an extended discussion of the logsum method and calculations.

Appendix C Logsum methodology

C.1 Definition of the logsum

The logsum is the correct measure of user benefit when a logit model is used. The logsum brings together the logistic function, offering the practical advantage of keeping forecast shares within the 0 to 1 interval in a mathematically tractable way, and random utility maximisation, which provides an economic basis for explaining the choices made by individuals.

C.2 Logistic function

The logistic function is an S-shaped or 'sigmoid' curve. When used to model market shares for two competing transport modes, the logistic curve or logit model has the form

$$P_A = \frac{e^{k+\beta X_A}}{e^{k+\beta X_A} + e^{\beta X_B}} = \frac{1}{1 + e^{-[k+\beta(X_A - X_B)]}}$$

where

P_A is probability that an individual will choose mode A over mode B, which can be interpreted as the market share of mode A.

X_A and X_B are the quantities of the attributes of modes that affect model choice, such as time or cost

β and k are constants that determine the position and steepness of the curve.

The model can be linearised into the 'log-odds ratio', which can be useful for parameter estimation with linear regression where proportions are not zero or one.

$$Ln\left(\frac{P_A}{1 - P_A}\right) = k + \beta(X_A - X_B)$$

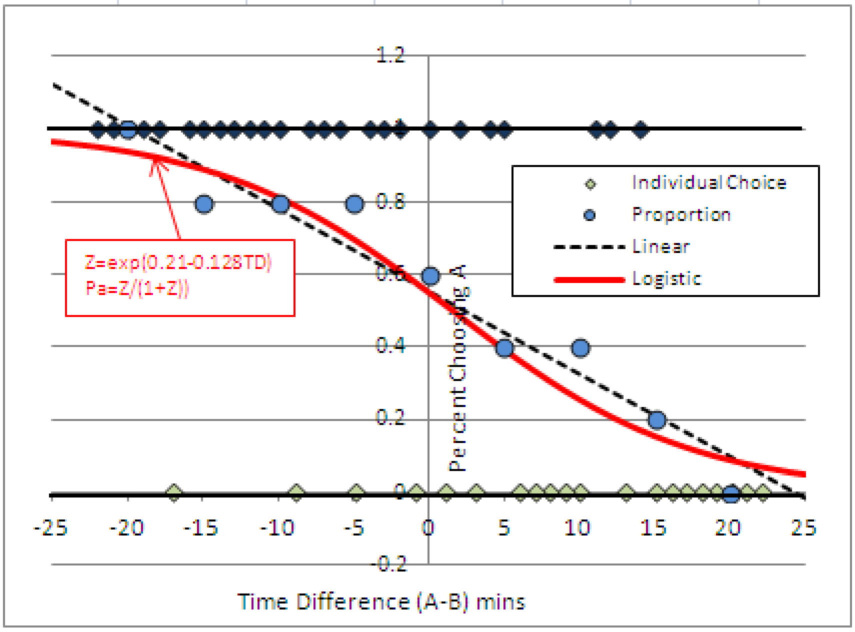
It can be generalised to the case of multiple alternatives (subscript *j* which includes *i*) as

$$P_i = \frac{e^{k_i+\beta X_i}}{\sum_j e^{k_j+\beta X_j}}$$

For attributes of modes such as time and cost, less is preferred to more, so an increase in time or cost for one mode reduces the probability of choosing it. Hence, $\beta < 0$. The constant term, *k*, called the 'alternative-specific constant', serves a similar function as the constant in a regression model, capturing the average impact on utility of all factors not included in the model. Only differences between alternative-specific constants are relevant, not the absolute levels, so the standard procedure is to normalise one of the constants to zero, as shown above for mode B. (Train 2003, pp. 25-26)

Figure 6 plots a plots a logit curve for a choice of two transport modes A and B which vary in terms of the difference in travel time from A being 25 minutes quicker than B to taking 25 minutes longer. People can either travel by A or B.

Figure 6 Illustrative logit curve



Individuals choosing mode A are shown as the dark blue diamonds along the top axis (a probability of 1). Individuals choosing mode B are the light green diamonds along the bottom axis. As can be seen, more individuals choose A the larger the time saving but some still choose A when it takes longer than B. The aggregate proportions choosing A (averaged by five minute period) are shown as the light blue circles and trend upwards from right to left showing the effect of the time saving more clearly.

The logit curve, fitted on the individual (1, 0) observations using maximum likelihood, traces the proportions. The 'curve' is almost a straight-line between 20% and 80% then flattens out so that the predicted proportion does not exceed 1 or fall below 0. The alternative-specific constant is 0.21 and β = –0.128. The curve is symmetrical around its mid-point, which, in this example, occurs where the time difference is 1.64 minutes (= $-k/\beta$) for a 50:50 market share split, not zero. Also plotted is a linear probability function that crosses 0% (all choosing B) at 25 minutes and 100% (all choosing A) at –20 minutes and thus has the drawback that it would have to be constrained in application.

C.3 Random utility maximisation[24]

Random utility maximisation is used to model choices by individuals among discrete sets of alternatives. A decision maker would obtain a certain level of utility (or profit) from each alternative. Say the decision-maker obtains U_j in utility from alternative *j* and U_i from alternative *i*. The decision maker will choose alternative *i* if $U_i > U_j$. A researcher cannot observe the decision-makers' utility but only some attributes of the alternatives faced by the decision maker, which we label x_j and x_i for alternatives *j* and *i*. The function $V_j = V(x_j)$, called 'representative utility', models utility dependent on the value of the list (vector) of parameters x_j that the researcher can observe for alterative *j*. Examples of observable parameters are money cost, time taken and service reliability. Since there are aspects of utility that cannot be observed, $U_j \neq V_j$. Utility can be decomposed into $U_j = V_j + \varepsilon_j$ where ε_j captures the unobserved factors that affect utility.

The main sources for the unobserved 'random' component are:

- Omitted service attributes
- Costs that vary randomly
- Measurement errors e.g. averaging of times/costs over a travel zone
- Random 'taste' variations across individuals (which can be reduced to some extent by market segmentation).

The probability that the decision-maker chooses alternative *i* is

$$P_i = Prob(U_i > U_j) = Prob(V_i + \varepsilon_i > V_j + \varepsilon_j) = Prob(\varepsilon_j - \varepsilon_i < V_i - V_j)$$

Different discrete choice models are obtained from different assumptions about the probability distribution of the unobserved part of utility, ε_j. If the unobserved part of utility for each alternative is assumed to be independent and identically (iid) Gumbel distributed, the logit model is obtained. The Gumbel distribution has a shape similar to the normal distribution and is often used to model the distribution of maximum or minimum values from a number of samples. The independence assumption is that the unobserved portion of utility for one alternative is unrelated to the unobserved portion of utility for another alternative.

Representative utility is usually specified to be linear, $V_i = \beta' x_j$, where x_j is a vector of observed variables for alternative *j* and β is the vector of coefficients. Numerous computer packages contain routines for estimating logit models with linear representative utility.

For multiple alternatives, the probability of choosing alternative *i* is

$$P_i = \frac{e^{V_i}}{\sum_j e^{V_j}} = \frac{e^{\beta' x_i}}{\sum_j e^{\beta' x_j}}$$

[24]The exposition in this section and the next is based on Train (2003). See Train (2003) and De Jong et al. (2007) for further detail on the logsum methodology.

C.4 Consumers' surplus

Total consumers' surplus gained from making the utility maximising choice is $CS = \frac{1}{\alpha} max_j(U_j \; \forall \, j)$ where α is the marginal utility of income, $dU/dY = \alpha$. Division by α translates utility into dollars. Since U_j is not observed, expected consumers' surplus has to be calculated. Provided the ε_j for each alternative is iid Gumbel distributed and utility is linear in income

$$E(CS) = \frac{1}{\alpha} E\left[max_j(V_j + \varepsilon_j \; \forall \, j)\right] = \frac{1}{\alpha} ln\left(\sum_{j=1}^{J} e^{V_j}\right) + C$$

where C is an unknown constant that represents the fact that the absolute level of utility cannot be measured. The expression in brackets is the denominator of the logit choice probability formula. Aside from the marginal utility of income and the constant, consumers' surplus is the log of a summation, hence the term 'logsum'. The logsum is the expected maximum utility.

The change in consumers' surplus from a change in attributes of alternatives is

$$\Delta E(CS) = \frac{1}{\alpha}\left[ln\left(\sum_{j=1}^{J^2} e^{V_j^2}\right) - ln\left(\sum_{j=1}^{J^1} e^{V_j^1}\right)\right]$$

The superscripts 1 and 2 indicate Base Case and Project Case respectively. The unknown constant C drops out.

To calculate the change consumers' surplus, it is necessary to know the marginal utility of income α. This can be obtained from the utility function. Say representative utility depends on money cost and time, $V_j = \beta_c c_j + \beta_t t_j$. Both coefficients, β_c and β_t, are negative indicating that utility decreases as the cost or time of a trip increases. The negative of the cost coefficient, $-\beta_c$, is the amount utility rises due to a one dollar increase in cost. A one-dollar reduction in costs is equivalent to a one-dollar increase in income, since the person gets to spend the dollar that he or she saves in travel costs just the same as if they received the extra dollar in income. The amount $-\beta_c$ is therefore the increase in utility from a one-dollar increase in income: the marginal utility of income, hence, $\alpha = -\beta_c$. Note that the negative of a negative cost coefficient gives a positive α value.

As utility can be expressed in any scale, one can divide through by β_c to obtain $V_j = c_j + \frac{\beta_t}{\beta_c} t_j$. Now, $\alpha = 1$ and β_t/β_c is the value of time. Utility then equals generalised cost. The conventional approach for urban transport initiatives, however, is to convert the logsum measure into a generalised time measure and only convert into dollars as a final stage calculation. In this way, it is possible to use behavioural values of time within the model and replace them by equity values of time for benefit calculations. Expressing the logsum in generalised time units requires division by β_t.

C.5 Logsum measure

Table 5 illustrates the concept of expected maximum utility represented by the logsum measure. Rather than maximise utility, the 'mirror image' of minimising transport time is shown. Service A takes 20 minutes and service B, 30 minutes. Based on the observed times, service A should always be chosen. However unobservable random effects influence the choices made. The random component is distributed so that there is a 50:50 chance of adding or subtracting 10 minutes. The chance is assumed to be the same for A or B (same distribution) but is independent (no correlation between A and B). This produces four equally likely outcomes (rows 1 to 4). Three outcomes result in option A minimising the total cost, and one outcome (2) results in option B minimising the cost.

Table 5 Observed and unobserved components of travel time (minutes)

	Observed		Unobserved 'Random'		Total			
Outcome	A	B	A	B	A	B	Minimum	Select
1	20	30	10	10	30	40	30	A
2	20	30	10	-10	30	20	20	B
3	20	30	-10	10	10	40	10	A
4	20	30	-10	-10	10	20	10	A

The expected received cost (maximum utility) is the average of the four minimums (i.e. 30, 20, 10 and 10 minutes, which is 17.5 minutes). This is less than all of the minimum observed time of 20 minutes, the weighted average of 22.5 minutes = 0.75 × 20 + 0.25 × 30, and the simple average of 25 minutes. Thus, by taking account of the unobserved random component, the expected time is reduced below that of the observed times.

Of course, it will never be possible to measure the unobserved random component directly, but it can be inferred once assumptions about the distribution of the random component are made. Assuming iid Gumbel distributed unobserved random components, the expected maximum utility (or minimum 'cost') is the logsum.

For the logit curve shown in Figure 6, with $V_A = 0.21 - 0.128t$ and $V_B = -0.128t$ where t is time, say the time taken for mode A is 20 minutes and for mode B, 30 minutes. The predicted market shares are

$$P_A = \frac{e^{0.21-0.128\times20}}{e^{0.21-0.128\times20}+e^{0.128\times30}} = 0.816 \text{ and } P_B = \frac{e^{-0.128\times30}}{e^{0.21-0.128\times20}+e^{0.128\times30}} = 0.184$$

The logsum is –16.77 minutes.

$$Logsum = \frac{1}{0.128} ln(e^{0.21-0.128\times20} + e^{-0.128\times30}) = -16.77\ minutes$$

The logsum implies a higher level of utility (loss of 16.77 minutes) than the weighted average time of 21.84 minutes = 0.817 × 20 minutes + 0.184 × 30 minutes and the minimum time of 20 minutes.

It can be shown that the logsum cost will never worsen if new choices are added even if the times and costs are higher than existing choices. By extension, removing a choice always makes the logsum worse. For example, removing choice B in the example increases the cost from –16.77 minutes to –18.36 minutes.

The size of the coefficient for time, –0.128 in the example, reflects the net effect of the unobserved components. The smaller the coefficient (closer to zero), the greater the importance in the unobserved random component and the greater the difference between the logsum from the observable cost measure, and conversely.

If choices are perfect substitutes (with no unobservable random error), the coefficient will be infinite (negative), the shares will be 'all or nothing' and the logsum will equal the minimum cost.

C.6 Comparison with rule-of-a-half

Continuing the numerical example based on Figure 6, say a transport initiative reduced the time taken for mode A from 20 minutes to 15 minutes. From the logit model, the probability of choosing mode A would rise from 0.816 $= 1/\{1 + Exp[-(0.21 - 0.128(20 - 30)\ minutes)]\}$ to 0.894 $= 1/\{1 + Exp[-(0.21 - 0.128(15 - 30)\ minutes)]\}$.

If there were 1000 users choosing between the two modes, the number of users of mode A would rise from 816 to 894. Using the rule-of-half, the consumers' surplus gain expressed in units of generalised time would be

$$0.5 \times (816\ users + 894\ users) \times (20\ minutes - 15\ minutes) = 4275\ minutes$$

The logsum formula gives

$$1000\ users \times \left[\frac{1}{0.128} ln(e^{0.21-0.128\times15} + e^{-0.128\times30}) - \frac{1}{0.128} ln(e^{0.21-0.128\times20} + e^{-0.128\times30})\right] minutes =$$

$$1000\ users \times [-12.48 - (-16.77)]\ minutes = 4289\ minutes$$

The difference of 14 minutes between the two estimates comes about because of curvature of the logit demand curve (quantity as a function of time for mode A with time for mode B fixed at 30 minutes). At the intermediate time for mode A of 17.5 minutes, the demand estimated by the logit model is 859 users $= 1000/\{1 + Exp[-(0.21 - 0.128(17.5 - 30)\ minutes)]\}$ compared with 855 users = (816 users+ 894 users)/2 estimated by linear interpolation between the 15 and 20 minute points.

The inaccuracy caused by the linear approximation of the rule-of-a-half method increases with the size of the change in generalised time or cost.

C.7 New modes, services and routes

As discussed in Section 6.5 above, when a new mode or service or route is introduced, the consumers' surplus benefit is the entire area under the demand curve (willingness-to-pay) for the quantity consumed minus the generalised cost as shown in the left part of Figure 4. Estimating the area is difficult because the price at which the demand curve intersects the vertical axis is unknown, as well as the shape of the curve over the large range of quantities from zero to the forecast demand level (Q_2 in Figure 4).

Since the logsum reduces when new choices are added, it provides a ready way to estimate the benefit from introduction of a new mode, service or route. In our numerical example, say a third mode, C, with a time of 15 minutes is introduced in the project case, with the times for modes A and B unchanged at 20 and 30 minutes respectively. With 1000 users, the logit formula predicts a change of mode shares, A:B:C, from 816:184:0 in the Base Case to 320:72:608 in the Project Case.

The logsum consumers' surplus benefit estimate from introduction of mode C is

$$1000\ users \times \left[\frac{1}{-0.128} ln(e^{0.21-0.128\times20} + e^{-0.128\times30} + e^{-0.128\times15}) - \frac{1}{-0.128} ln(e^{0.21-0.128\times20} + e^{-0.128\times30})\right] minutes =$$

$$1000\ users \times [-9.46 - (-16.77)]\ minutes = 7306\ minutes$$

Note that even though the demand curve implied by a logit model approaches the price axis asymptotically, the consumers' area between the actual price and upwards to infinity is a finite amount.

Appendix D Cost–benefit analysis documentation and quality control

D.1 Introduction

The methods outlined above in T2 describe how a CBA should be undertaken. This appendix provides practical guidance on two further aspects of the CBA — documentation; and quality control.

As outlined in ATAP Part F4, the Business Case is the mechanism by which the overall merits and justification of an initiative are presented to decision-makers and funders. It should contain all of the information the decision-maker requires to make a fully informed decision. This should include all supporting material outlining the assumptions, assessment techniques and parameter values used in the assessment process, demonstrating that the appraisal is robust, defendable and reliable.

Internally, the project proponent should maintain good documentation and transparent benefit and cost calculations to facilitate its own quality control procedures as well as post-completion evaluations. The ex-post evaluations in BITRE (2018) found significant errors in some of the ex-ante CBAs reviewed. Some of these errors were simple mistakes that could have been avoided had a peer review or quality checking process been in place.

This appendix presents a checklist of items to cover in a good CBA report, or CBA component of an appraisal report. The checklist is at a high level, in order to be of relevance to a wide range of applications, from small to very large initiatives. In application, the level of detail will typically increase with the scale and complexity of the initiative. The level of detail will also vary between jurisdictions, and it is important for practitioners to discuss those details with the relevant bodies in their jurisdiction (e.g. Infrastructure Australia, the Australian Department of Infrastructure, Transport, Regional Development and Communications, and relevant State and Territory Departments).

The aims of this appendix are to:

- Promote consistency across the nation in the way CBAs are presented
- Ensure transparency, which will assist both reviewers and decision-makers
- Facilitate replicability of results. This increases the confidence of the robustness of assessments, and paves the way for successful ex-post reviews of CBA assessments
- Assist less experienced practitioners to implement good CBA reporting and quality assurance practices.

D.2 Documentation in a CBA Report

Table 6 presents what ATAP considers to be good practice regarding the content of a CBA report. Overall, the table aims to ensure the report:

- Introduces the initiative, existing problems, issues or opportunities and the CBA
- Explains the options being identified and assessed
- Describes the inputs used in the CBA
- Provides supporting explanations for the inputs used
- Presents and discusses the results of the CBA.

Table 6 also provides a basis for a potential chapter structure of a CBA report.

The ATAP worked examples (https://www.atap.gov.au/worked-examples/index) illustrate this. However, they do so at a high level only, and practitioners need to determine the required level of detail on a case-by-case basis for each initiative.

Table 6 Suggested structure and content of a best-practice CBA report

Structure	Relevant Section (2)
Chapter 1: Introduction	
• Name of initiative	
• Problem, issue or opportunity description (1)	F2
Chapter 2: Options being assessed	
• Base Case description	1.6
• Options / Project Cases descriptions (1)	1.7
– These descriptions should clearly describe the scope of works associated with each option.	
• Describe the assessment process by which the long list of options was reduced to a shortlist	F2, chapter 3
Chapter 3: Methodology, inputs and assumptions used in the CBA	
General	
• Perspective (standing or point of view) of the CBA	2.3
• Base year, price year	A2
• Construction period: start and end years; duration (years)	
• Operational period: start and end years; duration (years)	
• Assets: For each asset type: economic life, proportion of overall cost	Mode-specific guidance
• Appraisal period: Start and end years; duration (years)	2.4
• Real discount rate (%)	10.1
• Growth rates with projection method (compound or linear) across appraisal period for demand, benefits and operating costs	Chapter 4, mode-specific guidance
• Years for which benefits calculated and interpolation/projection method	6.1
Demand forecasts	
• Table(s) showing what initiatives are in, and what are out, of the Base Case and each Project Case for each modelled year. A clear description of the scope of those initiatives should also be provided, either here, in Chapter 3 or in an appendix. • Table(s) of demand (traffic/patronage) forecasts for key years of the appraisal period for: (1)	Chapter 4
– Base case	

Structure	Relevant Section (2)
– Project case	
– The change from the Base Case to the Project Case).	
Benefit and cost lists	
• Table listing:	2.1, 2.5
– Benefit and cost items included in CBA	2.1
– Classification of benefits and costs: monetised, non-monetised. Note any disbenefits (e.g. congestion disbenefits during construction, increased air pollution).	2.1, F4 chapter 3
– Classification of costs as investment or operating.	2.1, F4 chapter 3
– Other impacts excluded from CBA because they are secondary/flow-on	2.1
Time streams of individual benefits and costs, i.e. $ value for each year of appraisal period	
• Table showing time streams in *undiscounted* units in real terms (here or in an appendix):	
– Capital costs:	Chapter 3
- In Base case	
- In Option/project case	
- Cost increase from Base Case to Project Case	
– Each recurrent cost element (operating and maintenance):	Chapter 5
- In Base case	
- In Option/project case	
- Cost increase from Base Case to Project Case	
– Each benefit:	Chapters 6 to 9
- Base case outcome (e.g. generalised user cost, crash cost, revenue, etc)	
- Option/project case outcome (e.g. generalised user cost, crash cost, revenue, etc)	
- Benefit as the change in outcomes from Base Case to Project Case. Include physical units (base case, project case and change) either for the years they were calculated or for all years (e.g. hours of time saved by vehicle/trip/user type, crashes avoided by severity level) - Any helpful breakdowns, e.g. generalised user cost savings into components (e.g. travel time, vehicle operating costs, by beneficiary category such as private cars, business cars and commercial vehicles) - Any helpful breakdowns or groupings of benefit (e.g. benefits for existing trips, benefits for diverted and generated trips (using rule-of-a-half), producer surplus, taxes accruing to governments, externalities (e.g. environmental benefits or disbenefits), etc)	
– Residual value in last year of appraisal period noting the calculation method	Chapter 3
• For each individual benefit and cost, show summed totals of the time stream in *discounted* present value terms	Chapter 10
• For non-monetised benefits and costs, provide a genuine discussion of each item presenting evidence to demonstrate their scale.	
Assumptions	
• Assumptions relevant to the above items should be mentioned at the appropriate point in the Chapter. Any other assumptions should be mentioned at the end of the Chapter. Each assumption should be clearly documented, explained and justified either in this Chapter or the next. • Where a jurisdiction deviates from standard approaches set out in ATAP Guidelines, the proponent should explicitly disclose these here. Explanations of why and how the CBA departs from standard/recommended approaches should be provided in this Chapter or the next.	

Structure	Relevant Section (2)
Chapter 4: Supporting explanations of inputs, models and assumptions	
• Formulas used for calculating each annual benefit and recurrent cost element	
• Numeric application of the formulas for a given future year of the appraisal period to demonstrate replication of the time stream results in Chapter 3	
• For all aspects of the analysis, provide adequate supporting explanations, discussions and justifications to demonstrate that the analysis is robust, defendable and reliable	
• This should include discussions of: data, models (demand, cost, economic, etc), parameter values (e.g. unit value of travel time savings, unit crash costs, etc), any growth in inputs (e.g. growth in demand, real escalation in parameter values), ramp-up in benefits and costs, how NPV and BCR are calculated, how has the influence of related initiatives been taken into account in the analysis and the results, processes, etc • Where changes have been made to capital or operating costs during the course of the appraisal, a history of those changes should be clearly documented. The resulting implications for the CBA should be explained, particularly if any real escalation has been added.	
Chapter 5: CBA results and conclusions	
• Table(s) showing for each option/project case:	
– CBA results (NPV, BCR1, BCR2, FYRR, IBCRs if relevant) for:	Chapter 10
- The central appraisal case	Chapter 10
- Relevant sensitivity test cases	Chapter 10
- If calculated, probabilistic CBA results. – Accompanying breakdown into benefit and cost elements (all calculated as changes from Base Case to Project Case), consistent with Chapter 3 – For sensitivity tests provide: - Key indicator (NPV, BCR, etc) results in the main text - A full breakdown of results for each test in an appendix. For best practice, also provide for each sensitivity test the undiscounted time streams. These can be located in an appendix.	T7
• Where appropriate, how robust are the costs and benefits of each project case across different future scenarios?	
• Charts showing the results visually	
• Any required supporting discussion of the table of results, including qualifications and caveats	
• Provide details of any independent reviews of the CBA and its inputs	
Appendices	
• Appendices of any dense, complex, abstract and highly technical material that has been placed in an appendix to maintain readability of main text	
References	
• Reference list of all published and unpublished reports, websites, etc that have been referred to or are sources for data and information used in the analysis	
• Provide web addresses where possible	
• Copies of key supporting reports would generally be made available	

Notes: 1. Where these are already provided in detail elsewhere in the Business Case, provide a brief summary and suitable cross-references.
2. In ATAP Part T2 unless otherwise stated.

Computerised CBA model

Separate to the CBA report, but equally important, is the computer model used to undertake the analysis. This usually consists of an Excel workbook, but sometimes consists of a model written in another software platform and/or language. This should be made available to any reviewer and funding body. Adequate documentation of how the model is laid out and works is also required. This could be undertaken within the model, in a separate report on the model, or as an appendix of the CBA report.

Distributional impacts

An assessment of the distributional impacts of an initiative is a key element of an appraisal — that is who gains and who loses from the initiative. A discussion of the distributional impacts would feature in a Business Case. A brief summary of the distributional impacts can be also be included in the CBA report.

D.3 Quality control

Quality control here refers to a process of checks used whilst undertaking a CBA to minimise the number of errors. These checks should be undertaken throughout the CBA process.

Table 7 provides an indicative series of quality checks.

Table 7 Quality assurance checks

Item	Check
Content	Check that the requirements of ATAP Part T2, as summarised in Table 6, have been reflected in the analysis
Data entry	Check input data are entered correctly on a regular basis
Data verification	Verify that the same data items for versions of the CBA are the same. Check for correct and consistent use of CBA decision rules. Ensure NPV and BCR are estimated with the most up-to-date parameter values. Ensure user benefits are not included during the project construction stage (before the project has been completed). Equally, ensure that any disbenefits during the construction period occur only during the construction period.
Real and nominal prices	Ensure that costs and benefits are expressed in real terms for the same price year
Changes in scope	A CBA can only be undertaken for a specific scope. If the scope changes, the CBA must be redone. Different scope can also be considered as different project options. Timing and delivery. In conjunction with scope changes, adjust the timing and delivery of a project's timeline. Re-estimate the CBA if necessary. Project assumptions. Identify if there are any changes in project assumptions associated with any changes in the project scope. Project methodology. Identify if there are any changes to the project methodology associated with any change in the project scope.
Version control	When a new version of the CBA has been completed and the results changed, ensure all material reporting or referring to the results has been updated. Ensure that the Executive Summary, main body of the report and appendices are consistent. Technology upgrades, e.g. migration of IT platform in organisation, new software versions. The CBA model and results should be readable and replicable in the new platform or the latest version of software
System of quality checks	Peer and supervisor review. Implement a system of quality checks, i.e. peer review, supervisor review and finance audits (if necessary) — the scale of which should match the scale and complexity of the initiative. It is noted that a finance audit involves the examination and verification of a project's financial budget. The audit of the budget figures is critical as it forms part of the cost input items in CBA. Change management process. For changing project initiatives, implement a change management system, e.g. supervisor review, finance audits, IT works (if necessary) and authorisation from senior personnel in the organisation
Documentation	Ensure that a CBA report has been written Check that the report complies with the content of Table 6. To facilitate future Performance Review and Post-completion Evaluation (ATAP Part F7) and implementation of the Benefit Management Plan (ATAP Part T6), ensure all electronic files (including model inputs and outputs) and printed copies of documents are assembled and stored where they can be easily located.

Source: Adapted from Austroads (2012), IA (2018 Table 20).

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