GUIDE TO PROJECT EVALUATION

Part 2: Project Evaluation Methodology
Guide to Project Evaluation
Part 2: Project Evaluation Methodology

Summary
Part 2, Edition 2 includes the insertion of Commentary F – Documentation and Quality Control of Benefit-Cost Analysis, and Commentary G Small Travel Times Savings, along with additional references.

Part 2 provides guidelines for conducting benefit–cost analysis (BCA) and multi-criteria analysis (MCA) on public transport infrastructure projects, policies and programs—any choice in fact that can be characterised in terms of positive and negative economic impacts. Its aim is to foster good practice, consistency and transparency in the evaluation of transport projects. A tool (Risk Explorer™ software) used for identifying, assessing and analysing risks related to uncertain factors impacting on project benefits and costs is included to help the practitioner perform a risk assessment and analysis.

Keywords
Transport project evaluation, benefit cost analysis, benefit cost ratio, economic/impact/multi criteria analyses, risk analysis in project evaluation, Risk Explorer™ software tool

First Published 2005
Second Edition 2012

© Austroads Ltd 2012

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without the prior written permission of Austroads.

National Library of Australia Cataloguing-in-Publication data:
ISBN 978-1-921991-54-7

Austroads Project No. TP1113
Austroads Publication No. AGPE02-12

Authors
Nigel Rockliffe
Sarah Patrick
Dimitris Tsolakitis

Published by Austroads Ltd
Level 9, Robell House
287 Elizabeth Street
Sydney NSW 2000 Australia
Phone: +61 2 9264 7088
Fax: +61 2 9264 1657
Email: austroads@austroads.com.au
www.austroads.com.au

This Guide is produced by Austroads as a general guide. Its application is discretionary. Road authorities may vary their practice according to local circumstances and policies.

Austroads believes this publication to be correct at the time of printing and does not accept responsibility for any consequences arising from the use of information herein. Readers should rely on their own skill and judgement to apply information to particular issues.
CONTENTS

1. INTRODUCTION TO BENEFIT COST ANALYSIS ................................................................. 1
2. PROJECT DEFINITION ....................................................................................................... 2
   2.1 Scoping the problem .................................................................................................... 2
   2.2 Identifying options ..................................................................................................... 3
   2.3 Project interdependence ............................................................................................ 4
   2.4 Sustainability and other constraints ........................................................................... 5
   2.5 Level of analytical effort ........................................................................................... 6
3. ANALYTICAL PROCEDURES ............................................................................................ 7
   3.1 Discount rate ............................................................................................................ 7
   3.2 Discount period ......................................................................................................... 8
   3.3 Community of interest ............................................................................................. 8
   3.4 Planning horizon ...................................................................................................... 9
   3.5 Prices ....................................................................................................................... 9
   3.6 Numéraire, price year, and base year ..................................................................... 9
   3.7 Treatment of inflation ............................................................................................. 10
   3.8 Use of ‘expected’ values ......................................................................................... 11
4. TYPES OF IMPACTS ....................................................................................................... 12
   4.1 Impacts on operators .............................................................................................. 13
   4.2 Impacts on users ..................................................................................................... 13
   4.3 Impacts on non-users ............................................................................................ 14
   4.4 Impacts excluded from BCA .................................................................................. 15
5. ANALYSIS ....................................................................................................................... 18
   5.1 Decision criteria ..................................................................................................... 18
   5.2 Multi-criteria analysis ............................................................................................. 20
   5.3 Decision context ..................................................................................................... 22
   5.4 Scenarios ............................................................................................................... 23
   5.5 Sensitivity analysis ............................................................................................... 24

ANNEX TO PART 2: RISK ANALYSIS ................................................................................. 26

Risk analysis in project evaluation ................................................................................. 26
Identifying sources of risk ................................................................................................. 26
Process of risk analysis ...................................................................................................... 28
Results from the risk analysis process ............................................................................. 33

PART 2: COMMENTARIES .................................................................................................. 34

COMMENTARY A: INTRODUCTION TO BENEFIT–COST ANALYSIS ................................ 34
   A.1 Where markets fail ................................................................................................. 35
   A.2 That is where BCA comes in ................................................................................ 35
   A.3 An ambitious goal ................................................................................................. 36
   A.4 The BCA toolkit ................................................................................................... 36
   A.5 Economic efficiency .............................................................................................. 37
   A.6 Method ................................................................................................................. 37
   A.7 Uses of BCA ........................................................................................................ 38
   A.8 Triple Bottom Line ............................................................................................... 38

COMMENTARY B: IMPACTS ............................................................................................... 40
   B.1 Determining what is a cost and benefit ................................................................. 40
   B.2 Internal versus external impacts ........................................................................... 40
   B.3 Economic versus financial impacts ....................................................................... 40
TABLES

Table 2.1: Composition of options composed three interdependent projects ........................................ 5
Table 4.1: Impacts .................................................................................................................................. 12
Table 5.1: Decision criteria .................................................................................................................. 18
Table 5.2: Payoff matrix: value of option, by scenario ...................................................................... 24
Table 5.3: Suggested rules for sensitivity analysis ............................................................................. 25
Table Annex.1: Traffic forecasting and modelling uncertainty ........................................................... 27
Table Annex.2: Construction cost uncertainty ................................................................................... 28
Table A.1: A comparison of financial analysis and BCA ................................................................. 37
Table E.1: Qualitative measures of likelihood ..................................................................................... 49
Table E.2: Qualitative measures of impact .......................................................................................... 49
Table E.3: Combining likelihood and impact ...................................................................................... 50
Table E.4: Risk identification and rating table ................................................................................... 50
Table E.5: Example of classification ratings for Base Travel Demand uncertainties .................... 51
Table F.1: Checklist of assumptions and modelling inputs ............................................................... 59
Table F.2: List of monetised BCA unit values and volume measures .............................................. 62
Table F.3: Presentation of BCA results ............................................................................................... 63
Table F.4: Sensitivity testing ................................................................................................................ 65
Table F.5: Presentation of non-monetised BCA results ....................................................................... 67
Table F.6: Quality assurance for BCA checklist ................................................................................ 68
Table F.7: Deliverability assessment .................................................................................................. 70
Table G.1: Current practice – for valuing small travel time savings ................................................ 76
FIGURES

Figure 2.1: Scoping a road congestion problem ................................................................. 2
Figure 2.2: Defining the base case option ........................................................................ 3
Figure 2.3: Types of project interdependence ................................................................. 4
Figure 2.4: Natural capital and sustainable development ..................................................... 5
Figure 3.1: Discount factors, by discount rate and planning horizon ................................. 7
Figure 3.2: Temporal aggregation of monetary impacts ...................................................... 8
Figure 3.3: Compounding and discounting to the base year .............................................. 10
Figure 3.4: Selected inflation indexes (1996 = 100) ......................................................... 11
Figure 5.1: Recommended IRR Reporting ..................................................................... 19
Figure 5.2: Example BCA and MCA analysis ................................................................ 21
Figure Annex.1: Example probability distributions ......................................................... 29
Figure Annex.2: Cumulative distribution function ......................................................... 30
Figure Annex.3: Monte Carlo sampling ......................................................................... 30
Figure Annex.4: Latin Hypercube sampling .................................................................. 31
Figure Annex.5: Example of a histogram: output from risk analysis .............................. 32
Figure Annex.6: Example of a tornado diagram: output from risk analysis ................... 32
Figure Annex.7: Probabilistic Outcome Distributions ..................................................... 33
Figure B.1: Impacts classified by monetisability and quantifiability ............................... 41
Figure C.1: Social cost of traffic flow ............................................................................. 43
Figure E.1: Risk management overview ....................................................................... 48
Figure E.2: Probability density function ....................................................................... 52
Figure E.3: Cumulative distribution function corresponding to PDF ......................... 52
Figure E.4: An example of triangular distribution ......................................................... 53
1. INTRODUCTION TO BENEFIT COST ANALYSIS

This document is Part 2 of the Austroads Guide to Project Evaluation (the Guide). It provides guidelines for conducting benefit–cost analysis (BCA) and multi-criteria analysis (MCA) on publicly provided transport infrastructure projects, policies and programs—any choice in fact that produces positive and negative economic impacts.

Its aim is to foster good practice, consistency and transparency in the evaluation of transport projects. It does so by setting out a comprehensive set of procedures and assumptions to be incorporated in all evaluations, and by recommending an accessible and standardised format for the presentation of results. However, it is not a textbook on the theory of BCA, nor a ‘how-to’ guide for novices, but demands a basic knowledge of appropriate skills before it can be safely used. A BCA checklist on how assumptions, tasks, key parameters and measures can be applied in project evaluation is provided in Commentary F.

Although Part 2 is applicable to most projects requiring evaluation, it excludes the following classes of project that raise methodological problems that should be left to specialists:

- very large projects with complex impacts (these will be identified as such by their sponsoring agencies)
- projects—typically public-private partnerships (PPPs)—that require a kind of accounting-based analysis known as financial analysis that is not covered by the Guide.

Part 2 does not deal with the following issues:

- determination of parameters - which requires specialised skills that are not only beyond the scope of the Guide but in any case unnecessary, as the work has been done elsewhere
- determination of capital budgeting and sustainability constraints - which are policy matters that should be left to sponsoring agencies
- determination of regional and macroeconomic impacts - which demands specialised analytical techniques that are too complex to be covered in Part 2. However, it is rare for such impacts to constitute net benefits, so their omission is unlikely to affect the worth of a project. For more information about this issue see Part 5: Impact on the national and regional economies.

[1]Technical terms in this document are hyperlinked and further described in the Glossary at the end of Part 2.
2. PROJECT DEFINITION

Project definition is a crucial stage of the analysis. Unless the best option is among those to be analysed, there is no possibility of selecting it, however competently the rest of the analysis is carried out.

2.1 Scoping the problem

Once a potential project has been identified, the next task is to scope the problem that the project is intended to address. Scoping requires that the problem be defined in such a way that all potential solutions are considered, so that it is possible to test objectively whether the problem has been solved or not. Its purpose is to help the analyst define a set of options all of which demonstrably solve the problem and which include the global optimum. Consider a congested road. The problem could be progressively defined as:

- a narrow engineering issue (widen or re-engineer the road)
- a wider engineering issue (build a bypass)
- an urban planning issue (change land-uses in the vicinity)
- a local pricing issue (tolling), or
- a network pricing issue (introduce general road pricing).

These definitions greatly affect the range of options to be considered, and probably also affect the optimal choice of option. In general, the wider the scope of the problem, the more options there are to analyse, but the more likely that one will be globally optimal.

![Figure 2.1: Scoping a road congestion problem](image)

It is the analyst’s task to trade off work effort against probability of ‘capturing’ the global optimum in this analytical net. As the scope of the problem grows, not only are there more options to analyse, but the analysis gets more complicated. In this case, analysing a network-wide road pricing scheme is vastly more difficult than analysing a few engineering works. Of course, some options may be ruled out on political grounds. If so, the ground rules must be made explicit in advance.
2.2 Identifying options

2.2.1 Base case option

It is meaningless to ask the value of an option without first defining a reference point against which to measure it. This means that every project is represented by at least two options, one of which is the option against which all the others are compared.

This option is termed the base case option, and normally reflects the best that management can do without significant additional investment. It is the typical 'business-as-usual' option. It is not necessarily an extrapolation of past trends, though this may be an acceptable approximation. Rarely is it the same as the 'do-nothing' option (even if to do nothing is even feasible), and rarely does it equate to the 'before project' situation.

2.2.2 Project options

The other options represent the variants of the project that are to be analysed. They are developed only after the project is correctly scoped. The following commentary provides an example of defining base case and project options. Consider the following situation. A particular transport link is providing a benefit that is growing through time (see figure below). An improvement project is undertaken in year 2 that entails capital expenditure but increases the level of benefit thereafter. The value of the project is given by (1) the net benefits with the project in place, less (2) the benefits without the project—known as a 'with-and-without' analysis. This is the correct way to value a project because it allows for the fact that in its absence, benefits could (and usually do) change. Under this approach, the 'without project' option is the 'base case' option.

It is important to define the base case correctly as it affects the value of the 'with project' option or options. For instance, if the base case is wrongly assumed to be the same as the 'before-project' situation, and if benefits are growing (normally the case), project impacts will be overstated. This will not change the ranking of other options, as all are affected equally, hence the same optimal option will be identified. But it will alter the apparent performance of the project relative to other projects, which leads to misallocation of resources.

![Figure 2.2: Defining the base case option](image_url)
2.3 **Project interdependence**

When one project affects the performance of another, the projects are said to be interdependent. This complicates the analysis. The commentary outlines types of project interdependence. Consider two projects that, in isolation from each other, are valued at $A$ and $B$ respectively. Now consider their value in combination, $C$.

**Independence.** If both projects have no effect on each other, their combined value is the sum of their values in isolation: $C = A + B$. This is the case with most projects.

**Synergy.** If both projects reinforce each other in some way, their combined value is greater than the sum of their values in isolation: $C > A + B$. This is the case with projects that share joint costs (for instance, pedestrianisation and the construction of new road or rail links), or whose benefits are complementary (for instance, road safety enforcement and road safety publicity).

**Negative synergy.** If both projects interfere with each other in some way, their combined value is less than the sum of their values in isolation: $C < A + B$. This is the case with safety projects that target the same traffic, since a life saved by one project cannot be saved again by another.

**Mutual exclusiveness.** If both projects completely negate the effect of the other, their combined value is the greater of $A$ or $B$: $C = A \mid A > B$; $C = B \mid A < B$). This is the case when both perform essentially the same task in different ways, for instance two different bridge designs for the same location, or two different timings for the same project.

Separate procedures exist for analysing independent projects and mutually exclusive projects, which are discussed later. This leaves projects exhibiting negative and positive synergy. The simplest procedure here is to define another project representing the combination, and to analyse it in the usual way, either in the context of independent projects or of mutually exclusive ones, as appropriate. If there are $n$ interdependent projects, there are $2^n$ combinations, each with a possibly unique value (see Table 2.1).
Table 2.1: Composition of options composed three interdependent projects

<table>
<thead>
<tr>
<th>Option</th>
<th>Project A</th>
<th>Project B</th>
<th>Project C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Option 2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Option 3</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Option 4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Option 5</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Option 6</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Option 7</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Option 8 (Base case)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Key: 0 = excluded; 1 = included.

Clearly, project synergy is desirable and normally, synergistic combinations are to be preferred over their constituent projects in isolation. At the same time, negative synergy does not necessarily condemn a project. For instance, airbags may still be worthwhile even though their benefit is lessened once seatbelts are installed.

2.4 Sustainability and other constraints

Sustainability is one of the most misunderstood concepts in environmental economics. Often it is no more than a vague claim that a project is environmentally benign. This is unfortunate, as the notion of sustainability is both of vital importance and capable of precise meaning in economics.

The World Commission on Environment and Development (or Brundtland Commission) defined sustainability as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’.

Pearce and Barbier (2001) provide another description of sustainability, shown below.

![Figure 2.4: Natural capital and sustainable development](source: Adapted from Pearce and Barbier (2001)).
Translating this principle into practice is not without difficulty or contention. But that is not the concern of Part 2. To the extent that transport agencies aim to be sustainable, they will translate that aim into practical rules for practitioners.

Although often variously described as a goal, aim or objective, sustainability is quite unlike the objective of economic efficiency that guides BCA. It is more helpful to regard it as a constraint; a condition to be satisfied and which constrains the design and selection of project options. For instance, a project that destroyed irreplaceable and rare flora or fauna might be ruled out because it violates a sustainability constraint. By definition such constraints are imposed from outside the BCA framework and not determined within it.

Sustainability is not the only source of constraints on project definition and selection. Others concern ethical values, health and safety, and, naturally, the law. One might even regard distributional fairness, or equity, as a constraint of this kind. The Austroads Transport Planning Guide provides more information on sustainability, while Part 6 examines distributional (equity) effects.

2.5 Level of analytical effort

The appropriate level of effort to be devoted to the analysis is a matter of judgement. In making it, the analyst should pose the following questions.

- **Does the project warrant formal analysis?** Small projects may not warrant any individual BCA analysis at all. Instead, they could be analysed generically. Traffic-based warrants are an example, whereby certain generic treatments are deemed to be justified depending on the level of traffic and other characteristics of the link to be treated. Developing warrants of this kind can be analytically difficult, but is worthwhile if they can be widely applied with little additional analytical effort.

- **What is the value of the incremental effort?** At each level of analytical effort, ask what the cost is of increasing it, and the value to be gained by doing so. It never makes sense to spend more than is warranted by the additional accuracy. Only in the case of very large projects will it be worthwhile to formally estimate the optimal level of effort.

- **Will it change the decision?** At each level of analytical effort, ask whether increasing the effort could change the decision as to the preferred option, and if so, what difference it makes to the value of the preferred option.

- **Are all options analysed with the appropriate level of precision?** In general, options with similar levels of performance should be analysed to similar levels of precision. Otherwise there is a risk that the selection will be biased. Likewise, options that perform well above the level required for acceptance can tolerate a lower level of precision.

As a rule of thumb, the cost of analysing a project should not exceed 1% of the value of the project. However, note that it is always the value of the incremental effort that determines when to stop, not the value of the total effort. So for instance, if the value of the incremental effort declines rapidly, or is small to begin with, it may not be worth putting much effort into the analysis, even if the project is large.
3. ANALYTICAL PROCEDURES

This section consists of a checklist of analytical procedures and underlying assumptions. Its purpose is to establish the analytical ‘rules of the game’, so that all options are evaluated on a consistent basis.

3.1 Discount rate

The discount rate is used to calculate discount factors, which can be regarded as ‘exchange rates’ for converting values at one period to values at another. For instance, the discount factor in real terms over 30 years at 7% p.a. is 0.13, which means that $1 in 30 years time ‘converts’ to about 13 cents now. The recommended annual discount rate for public transport infrastructure projects is currently 7% in real terms.

![Discount factors chart](image)

Note: Chart is for illustration only and should not be used to obtain discount factors.

Figure 3.1: Discount factors, by discount rate and planning horizon

Discount rates are determined by state Treasuries. The calculations underlying them are complex and beyond the scope of the Guide. As a simplification the discount rate has two components: the social discount rate and a premium for the riskiness of the project in question.

The social discount rate is the amount needed to compensate society for the postponement of present consumption, and the risk premium is the amount needed to compensate it for accepting a risky outcome. Since the social discount rate is believed to vary slowly if at all, and since most infrastructure projects covered by Part 2 carry little risk, the discount rate recommended for them seldom if ever changes.

2 This is generally true of smaller transport projects, which are those covered by this document. These include road upgradings and the like. It may not be true of very large projects, especially ones whose benefits materialise slowly. However, the evaluation guidelines for such projects, including the risk-adjusted discount rate, will typically be specified by the sponsoring agency on a case-by-case basis, although they would desirably accord with this document as far as possible.
3.2 Discount period

When discounting, economic impacts are normally aggregated into discrete discount periods, and as an approximation are all deemed to occur at a single instant in the middle of the period in which they fall. Normally it is sufficiently accurate to use the calendar or financial year as the discounting period. Although this understates the value of impacts that occur early in the year, it overstates those occurring late; and the errors tend to cancel out.

However, to avoid possible error the analyst may in some cases prefer to use a shorter discount period—quarters, months, or conceivably weeks. If so, the discount rate must be re-expressed in different time units. Compounding must be allowed for, so a discount rate of 12% per annum, say, does not equate to 1% per month but 0.9489%, this being the monthly rate that, when compounded, equates to 12% per annum.

![Temporal aggregation of monetary impacts](image)

As an approximation, quarterly impacts can be aggregated to annual ones that are deemed to occur at the mid-point of each year.

3.3 Community of interest

Whose impacts should be considered in estimating the value of a project? Should concern be limited to residents of the jurisdiction in which the project is located, or should all affected persons be included, wherever they live?

For most projects and most types of impact the question hardly arises. Most users are likely to be from within the state and those affected by its environmental impacts are mostly locals. But there are exceptions. Some interstate and tourist roads carry many overseas and interstate users and some environmental impacts (for instance climate change through the emission of greenhouse gases) impinge mainly on non locals.

Although a case could be made for ignoring the interests of residents of other jurisdictions, it complicates the analysis as few data sources distinguish the residency of affected persons. For these reasons, it is convenient (as well as equitable, perhaps) to define the community of interest as all affected persons.
3.4 Planning horizon

Ideally one would adopt a planning horizon long enough to accommodate all material impacts, however far in the future they lie, but in practice it is usually adequate to limit the analysis to a planning horizon of 30 years (50 years for rail projects). Few built assets last longer than that, and few impacts amount to much when discounted over such a period.

There are two main circumstances under which the planning horizon must be extended, or if not, allowance must be made for impacts beyond the planning horizon.

- **Assets with long economic lives.** Long-lived assets require a residual value equal to their forecast market value to be inserted in the last year of the analysis. The longest lived asset in most projects is land. If the land has an alternative use (for instance, industrial land for a freight terminal) it should be included as a cost at the beginning, and a residual value at the end. But this is unusual in transport projects, where most land is needed for rights-of-way and is unlikely ever to be relinquished. In such cases it is normally best to ignore land altogether.

- **Recurrent impacts of long duration.** Long-lived recurrent impacts and perpetuities require a residual value to be inserted in the last year of the analysis. The residual value should equal the net present value of the missing impacts.

3.5 Prices

**Shadow prices** often diverge from market prices. There are two main reasons for this. First, market prices generally include taxes and subsidies that must be excluded as they are a transfer within society and not a use of valuable resources. Second, many impacts (such as noise and other forms of pollution) have no market price as no market for them exists.

For these and other reasons, the computation of shadow prices is complex and beyond the scope of the Guide. Instead, shadow prices will be provided to the analyst as prices and unit costs for the calculation of impacts.

3.6 Numéraire, price year, and base year

The choice of numéraire is governed mainly by convenience: it should be one that readers are familiar with, and into which all economic impacts can be readily converted. This requires us to specify a particular national currency at a particular point in time, namely the price year. In general, the numéraire currency is Australian or New Zealand dollars, as appropriate; and the price year is the current year.

The base year is the year to which all impacts are discounted or compounded. For small projects, the base year is normally the first year of the project. But for large, long-lived projects, in which operation may be preceded by many years of design and construction, there are two widely used approaches. The base year is commonly defined as the year immediately preceding construction. Alternatively, it is the last year of construction, or the year immediately preceding operation.\(^3\)

For smaller projects the base year is typically the same as the price year. But for large projects they may differ. Consider a project designed to commence in, say, 2010; one might calculate its net present value in 2009 but measured in dollars of today.

\(^3\) A helpful convention is to number project years (or periods) with the base-year as zero. Years succeeding the base year are numbered ‘1, 2, 3…’, and years preceding it (if any) are numbered ‘-1, -2, -3…’. Cash flows that take place before the base year are compounded, and those after it discounted. Numbering years in this way allows the year to be used as a variable in discounting formulae.
3.7 Treatment of inflation

Inflation distorts the yardstick by which value is measured. The simplest way to allow for it is to remove it from the analysis at the outset. This is done by converting economic impacts at nominal prices (if any) to real prices. Past nominal impacts should be deflated by the inflation index endorsed by the particular agency, such as the official consumer price index (CPI). Forecast nominal impacts should be deflated by removing inflation at the same rate as was assumed when the forecasts were prepared.

Sometimes escalation indices are used in forecasting costs. Depending in how they were derived, such indices may be either nominal or real. If nominal, they must be converted to real by removing the inflation embodied in their construction. For instance, nominal escalation of 5% pa with inflation of 2% pa equates to real escalation of approximately 3% pa.4.

Inflation is normally only included in an analysis when the results are to be used by commercial lending institutions and not public sector agencies, in which case it is also customary to produce nominal pro forma financial statements, which are always in nominal terms. This type of analysis, known as financial analysis, is beyond the scope of the Guide.

4 More precisely slightly less than 3% since it can be shown that the nominal discount rate is equal to the sum of the discount and inflation rates plus their multiple. If the rates are small, as they usually are, then their multiple can normally be ignored.
3.8  Use of ‘expected’ values

This document adopts a deterministic approach to project analysis; that is, the variables in the analysis are point estimates, not stochastic variables described by probability distributions (see Annex to Part 2 Risk analysis below for a stochastic approach to project evaluation). But since most variables are subject to uncertainty, a general rule is needed for selecting which value from the variable’s probability distribution to use in the deterministic analysis. The rule is that each variable should be given its ‘expected’ value, that is, the average value it would have in the long run.

This rule should be borne in mind particularly when interpreting engineering cost estimates. Often these include amounts termed ‘contingencies’. If a contingency represents costs that the engineer believes are present but cannot be identified, then it should be included. But if it is included so as to diminish the likelihood of a cost overrun, then it should be excluded. This practice implies that (if the probability distribution of a cost is symmetrical) there should be an equal likelihood of its being overestimated as underestimated. Note that some so-called contingencies are mixtures of both types, in which case the engineers should be required to separate them.

Figure 3.4: Selected inflation indexes (1996 = 100)
4. TYPES OF IMPACTS

An impact is any cost or benefit attributable to a project. In Part 2, impacts included in BCA analyses are classified by the party that is affected by them. Because impacts can just as easily increase as decrease, it is generally unhelpful to classify them as costs or benefits.

Impacts are identified and briefly described on the following page. Commentary B provides further guidance on classifying impacts of transport projects. Part 4 of the Guide to Project Evaluation, contains valuation parameters for use in BCA valuations, and instructions on their use.

[see Commentary B]

<table>
<thead>
<tr>
<th>Affected party</th>
<th>Impact</th>
<th>Main components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>Capital items</td>
<td>New construction, Rehabilitation, Land acquisition/disposal, Environmental mitigation, Routine maintenance, Network management</td>
</tr>
<tr>
<td></td>
<td>Network operation</td>
<td>Fuel and lubricants, Repairs and maintenance, Economic depreciation, Tyres</td>
</tr>
<tr>
<td>Users a</td>
<td>Vehicle operating cost (VOC)b</td>
<td>Mean walking time, Mean waiting time, Mean in-vehicle time, Variability of trip time, Death, pain and suffering, Property damage, Emergency services etc.</td>
</tr>
<tr>
<td></td>
<td>Travel time</td>
<td>Mean delivery time, Variability of delivery time, Damage in transit</td>
</tr>
<tr>
<td></td>
<td>Crashes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freight performance</td>
<td></td>
</tr>
<tr>
<td>Non-users</td>
<td>Noise</td>
<td>Engine noise, Tyre noise, Small particulates (PM_{10}), Oxides of nitrogen (NO_x), ozone (O_3), Carbon monoxide (CO), Oxides of sulphur (SO_x), Volatile organic compounds etc. Visual intrusion, Loss of flora and fauna, Pedestrian walking time, Greenhouse gases (GHGs)</td>
</tr>
<tr>
<td></td>
<td>Air pollution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nature and landscape</td>
<td>Visual intrusion, Loss of built environment</td>
</tr>
<tr>
<td></td>
<td>Severance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Climate change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culture and heritage</td>
<td></td>
</tr>
</tbody>
</table>

Note:
(a) Congestion is not separately classified as it manifests itself in terms of other impacts.
(b) Although VOC normally apply to road vehicles, they have their analogs for other modes: rail (train operation costs), sea (ship operation costs), and air (aircraft operation costs).
(c) Not to be confused with accounting depreciation, which is excluded from BCA.
4.1 Impacts on operators

There are no standardised rules for calculating impacts on transport agencies, as projects and agencies differ too much one from another. Instead, estimates must be worked up using conventional cost engineering methods. Most agencies provide internal guidelines for this.

4.1.1 Capital items

Transport agencies are generally responsible for building infrastructure. This means they incur capital expenditure to expand and rehabilitate it. Less commonly, they dispose of assets, usually land. The main types of capital item are new construction (including design and project management), rehabilitation, land acquisition and disposal, and environmental mitigation (noise barriers, fencing, landscaping etc.). Capital items may be both costs or benefits: costs when assets are purchased or constructed; benefits if assets are disposed of (though land is normally the only capital item affected in this way).

4.1.2 Network operation

Besides building networks, transport agencies may be responsible for operating them. The main recurrent items are routine maintenance and network management. Network operation is costed at long-run marginal cost, meaning that most recurrent costs and overheads, which are fixed in the short run, are treated as variable in the long run.

4.2 Impacts on users

User impacts are calculated using algorithms driven by traffic volume and parameters representing unit costs, more precisely, shadow prices for the impact in question. For simple projects the analyst simply multiplies the appropriate parameter by the traffic volume.

Large projects in dense networks are usually evaluated by means of transport models that incorporate algorithms for calculating user impacts, as it can be hard to predict how traffic will divert from one link to another in response to the project, particularly if there is congestion. Commentary C provides further information on transport models, congestion and road pricing.

4.2.1 Vehicle operating cost

Vehicle operating cost (VOC) is the cost to the owner of operating a motor vehicle (or its analogs for other modes: trains, ships and aircraft). It mainly comprises the cost of fuel and lubricants, repairs and maintenance, and tyres. It is expressed as a rate per vehicle-kilometre, and is largely a function of vehicle type, speed, road condition (or its analog for other modes), and the prices of inputs such as fuel and vehicles (see Part 4).

4.2.2 Travel time

The value that travellers place on time spent travelling depends on the type of person travelling and the purpose of the trip. The most elaborate measures of travel time distinguish between time spent walking to and from vehicles or public transport, waiting time (for public transport), and in-vehicle time. Travel time is expressed as a rate per vehicle-kilometre, and is largely a function of vehicle type (as a proxy for the number of occupants), speed, and trip purpose (see Part 4).

Recent developmental work on small travel time savings and their possible implications for project evaluation are included in Commentary G.
The currently accepted best practice in relation to the treatment of small travel time savings is that, at this stage, there is no definitive conclusion that can be readily applied to the economic appraisal of road projects.

Based on the data and findings of the recent literature review (see Austroads Project TP1444 Part 3 referenced as Austroads 2011b), at this stage, it is recommended that the current practice of using the same unit value of time (for a given traffic type), for both small and large time savings, continues to be applied when evaluating time savings.

If jurisdictions decide to use non-standard values of time they will need to justify these values separately. [see Commentary G]

### 4.2.3 Crashes

The social cost of crashes is the cost to society of the trauma and property damage occasioned by crashes. For road travel, social cost is conveniently expressed as a cost per vehicle-kilometre (that is, a level of risk), and is largely a function of road type. Some algorithms distinguish the type of vehicle as a proxy for the number of occupants and the level of safety embodied in the vehicle itself. Analogous calculations are possible for non-road modes, but since they are very much safer than road travel, the social cost of accidents on these modes is normally very small (see Part 4).

### 4.2.4 Freight performance

In much the same way that vehicle occupants place a value on their own time and safety, so the shippers of freight place a value on receiving shipments in full and on time. Freight-related benefits depend on:

- mean delivery time
- variability of delivery time
- damage in transit
- type of vehicle.

Apart from the obvious gains to shippers, a prompt, reliable and secure freight service sometimes allows consigners and consignees to be more productive in their core activities; and the fact that these benefits are realised ‘off-road’ (so to speak) does not make them less relevant for transport evaluation (see Part 4).

### 4.3 Impacts on non-users

Like user impacts, non-user impacts are calculated using algorithms driven by traffic volume and impact-specific parameters. Unlike user impacts, the valuation of some non-user impacts demands additional information about the number and nature of affected parties. For instance, noise affects people living and working near the source, and does so to varying degrees. Air pollution is similar, though its effects carry further than noise.

#### 4.3.1 Noise

Traffic is noisy. Noise is disliked by those who are subjected to it, and exposure has been linked to certain illnesses (see Part 4).
4.3.2 **Air pollution**

Vehicles emit a variety of noxious air pollutants, whose effects on human health and property are only partly understood. These pollutants include ultrafine particulates (those less than 10 microns in diameter), ozone, and oxides of nitrogen and sulphur—all implicated in respiratory and other diseases; plus volatile organic compounds including benzene, some of which are known to be carcinogenic (see Part 4).

4.3.3 **Nature and landscape**

Major transport links sometimes cause visual blight, and can harm flora and fauna by destroying and severing habitats. It is hard to devise general rules for valuing such impacts as they depend very much on circumstances. Nevertheless, valuation parameters have been developed for the more commonly encountered situations (see Part 4).

4.3.4 **Severance**

Major transport links sever communities by being hard for pedestrians and in the case of freeways, for drivers to cross. Bridges and underpasses alleviate the problem, but do not eliminate it (see Part 4).

4.3.5 **Climate change**

Vehicles emit carbon dioxide, the principal (though not most potent) greenhouse gas. Unlike other types of air emission, greenhouse gases have a global impact, which makes their valuation independent of local land-uses (see Part 4).

4.3.6 **Culture and heritage**

The loss of cultural heritage is analogous to the loss of natural assets (described above) from human activity. No generalised rules exist for this type of impact as individual circumstances are too variable. Instead, principles are given for evaluating individual cases on their merits.

4.4 **Impacts excluded from BCA**

The following impacts should *not* be included in BCA analyses, although some are properly included in a distributional analysis which is discussed in Part 6.

4.4.1 **Sunk costs**

*Sunk costs* are excluded because they should not affect decisions about the future. For instance, an asset acquired in the past should not be valued at historical cost when used in a project. Instead, it should be valued at its next most valuable use, known as *opportunity cost*, which in this case is probably what it could be sold for. This implies that if it had absolutely no other use, it should be costed at zero.

4.4.2 **Transfer payments**

Transfer payments are excluded from BCA as they do not represent a real use of resources. Tolls and other user charges are normally transfers: they are costs to users but simultaneously benefits to transport operators, so have no net effect on society overall.

An exception arises when tolls are taken to reflect the cost of providing the facility, in which case, to avoid double-counting, the facility’s capital and recurrent costs should *not* be included in the BCA. This typically occurs in public-private partnerships (PPPs). But even then the toll cannot be
assumed to cover the full cost of the facility, as PPP contractual arrangements are rarely that simple. In most cases such arrangements require financial analysis (as well as BCA) which is beyond the scope of the Guide.

4.4.3 Land prices

Transport projects may increase the value of land by making it more accessible and, for industrial land, more productive. Alternatively, they may decrease its value by reducing amenity. However, land prices only reflect the accessibility, productivity and amenity of land. Hence they must not be counted in addition to the costs or benefits arising from changes in accessibility, productivity and amenity, as to do so would be double-counting. For instance, when a freeway is built to service industrial land, its value will rise to reflect the expected time, VOC and other savings for the land-owner.

4.4.4 Impacts relating to the financing decision

Behind every project are two decisions: the ‘project decision’ that decides whether or not the project is worthwhile, and the ‘financing decision’ that decides how to finance it once the decision is made to go ahead. Mirroring these impacts are the project’s ‘financing cash flows’. They include monetary impacts (‘cash flows’) related to borrowing—interest, and the receipt and repayment of principal; and monetary impacts related to the raising of share capital and payment of dividends.

Part 2 deals only with ‘project impacts’, that is, ones representing costs and benefits to society. It excludes ‘financing cash flows’, most notably interest, on the grounds that they do not represent real uses of resources. Normally, impacts of this kind only arise in the case of public-private partnerships, which are beyond the scope of Part 2.

4.4.5 Depreciation

Depreciation comes in two forms, one of which may be included in BCA, the other not. Accounting depreciation is a theoretical construct used in the preparation of financial statements. It is excluded from BCA because it does not represent a real use of resources. It represents—usually inaccurately since it ignores the time value of money—the historical acquisition cost of an asset. (In BCA such costs are normally included as and when they occur).

Economic depreciation measures the decline in an asset’s value during a specified period, and unlike accounting depreciation, does reflect a real use of resources. It is used in BCA in place of capital costs where it is inconvenient or impossible to represent assets individually, usually because they are too numerous or uncertain to warrant enumeration.

4.4.6 Transmitted impacts

Transport projects (like other projects) have ramifications throughout the economy. These are termed transmitted impacts and can be predicted using macroeconomic models of the national and regional economies. For instance, cheaper transport can ripple through to cheaper goods, especially when there is a big transport component. This in turn can cause some industries to expand and others to contract.

Such impacts are generally neither costs nor benefits—or rather, they are, but they are balanced in such a way that there is no net benefit to society. For this reason, they should normally be ignored for the purpose of BCA. An exception arises where resources would otherwise lie idle or under-exploited. For instance, employing otherwise unemployed persons would produce a benefit if they were paid more than the value they placed on their lost leisure. Another exception arises where cheaper transport boosts competition, so reducing the deadweight losses of monopoly. Part 2
takes the view that such occurrences are either rare or small, and that in any case the overall direction of the resulting errors will vary between projects.

Part 5 provides a detailed discussion of the application of economy wide models in project evaluation. For more detail see also Commentary D.

4.4.7 Regional development

Regional development impacts are a special case of transmitted impacts. Transport costs can be regarded as a kind of tax on trade between regions. When transport improves, the tax effectively declines and trade flourishes. Farm-gate prices (and mine-mouth and factory-gate prices for that matter) typically rise, or alternatively, delivered prices fall, or both. Consumers benefit from lower prices, producers benefit from higher ones, and regional economic activity receives a boost.

Is this a benefit? No. Or rather, it is a benefit, but not an additional one. It is possible to show that regional impacts of this kind are exactly equal to the direct savings in travel time and VOC etc that have already been accounted for in the region where the project is located. So to include regional development impacts elsewhere is double-counting.
5. **ANALYSIS**

This section shows how the impacts identified and defined above are analysed within the analytical procedures established.

5.1 **Decision criteria**

If project impacts all occurred at the same instant there would be no need for elaborate decision criteria. One would simply sum them and choose projects in such a way as to maximise net benefit. However, since impacts do occur at different times, they must be converted to a common numéraire by means of discounting. Only then can they be properly summed.

This section describes the different criteria that can be used to measure project performance. Only criteria based on discounted cash flow (DCF) techniques are acceptable because only DCF is based on the economic theory of inter-temporal choice.\(^5\)

Part 2 deals with three DCF criteria (see table below). Although other DCF criteria exist, they either have specialised applications not normally relevant to transport (like levelised cost) or offer little new (like equivalent annual worth).

<table>
<thead>
<tr>
<th>Decision context</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unconstrained budget</strong></td>
<td></td>
</tr>
<tr>
<td>Accept–reject decision</td>
<td>Accept if NPV is non-negative</td>
</tr>
<tr>
<td>Option selection</td>
<td>Select project with highest non-negative NPV</td>
</tr>
<tr>
<td><strong>Constrained budget</strong></td>
<td></td>
</tr>
<tr>
<td>Accept–reject decision</td>
<td>Select project set such that NPV of project set is maximised subject to budget constraint</td>
</tr>
<tr>
<td>Option selection</td>
<td>Highest NPV subject to budget constraint</td>
</tr>
</tbody>
</table>

Note: (a) An approximation that applies when certain conditions (see text) are satisfied.

\(^5\) Non discounted cash flow criteria such as payback period and accounting ratios should be avoided, not because they are always wrong, but because they cannot be guaranteed to be right. This is not to suggest that accounting ratios are always misleading. Companies can be regarded as ‘bundles’ of many projects of different sizes and timings. For analysing company performance, therefore, accounting measures like return on capital (RoC) and return on equity (RoE) may be the only practical choice. Besides, it can be shown that in many circumstances accounting ratios approximate their DCF equivalents. However, unlike DCF criteria, these criteria are not built on a solid theoretical foundation, namely the theory of intertemporal choice.
5.1.1 **Net present value**

*Net present value* (NPV) is unquestionably the most fundamental DCF criterion. It can be used in all decision contexts. Indeed, little would be lost if it were the only decision criterion. Because of its importance in decision-making, NPV should be reported for all evaluations. If it has one disadvantage, it is that it is not readily explained to a non-technical audience.

5.1.2 **Benefit–cost ratio**

*Benefit–cost ratio* (BCR) is perhaps the most widely used DCF criterion in the transport sector, especially for small projects. It is readily understood by non-experts. It is also universally used to rank projects for inclusion within capital budgets. Although ranking by BCR is widely accepted as the right way to get the most out of a constrained capital budget, it should be noted that it is an approximation that only works well when certain important conditions are satisfied.

5.1.3 **Internal rate of return**

*Internal rate of return* (IRR) has intuitive appeal to a non-technical audience: it resembles the interest earnings on a loan, and is widely (and not incorrectly) understood that way. However, it is also the least helpful measure for the decision-maker, as it can only be used where budgets are unconstrained and projects are independent—a rare occurrence. For this reason, IRR should only ever be reported as an adjunct to other DCF measures, and then to aid comprehension, not decision-making.

It is recommended that IRR be reported in a graphical format (as shown in graph below). Besides being a powerful visual aid in its own right, a graphical presentation of this kind shows how the preferred option might be one with a lower—not higher—IRR. It is also helpful in *sensitivity analysis* as it shows how the discount rate affects project performance, and shows which options are optimal at which discount rates.

![Figure 5.1: Recommended IRR Reporting](image-url)
5.2 Multi-criteria analysis

Multi-criteria analysis (MCA) is neither an alternative to BCA, nor an extension of it but is best regarded as an adjunct to BCA. Specifically, it is a means of coping with a partial BCA—one that fails to monetise significant impacts. Although BCA requires that every impact be monetised (see panel 1 in the figure below), this is often impossible. Sometimes the unmonetisable impacts may be safely ignored; but if not, decision-makers may have to trade-off the incommensurable monetary and non-monetary impacts. Formal mechanisms for doing so, such as the Goals Achievement Matrix (GAM) are collectively known as MCA (see panel 2 of the figure below). These are detailed in Part 3.

Perhaps the main criticism of MCA is levelled against the weights attached to the non-monetary objectives. These are necessarily arbitrary and subjective; if they were not, it would be possible to conduct BCA in the normal way by treating weights as conversion factors to translate non-monetary objectives into monetary ones. However, this criticism only applies to the ‘strong’ version of MCA, which applies explicit weights to every objective. In ‘weak’ MCA, objectives are left unweighted; or rather, their weights are implicit in decision-makers’ decisions.

Clearly, it would be preferable if all significant impacts could be monetised, as is done in BCA. This would make weighting unnecessary. However, since this is rarely possible, MCA provides a valuable conceptual framework to enable decision-makers to marshal the known facts, and to reduce the role of subjective judgment to a minimum.
Panel 1: BCA analysis

Expressed in monetary units

Social welfare

Impact A
Impact B
Impact C
Impact D
Impact E
Impact F

Expressed in non-monetary units

Convert non-monetary units to $

Panel 2: MCA analysis

Expressed in monetary units

Social welfare (partial)

MCA metric

Impact A
Impact B
Impact C
Impact D
Impact E
Impact F

Expressed in non-monetary units

Convert to single metric using MCA weights

‘Strong’ MCA imposes explicit weights; ‘weak’ MCA leaves weights implicit in decision-makers’ judgments.

Convert non-monetary units to $

Figure 5.2: Example BCA and MCA analysis

5.2.1 Goals achievement matrix

A common MCA technique is the goals achievement matrix. In GAM, impacts are objectively quantified wherever possible, and subjectively scored where not. They are then collapsed into a single metric by means of subjective weights that are analogous to the unit costs and prices used in ordinary BCA. However, despite its apparent mathematical and statistical sophistication, GAM has important weaknesses.

- Scoring and weighting is necessarily arbitrary and subjective.
- Impacts are double-counted wherever GAM objectives overlap. This is not uncommon, as it is rarely possible to define all GAM objectives unambiguously.
It is rarely possible to compare projects in different sectors of the economy (say, transport versus health) as their GAM objectives are likely to differ.

GAM cannot guarantee to determine whether or not a project should be undertaken at all, as this demands knowledge of the project’s social welfare, which by definition is unknown.

5.3 Decision context

5.3.1 Unconstrained budget

When the capital budget is unconstrained and projects are independent of each other, all decision criteria can be used. The rule is to select all projects with non-negative NPVs; BCRs greater than or equal to unity and IRRs greater than or equal to the hurdle rate. Although selection of projects whose BCRs exceed unity is theoretically correct, this is rarely if ever done. Normally the BCR cut-off rate is set at, say, three or four to allow for capital constraints and to give a margin of error in the estimation of impacts. When the capital budget is unconstrained and projects are mutually exclusive, only NPV can be used. The rule is to select the option with the highest NPV provided it is non-negative.

5.3.2 Constrained budget

This is perhaps the most common decision context; most projects are independent, and practically all agencies operate under capital constraints most of the time. The rule of thumb for selecting projects under such circumstances is to rank by decreasing BCR, and to accept all projects whose BCRs exceed or equal a stipulated cut-off level. This rule gives good results, but only when certain conditions are satisfied.

- **Single constraint.** There must be only one constraint, and that must be a simple limitation on resources available to undertake the projects. Furthermore, the denominator of the BCR must be expressed in terms of the particular resources, and only those resources, that are constrained. For instance, if a transport agency is under a capital constraint, the BCR denominator normally excludes costs borne by users or other agencies (but see **Contributions by other parties** below). Normally the resource in question is investment capital. However, in principle it could be any physical input (such as management time); but if so, the BCR would have to be redefined as, in this case, the ratio of net benefits to management time.

- **Small size.** Projects must be small in relation to the resource constraint. If one or more projects are relatively large (say, greater than 5 or 10% of the budget) there is a significant risk that the selected project set could be sub-optimal.

- **Independent.** All projects in the choice set must be independent. If not, interdependent projects should be ‘packaged’ as separate individual projects.

If these conditions are materially violated, BCR ranking can produce a sub-optimal result. In such cases the only correct approach is to select the project set that collectively has the greatest NPV while still satisfying the constraints. Clearly, if there are many projects and more than one constraint (such as a different capital constraint in each year), this can be very difficult, and usually demands complex mathematical optimisation methods that are outside the scope of Part 2.

---

6 When using BCR to rank projects, should operating costs be placed in the numerator or the denominator? In general, current practice is to place operating costs in the denominator. This is reflected in the Austroads Benefit Cost Analysis Manual (Austroads 1996). However, the definition of BCR provided in the “National Guidelines for Transport System Management in Australia” (volume 2), recently published by the Australian Transport Council (ATC 2006): [http://www.atcouncil.gov.au/documents/NGTSM.aspx](http://www.atcouncil.gov.au/documents/NGTSM.aspx), puts them in the numerator as a negative benefit. According to the ATC Guidelines, treating future operating/maintenance costs as a negative benefit can (i) reduce the chances of making wrong decisions in projects prioritisation; (ii) provide flexibility in explicitly taking into account future opportunity costs of funds; and (iii) eliminate ambiguity about what is a cost and what is a negative benefit. The underlying principle is this: the denominator should contain only those resources that are constrained. So if only the agency’s capital budget is constrained, then operating costs should be placed as a negative benefit in the numerator; but if all funds are...
5.3.3 Contributions by other parties

It is common for private sector developers to contribute to capital works. For instance, a shopping centre developer might fund the construction of a road or public transport facility giving access to the centre. If the developer is funding the entire transport project, no evaluation is necessary, as it is a prerequisite for the shopping centre development.

But if the developer volunteers to contribute, then the contribution should be excluded from the denominator of the transport project’s BCR. This has the effect of pushing the transport project up the BCR ranking, so enhancing its viability (which is presumably the purpose of the contribution). In such a case it is immaterial whether or not the transport project exceeds the agency’s hurdle rate when all costs are counted. For what matters is that the developer perceives a benefit that exceeds its contribution, otherwise it would not contribute. This being so, the analyst must either include a benefit equal to the developer’s contribution, or alternatively reduce the cost by the same amount. It is simpler, and recommended (as above), to do the latter.

A different situation arises when the contribution is merely an agreed means of funding the agency concerned. This may be the case for some federal funding. Then, all costs should be included in the BCR denominator. That way, the ranking of projects is unaffected.

In conclusion, the appropriate treatment of contributions made by other parties depends on the purpose of the contribution. If it is to render a project more attractive, the contributed cost should be excluded from the calculation of BCR and other performance measures. But if the contribution is merely a funding device, it should be included.

5.4 Scenarios

Because the future is hard to predict, it is sometimes desirable to analyse options under more than one scenario, that is, a coherent set of assumptions describing all the characteristics of a ‘possible future’ that are relevant for the analysis. A scenario differs from an option in that it describes factors that affect the project’s value and that are not under the control of the decision-maker. An example is provided below.

Consider the following (very simple) project: to take an umbrella on a walk. The options are whether or not to take the umbrella, as that variable is controllable. The scenarios concern the weather, since that variable is not controllable. Scenario analysis requires that all options be analysed under all scenarios to produce a payoff matrix (see table below).

Often the results of the payoff matrix are presented without further analysis. This is particularly common when conducting sensitivity analysis, which merely specifies a project value for each scenario. However, sometimes probabilities are assigned to each scenario, and a single expected value calculated. More complex analyses using game theory are also possible but are beyond the scope of Part 2.
### Table 5.2: Payoff matrix: value of option, by scenario

<table>
<thead>
<tr>
<th>Option</th>
<th>Scenario</th>
<th>Expected value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rain</td>
<td>Shine</td>
</tr>
<tr>
<td>Probability of scenario</td>
<td>$p$</td>
<td>$1-p$</td>
</tr>
<tr>
<td>Leave umbrella (base case)</td>
<td>$W$</td>
<td>$-pW$</td>
</tr>
<tr>
<td>Take umbrella</td>
<td>$C$</td>
<td>$C$</td>
</tr>
<tr>
<td>Net value</td>
<td>$C - W$</td>
<td>$C - pW$</td>
</tr>
</tbody>
</table>

Key: $C =$ cost of taking umbrella; $W =$ cost of getting wet; $p =$ probability of rain.

### 5.5 Sensitivity analysis

It is rarely possible to be certain of all the input factors that affect project performance. Sensitivity analysis is one way of gauging the consequences of uncertain inputs. It is the simplest kind of risk analysis, and for this reason is almost universally used. Often this uses best and worst case scenario analysis to indicate the ‘extremes’ of a range of possible outcomes that might be assumed by the performance measure. Typically only one key variable is manipulated, for a limited range of values or levels. Sensitivity analysis can be used to test if small changes to costs or benefits have significant impact on project viability. For example, if a BCR falls below 1 as a result of a 5 per cent increase in capital cost estimates, the economic efficiency of that project may need to be questioned.

Sensitivity analysis has the advantage of being easy to use, requires little information and offers a quick turnaround of results. However, knowing the best and worst case tells the decision-maker nothing about the probability of either scenario occurring. Also, it provides no information about the shape of the distribution associated with the bottom-line performance measure.

There are no universally applicable rules for selecting which variables and their values to subject to sensitivity analysis, although the table below offers suggestions. Sensitivity analysis should be tailored to particular circumstances. In general, analysis should focus on the inputs that are simultaneously of high impact and also uncertain. At a minimum, variations in project capital costs, traffic growth rates and discount rates should always be tested.

Where project performance is sensitive to a particular input or combination of inputs, the analyst should explore two options: if possible the project should be redesigned to avoid the problem, or more effort devoted to estimating the sensitive variable more accurately. If neither is possible, the analyst may want to consider more sophisticated techniques such as Monte Carlo simulation for analysing risk (discussed in the Annex to Part 2). Another reason for adopting more sophisticated techniques of this kind is that sensitivity analysis, while adequate for analysing the effects of individual inputs in isolation, is unsuited to analysing their effects in combination.
Table 5.3: Suggested rules for sensitivity analysis

<table>
<thead>
<tr>
<th></th>
<th>Variation b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td><strong>Capital items</strong> a</td>
<td></td>
</tr>
<tr>
<td>Concept estimate</td>
<td>-20%</td>
</tr>
<tr>
<td>Detailed costing</td>
<td>-15%</td>
</tr>
<tr>
<td>Final costing</td>
<td>-10%</td>
</tr>
<tr>
<td><strong>Network operation</strong></td>
<td>-10%</td>
</tr>
<tr>
<td><strong>Traffic</strong></td>
<td></td>
</tr>
<tr>
<td>Volume (AADT)</td>
<td>-10 to 20%</td>
</tr>
<tr>
<td>Proportion heavy vehicles</td>
<td>-5 %age points</td>
</tr>
<tr>
<td>Proportion cars in work time</td>
<td>-5 %age points</td>
</tr>
<tr>
<td>Average car occupancy</td>
<td>-0.3 from estimate</td>
</tr>
<tr>
<td>Normal traffic growth rate</td>
<td>-2 %age points of forecast</td>
</tr>
<tr>
<td>Traffic generated by specific (uncertain) developments</td>
<td>zero</td>
</tr>
<tr>
<td>Traffic generated or diverted by project</td>
<td>-50% of estimate</td>
</tr>
<tr>
<td>Traffic speed changes</td>
<td>-25% of estimated change</td>
</tr>
<tr>
<td>Accident changes</td>
<td>-50% of estimated change</td>
</tr>
</tbody>
</table>

Notes: (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 the estimates after the final design stage. (b) The range of values relates to different project types: costing for the more routine projects (road shape correction, resealing) are generally more accurate than those for larger projects (new construction).
ANNEX TO PART 2: RISK ANALYSIS

The Annex to Part 2 provides a framework for risk analysis (as an option) in project evaluation. There are uncertainties in all stages of the project development cycle including uncertainty in the costs involved in selecting, designing and constructing transport infrastructure projects. These uncertainties represent project risks that may result in outcomes different from those intended. The project evaluation process should consider project uncertainty through the use of risk analysis techniques.

Risk analysis in project evaluation

Evaluation of risk is frequently based on the assumption that input data are deterministic, that is, their values are known with certainty. In practice, however, many project variables have the potential to produce a mix of project benefits and costs which are varied to those estimated using deterministic values. Rather than being treated as deterministic, these variables can be considered as probabilistic (stochastic) variables using probability distributions rather than single values to represent them. In doing so, additional information is generated that can be used to improve decision making related to the prioritisation of project investments.

Risk analysis, as described in the context of this Annex, represents a stochastic treatment of uncertain factors entering project evaluation. To perform risk analysis we require the use of analytical techniques and tools which may include user-designed spreadsheet calculations, or more advanced software functions. The tutorial tool (Risk Explorer) associated with this Annex illustrates both approaches using an illustrative Excel based model and the use of third-party software from Palisade called @Risk. This application together with a brief ‘how-to-use’ manual is currently provided with Part 2 (separate pdf files).

Risk analysis enables an estimate of the distribution (or the range of uncertainty) in the values of key project evaluation measures such as BCR and NPV. These distributions assist the practitioner in determining if the level of risk is acceptable or if risk reduction or risk management measures are required.

Different terms are used in the literature to describe various types of risk. ‘Pure’ risk and ‘downside risk’ are defined in Commentary E.

Identifying sources of risk

Risk identification is a critical element of project risk management and project evaluation. Sources of risk are identified by considering elements of the project that have some degree of variability or uncertainty. The majority of input variables to economic models have a degree of uncertainty.

The main sources of uncertainty for transport project evaluation come from:

- traffic (demand) forecasting and network uncertainties that affect the outcome benefits of a project
- construction cost uncertainties that affect the cost of a project (SKM, 1999).
Benefits: Traffic uncertainty

User effects (benefits/costs) are closely linked to changes in traffic levels and composition, VOC, travel time savings, accident costs and other 'external' costs such as environmental and congestion costs. Variables related to estimating, forecasting and assigning network traffic are important sources of uncertainty in estimating user effects.

Uncertainties in traffic forecasting and modelling are considered to be the main source of risk to the predicted benefits of projects that comprise savings in user costs (SKM, 1999). The risks are categorised as shown in the table below. For example, if growth in population is underestimated by a significant amount, higher congestion may result in user benefits (VOC and travel times) less than the benefits projected.

<table>
<thead>
<tr>
<th>Category</th>
<th>Element presenting risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel demand forecasting</td>
<td>Age of data</td>
</tr>
<tr>
<td></td>
<td>Data scope</td>
</tr>
<tr>
<td></td>
<td>Data reliability</td>
</tr>
<tr>
<td></td>
<td>Data validation</td>
</tr>
<tr>
<td>Growth forecasts</td>
<td>Population growth</td>
</tr>
<tr>
<td></td>
<td>Development related traffic as proportion of scheme traffic</td>
</tr>
<tr>
<td></td>
<td>Time series projection</td>
</tr>
<tr>
<td>Assignment model</td>
<td>Inaccuracies in assignment models</td>
</tr>
<tr>
<td></td>
<td>Network data</td>
</tr>
<tr>
<td></td>
<td>Impact of other projects</td>
</tr>
<tr>
<td>Inaccuracies in forecast crash reductions</td>
<td>Crash data</td>
</tr>
<tr>
<td></td>
<td>Reliability of standard reduction rates</td>
</tr>
</tbody>
</table>

Source: SKM (1999)

When examining the risk to project benefits with regard to traffic forecasting and modelling uncertainty, it is important to consider the following issues:

- model specification, data and parameter inputs, variables and coefficients used, are all sources of error. The intensity of these errors can be contained, provided that model inputs are carefully chosen or estimated
- data used in trip matrices are often generated from surveys and vehicle count and traffic composition data. The extent of uncertainty and the associated risk level concerning data age, data scope, quality and reliability must be assessed before decisions to quantitatively measure risk are taken
- the process of assigning traffic forecasts on the road network can also significantly influence the uncertainty in road user effects evaluation. Key sources of uncertainty are often found in the description and coding of network data, in traffic assigning methodologies (specification of congestion effects) and in model characteristics (model stability and convergence of solutions)
- crash data availability and quality and effectiveness of crash savings estimation techniques are all important sources of uncertainty in considering accidents as a component of road user effects. A large proportion of crash reduction out of the total value of benefits can add risk to project benefit outcomes.
Costs: Construction costs

Construction costs are another major source of uncertainty in project evaluation (SKM, 1999). Selected categories and elements presenting risk are identified as shown in the table below.

Table Annex.2: Construction cost uncertainty

<table>
<thead>
<tr>
<th>Category</th>
<th>Element presenting risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental and planning</td>
<td>Indigenous issues, Emissions, Landscape and visual, Ecological effects, Archaeological and historic sites, Social networks, Impacts on land users</td>
</tr>
<tr>
<td>Land and property</td>
<td>Property acquisition, Property economic value</td>
</tr>
<tr>
<td>Earthworks</td>
<td>Knowledge of ground conditions, Complex/unpredictable conditions, Road design form, Extent of topographical data, Source and disposal of material</td>
</tr>
<tr>
<td>Engineering costs</td>
<td>Engineering complexity</td>
</tr>
<tr>
<td>Services (telecommunications,</td>
<td>Existence, location and condition of services, Flexibility of site, Cooperation of authorities involved</td>
</tr>
<tr>
<td>electricity cables and wires, gas</td>
<td>mains, water mains, sewers)</td>
</tr>
</tbody>
</table>

Source: SKM (1999)

Environmental and planning issues can be significant sources of uncertainty in the process of evaluating benefits of road investment decisions. Data availability and quality, the ‘qualitative’ nature of environmental and planning factors, stakeholder consultation processes and the effectiveness of the techniques used to evaluate environmental impacts are important variables in the process of evaluating risk associated with environmental and planning factors.

Property acquisition of land outside existing road reserves and property prices are also important risk factors in road authority construction costs.

Ground condition uncertainties can be substantial when ground conditions are complex or unpredictable (eg, high water table, acid sulphate soils, high cuts/fills, tunnelling, bridges and material disposal requirements). The same applies to other engineering issues, which can be further complicated by utility services conditions such as underground and overhead wiring, gas mains and water mains.

Process of risk analysis

Risk analysis involves quantitative data as well as qualitative information based on experience and informed opinion. Practitioners should investigate all potentially risky variables that input into their analysis to gain a better understanding of possible outcomes and their probabilities of occurrence.

Risk analysis begins at a qualitative level to determine which risks are of the highest priority. This initial screening stage is useful to prioritise risks that have been identified as relevant risks to a project. Risks that are considered to have low impact may be left out of later, more detailed
analysis. Quantitative analysis then follows to describe the impact of the selected variable in more
detail using a quantitative process (such as statistical analysis).

**Qualitative risk assessment**

Qualitative risk assessment ranks level of risk in terms of an appropriate scale (e.g. ‘high’,
‘medium’ and ‘low’). The level of risk will be influenced by the likelihood and the consequences of
the uncertainty in each variable of interest. Likelihood and consequence can also be assigned
numerical values to allow a risk rating to be calculated by multiplying the likelihood rating by the
consequence rating. This method is described in Commentary E.

Classification tables can be used as a means of developing consistency in risk rating as well as
encouraging transparency. Qualitative classification tables can be tailored for a particular
organisation and can be developed to give further information on how the risk should be rated.
Classification tables are also shown in Commentary E.

The output of a qualitative analysis is frequently a prioritised list of variables, indicating the risk
level assigned to each variable of interest. This enables the practitioner to focus on risks that are
regarded as high priority and undertake quantitative analysis of these high priority risks. Low or
medium risks should be monitored to manage their influence on the project.

**Quantitative risk assessment**

Quantitative risk analysis involves the assignment of probability distributions to the variables of
interest. Probability distributions of continuous uncertain variables can be represented in terms of
probability density functions (PDFs). A range of probability distribution functions can apply in risk
analysis. The choice of the distribution function and the key parameters that determine its shape
will be based on experience. Examples of common distribution functions include triangular and
normal distributions as shown below. The horizontal axis shows a range of possible values and the
vertical axis shows the relative frequency weighting of the occurrence of a particular value. In all
cases, the total area under a PDF equals 1.0.

![Example probability distributions](image)

Source: FHWA (1998)

Figure Annex.1: Example probability distributions

Another way to represent probability is by using a cumulative distribution function (CDF). CDFs
illustrate the cumulative probability of an x axis value along the y axis. For example, the figure
below shows a CDF for the possible range of cost of a project. The CDF shows that there is a 75%
probability that project costs will be less than $9 million.
Triangular distributions

In situations where a particular distribution function is unknown, a triangular distribution may be selected for simplicity. The triangular distribution function has the advantage that it can be fully specified using only three distinctive values of a distribution (e.g., the minimum value, the maximum value and the most likely value). The minimum and maximum values represent the lowest and highest values conceivable. The minimum, maximum and most likely values of uncertain variables can be set objectively from either hard data (such as historical information) or subjectively from expert opinion. An example of a triangular distribution can be found in Commentary E.

Sampling and simulation techniques

Modern sampling and simulation techniques (e.g., Monte Carlo sampling and simulation) are useful to analyse distributions (Belli et al., 2001). In Monte Carlo simulation, the simulation software acts as if the same project were implemented hundreds or thousands of times under specified conditions. Since the project variables are uncertain, the simulated results are different each time.

As shown in the figure below, the Monte Carlo technique uses a uniform distribution to generate random numbers. This means all values on the y-axis have an equal probability of being selected. It also means that x-values corresponding to the steeper portion of the distribution curve are more likely to be sampled than those on the flatter parts of the curve. If a small number of iterations are performed, low probability outcomes are not sampled sufficiently as sampled values are clustered around mid-range probability outcomes. Techniques like Monte Carlo require a large number of iterations to avoid clustering of sampled values around particular probability outcomes.
On the other hand, stratified sampling techniques such as Latin Hypercube force a more representative sampling with a smaller number of iterations (FHWA, 1998). This is achieved by dividing the cumulative probability scale into equal intervals and a sample is randomly taken from each interval of the distribution, as shown in the figure below. Convergence is also achieved much more quickly than with Monte Carlo sampling.

![Latin Hypercube sampling](source)

**Figure Annex.4: Latin Hypercube sampling**

### Output from quantitative risk analysis

The final output of a project evaluation process, including risk analysis, includes standard output variables, such as BCR or NPV, expressed in the form of a probability distribution that describes the range of possible outcomes along with a probability weighting of occurrence. However, if required, risk analysis can be applied throughout the project evaluation process on specific variables such as project costs or project benefits, or particular sub-sets of variables representing benefits/costs.

The figure below is an example of a histogram showing the possible range of BCR values that could occur and the estimated probability of each outcome occurring. This histogram shows that the BCR is most likely to be around 3. However, there is a possibility, albeit less likely, that the BCR could be as high as 8 or even negative. For some projects, this level of risk may be acceptable. This information should be then used to understand which variable most affects the BCR and look at what can be done to prevent the BCR dropping to an unacceptable value. Software programs such as @Risk, for example, also allow the user to determine which risk variables have the greatest influence on the project outcome. This is frequently displayed in terms of a ‘tornado graph’ (see @Risk 2002) as shown below.
Figure Annex.5: Example of a histogram: output from risk analysis

**Distribution for BCR / $/1000 passenger km**

![Histogram](image_url)

- Mean = 3.086644

**Benefit/Cost Ratio**

Figure Annex.6: Example of a tornado diagram: output from risk analysis

**Regression Sensitivity for BCR / $/1000 passenger km/B42**

- Std b Coefficients
- PassCarCosts/D26: 0.013
- CycleCosts/D27: -0.276
- Cycle_Fraction/D20: -0.079
- Train_fraction/D23: -0.098
- WalkCosts/D28: 0.08
- Bus_fraction/D22: 0.044
- BusCosts/D29: -0.031
- Walking_fraction/D21: -0.03
- @Risk Triangular distribution/N16: 0.029

Note: Excel cell notations (such as /B42, D26 etc.) are appended by the @Risk software.
Results from the risk analysis process

The information about key project performance measures gained from risk analysis will help make a decision on:

- risks that require action to improve the certainty of an economic outcome for a project
- selecting one project/option over another project/option.

Risk analysis can be performed on a number of competing potential projects or options to provide detailed information to the decision maker. The figure below illustrates how additional project information from a risk analysis can inform the decision or project evaluation process.

This figure shows the NPV outcomes of two projects competing for funding. Project B has a higher mean NPV than alternative A. However, the NPV for alternative A has a tighter range of potential values than that of alternative B, and unlike alternative B, is not at significant risk of having a negative NPV value. If the decision maker was happy to take the risk, alternative B would be preferred, as it has a slightly higher NPV and possibility of upside outcomes. If the decision maker were more risk averse, alternative A, with its somewhat lower NPV but lower range of downside outcomes might be preferred (FHWA 2003).


Figure Annex.7: Probabilistic Outcome Distributions
PART 2: COMMENTARIES

COMMENTARY A: INTRODUCTION TO BENEFIT–COST ANALYSIS

Benefit cost analysis is an outgrowth of welfare economics, a branch of economics developed in the early 20th century to gauge the value of economic decisions in terms of their capacity to satisfy the totality of individual wants of all members of society.

BCA was first used as a practical tool by the US Federal Government to assess water resource projects in the 1930s. During World War 2 and the Cold War of the 1950s, it was further developed and refined as a tool for all kinds of public-sector decision-making.

It was during this time that a variant of BCA, cost-effectiveness analysis (CEA), was developed for the military. CEA is used to evaluate projects whose benefits cannot be quantified monetarily. Also, CEA came to be widely employed in the health sector, where it was used to show the most effective way to save lives and improve life quality.

BCA soon spread to the UK and other developed countries, becoming established there in the 1960s. It was famously used to evaluate London Underground’s Jubilee Line, even though this study lacked the sophisticated environmental evaluation techniques that have come to characterise many later BCA evaluations.

Another variant of BCA was developed in the 1970s to assist international agencies like the World Bank in addressing the requirements of developing countries. Because developing economies often exhibit large price distortions and income inequity, this version of BCA incorporates techniques for deriving and using shadow prices and for quantifying the distributional impact of projects.

BCA in one or other of its forms is now almost universally accepted for public sector decision making in all developed economies. And although few would claim that it is sufficient on its own, all agree that it is a crucial component of the decision-making process.

Confusingly, BCA goes under several names. In the United States and, increasingly, Australia it is generally called ‘benefit–cost analysis’, which is the terminology adopted in this document. In the UK it tends to be called ‘cost–benefit analysis’ (CBA); where, to distinguish it from a narrower financial procedure of the same name used in the private sector, it is also sometimes called ‘social cost–benefit analysis’ (SCBA), stressing its broader, societal scope. However, the important thing is that all these names refer to the same thing.

The BCA method is often thought of as a one-goal approach, that is, efficiency. Although efficiency is an important goal in policy analysis, other goals including equality of opportunity and outcome, budget limitations, political constraints and national security maybe as, or even in some cases, more important. Thus a multi-goal analysis may provide the appropriate evaluation framework. Most of the myths and concerns about BCA are related to the confusion caused by a mix of definitions adopted by practitioners and stakeholders. It is also because of the sometimes poor discipline and quality with which the BCA is applied in practice. Properly defined and used BCA within a multi-goal framework can avoid most of the concerns. For example, a number of goals such as budget limitations, political constraints, national security, quality of life and the integrity of the environment can be defined and specified as constraints within which a BCA evaluation is developed. A BCA with as many as possible benefits and costs monetised forms a quantitative
BCA, while a BCA in which a number of relevant impacts cannot be confidently monetised forms a qualitative BCA. In the literature, an alternative definition for a qualitative BCA is referred to as MCA (see Section 5.2). Finally, in cases where both efficiency and equity are jointly relevant goals, a distributionally weighted BCA can be used as an appropriate technique (for more detail see Part 6 of the Guide and also refer to Boardman et al. (2001) for more explanation of these definitions).

A.1 Where markets fail

If transport infrastructure projects were like most other economic goods, BCA would be unnecessary. A project would be undertaken if and only if its owner could benefit from it. But most transport infrastructure projects are not like other economic goods: there is generally no market for them. One cannot normally buy and sell individual roads or rail lines. There are various reasons for this, but perhaps the most telling is that transport infrastructure is generally a network good, that is, its value lies in being a component of a much larger network.\footnote{Other reasons are that transport projects are sometimes too large and risky for private capital markets to digest; they may benefit non-users, who benefit from the option value of improved access without having to pay for it; and it is impractical to exclude non-payers (the free-rider problem).} This means that the benefits of investing in one part of the network are often experienced by users of other parts.

However, in the end, the reasons for the failure of the transport infrastructure market do not matter. What matters is that, in the absence of a market, users cannot just go out and buy transport capacity when they want it. Instead, provision must be left to the public sector. Which presents the public sector with a problem: When is a transport project justified?

A.2 That is where BCA comes in

BCA tells operators what investments (and other management actions) are warranted; and it does so even though the usual price signals are lacking. But since it lacks a market to guide it, BCA invokes another guiding principle, that of consumer sovereignty, which holds that consumers themselves are the best judges of their own preferences. To determine the value of a project’s impacts, BCA looks to how consumers not ‘experts’ or politicians value them.

Under the principle of consumer sovereignty, the analyst’s task is not to tell decision makers what a project is worth but to interpret the sovereign preferences of consumers in such a way that they are satisfied to the greatest degree possible. In other words, the analyst is the spokesman for consumers, not their instructor. This is not to say that ethical and other values can play no part in project evaluation; but they are best treated as constraints or ground-rules within which BCA operates.

Consumer sovereignty is manifest in markets. Markets reveal consumers’ willingness to pay for a benefit or for the avoidance of a cost, and their willingness to accept compensation for tolerating a cost or foregoing a benefit. In this way, markets measure preferences. If markets existed for all the kinds of impacts that transport projects produce, BCA would be much easier than it is. Unfortunately, many transport impacts, for instance noise and safety, lack markets. Fortunately, BCA provides a toolkit of techniques to fill the gap.
A.3 An ambitious goal

BCA sets itself an ambitious goal. It aims at nothing less than the maximisation of all material wants within the constraints imposed by the scarcity of resources. This is the goal of economic efficiency. To achieve it requires a complete knowledge of all consumer preferences, not just for impacts for which markets exist but for non-market ones as well. This is all very well when consumers are maximising their own preferences, as happens in free, functioning markets; but it is another matter when markets are lacking, and government must attempt to do it for them. This is the case with many transport projects.

Fortunately, the analyst has an array of tools to assist in gauging consumer preferences for non-market impacts. But it is inevitable that some impacts cannot be evaluated with confidence. Few if any instances of BCA would claim to evaluate all impacts, and most explicitly acknowledge omissions. This should not be seen as an inadequacy of BCA but rather a reflection of our technical inability to practice what BCA preaches. Later in Part 2, methods are presented for tackling some of these difficulties.

Needless to say, there are many values that BCA makes no claim to embody. These include ethical values and, perhaps, the whole notion of sustainability. Again, their omission does not indicate an inadequacy of BCA. Such values can be, and ought to be, imposed as constraints in the political sphere.

Lest anyone think there is anything unusual about this, it is worth noting that all BCA analyses implicitly assume that nothing will be done contrary to the law of the land, a constraint so pervasive we do not give it a thought. Likewise, if society wishes to impose ethical limitations on its freedom of action, BCA can accommodate them as easily.

A.4 The BCA toolkit

There are two approaches to gauging consumer preferences where markets are lacking. They underpin many of the parameters that practitioners will use to express impacts in monetary terms.

Revealed preference (RP) methods look at 'surrogate markets'; markets that embody an impact as part of a 'bundle' of attributes. They comprise:

- random utility / discrete choice models
- avverting behaviour
- hedonic pricing
- travel cost method.

Stated preference (SP) methods use questionnaires to elicit preferences where there may be no surrogate market. They comprise:

- contingent valuation
- contingent ranking / conjoint analysis.

Replacement cost can also be used to estimate benefits. Though not strictly a valuation technique, it normally provides a minimum estimate.

Valuations by any of the above methods may be combined with dose-response functions to predict the output of a given impact (say, noise) on the basis of known inputs (typically the characteristics of the infrastructure link and the traffic on it). Having established the quantum of the impact in this way, it is valued by one or other of the above methods.
A.5 Economic efficiency

The purpose of BCA is to maximise social welfare, that is, the sum of consumers' preferences as measured by the above techniques. This is termed the goal of economic efficiency.

The economist Pareto provided the first criterion of economic efficiency in the 1880s. According to Pareto, scarce resources should be allocated in such a way that it is impossible to make anyone better off without simultaneously making someone else worse off. Such an allocation is said to be 'Pareto efficient'. However, the problem with this definition is that it is too strict; even very good projects generally disadvantage somebody.

In 1939, the economists Kaldor and Hicks devised another criterion. ‘Kaldor-Hicks (potential Pareto) efficiency’ requires only that gainers should be able to compensate losers—not that they should actually do so. Under this criterion, efficiency is promoted whenever a project generates more benefits than costs, regardless of who gains and who loses. It is this, less strict, criterion that is central to BCA.

A.6 Method

It would be true, but unhelpful, to describe BCA as a tool for comparing a project's benefits to its costs in order to find out which is bigger. It is more helpful to compare BCA to its private sector equivalent—financial analysis (see Table below). This comparison is cast in the light of the following areas of application:

- **Objective.** Financial analysis has as its objective the maximisation of shareholder wealth. BCA seeks to maximise social welfare. This means that BCA includes some impacts that financial analysis omits on the grounds that they do not affect profit. Although many such impacts are hard to express in monetary terms, they must be incorporated in any BCA that claims to be comprehensive.

- **Scope.** Financial analysis considers the interests of shareholders and generally ignores other parties. BCA considers the whole community. This means that BCA omits some impacts that the private sector includes. For instance, BCA omits certain taxes since their net effect on society is zero: the firm’s loss is the taxman’s gain.

- **Prices.** Financial analysis is based on market prices—that is, prices actually paid and received. BCA is based on shadow prices—that is, prices that reflect the true cost of resources to society. Unlike market prices, shadow prices (where they differ from market prices) must normally be calculated by experts, and may relate to impacts such as noise and other forms of pollution that are unpriced because no market for them exists. The Guide shows where such prices can be found (see Part 4).

As a consequence of its ambitious scope, BCA is in some ways more challenging than financial analysis since it relies on conceptual tools that are not needed in the private sector. Even so, BCA has much in common with financial analysis. The main difference between the two techniques lies in the impacts that are included and the prices that are attached to them: BCA generally includes more impacts, and uses prices that reflect a wider community of interest.

<table>
<thead>
<tr>
<th>Area of application</th>
<th>Financial analysis</th>
<th>Benefit–cost analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>To maximise shareholder wealth</td>
<td>To maximise social welfare</td>
</tr>
<tr>
<td>Scope</td>
<td>Shareholders</td>
<td>Society</td>
</tr>
<tr>
<td>Prices</td>
<td>Market prices</td>
<td>Shadow prices</td>
</tr>
</tbody>
</table>
A.7 Uses of BCA

BCA is mainly used in four decision contexts.

- **The accept–reject decision.** This is conceptually the simplest, but perhaps the least common, use of BCA. BCA provides rules as to whether a given project will increase social welfare (‘accept’) or decrease it (‘reject’).

- **Option selection.** It is more common for the analyst to be presented with a number of mutually exclusive options for achieving a given outcome, for example alternative routes for a bypass, where the task is to select the single best option. For this type of decision, BCA provides rules that differ from those for the accept–reject decision; and confusion of the two can result in costly mistakes.

Both the above types of decisions can be made under different budgetary environments.

- **Unconstrained capital budget.** Where capital budget constraints are absent, or effectively so, BCA offers simple rules to guide project selection.

- **Constrained capital budget (‘capital rationing’).** Agencies’ capital budgets are nearly always constrained—in other words, capital is rationed. This means that some projects have to be rejected even though they would, in isolation, increase social welfare. BCA requires that we seek to select the ‘bundle’ (or group) of projects that collectively maximise social welfare. If there are many constraints and many candidate projects, this can be a daunting task requiring computerised optimisation techniques. In simple cases, however, good results can be obtained with rules of thumb.

For more detail regarding BCA decision rules, see also Section 5.3.

A.8 Triple Bottom Line

The term Triple Bottom Line (TBL) was coined in 1997 by Elkington in his book, Cannibals with Forks. It is therefore appropriate to quote Elkington's own definition:

The triple bottom line (TBL) focuses corporations not just on the economic value they add, but also on the environmental and social value they add – and destroy. At its narrowest, the term ‘triple bottom line’ is used as a framework for measuring and reporting corporate performance against economic, social and environmental parameters.

At its broadest, the term is used to capture the whole set of values, issues and processes that companies must address in order to minimise any harm resulting from their activities and to create economic, social and environmental value. This involves being clear about the company’s purpose and taking into consideration the needs of all the company’s stakeholders – shareholders, customers, employees, business partners, governments, local communities and the public. (http://www.sustainability.com/)

Few would disagree that environmental and social goals are worth pursuing, though some might argue that private companies should not do so to the detriment of profit (and furthermore that if there is a dissonance between social goals and private ones, it is the job of government, not companies, to remedy it through regulation and the law). This is not a debate that the Guide should take a position on. But it does rightfully have a position on the notion that TBL should be applied to the public sector.

TBL was originally devised for the private sector. Its aim was to broaden the traditionally narrow wealth-maximising motive of companies. But as far as the public sector is concerned, there is no need to broaden government’s goal, let alone adopt TBL to help it do so. Government already knows what its goal is (or should be); and it already has the right tool for the job—BCA.
If so, why was TBL ever considered for the public sector? Perhaps because of a semantic confusion. The TBL literature describes the three bottom lines as ‘economic, social and environmental’, as if economic impacts could exclude ‘social’ and ‘environmental’ ones. This is a fallacy, possibly engendered by the fact that in business and legal circles the terms ‘economic’ and ‘financial’ are widely used as synonyms (they are not). This could explain why critics of BCA claim that it is too narrow, and that governments should therefore consider ‘social’ and ‘environmental’ impacts besides ‘economic’ (that is, financial) ones. If governments fail in this respect, it is not because they lack the tools but the will.

Which not to say that TBL has nothing to offer the analyst, still less that BCA solves all problems. TBL has much to contribute in terms of formalised reporting procedures for impacts that BCA does not, or cannot, quantify (for more detail about TBL see the Austroads Transport Planning Guide).
B.1 Determining what is a cost and benefit

Circumstances and semantics, not physical characteristics, determine whether a given type of impact is a cost or a benefit in any particular instance.

Consider road crashes. Often classified as a cost, crashes are in fact a benefit if they decline as a result of a road project. True, a reduction in crashes is a cost saving, which suggests that crashes are still fundamentally a cost. But a simple change of terminology will change that. If ‘crashes’ are renamed ‘road safety’, a decrease in the one becomes an increase in the other, turning a cost saving into a benefit. Likewise an increase in crashes becomes a decrease in road safety, which turns a cost into a benefit reduction (or disbenefit).

This suggests that impacts should not be forced into a simple cost/benefit dichotomy. It is more helpful to regard them as outputs that are sometimes good (when they are termed benefits), and sometimes bad (when they are termed costs).

B.2 Internal versus external impacts

Another dichotomy that tends to be misused, though for a different reason, is the internal/external distinction. The costs that transport-users impose on non-users (such as noise) are widely termed external impacts to distinguish them from other impacts. This is true but misleading, for many other impacts are external as well.

What makes an impact external is the fact that it is imposed on others besides the agent that caused it. By this definition, congestion and crashes are as much external as noise, even though they are imposed by transport-users not on non-users but on other users.

This distinction is more than academic, for external impacts give rise to detrimental economic consequences that require remedy. It is a distinction that is lost if the term ‘external’ is selectively applied to some external costs and not all.

B.3 Economic versus financial impacts

A third distinction is that between economic and financial impacts. Some observers, especially those advocating a Triple Bottom Line approach, seem not to appreciate the difference—a cause of much confusion.

Financial impacts are ones that are monetised because functioning markets exist for them. For this reason, private sector firms and individuals take them into account, and they appear in company accounts.

Economic impacts are much broader. They comprise not only financial impacts but unmonetised ones as well. These are impacts that are in principle quantifiable, if with difficulty, but not normally monetised as no functioning markets exist for them. Some are monetisable with the special analytical techniques in the BCA toolkit. They include noise, air pollution, climate change, and (arguably) the valuation of life and limb. Others, like some environmental and cultural assets, are hard or impossible to monetise with existing techniques; though as techniques improve, this may change.

Lastly, there are impacts that most (but not all) people would agree are not only unmonetisable but unquantifiable as well. They include ethical values and compliance with the law. Being
unquantifiable, they have no place in BCA except as constraints on the decision-maker’s scope of action.

Environmental impacts overlap these categories (see figure below). Some are unquantifiable (What price the extinction of a whole species?); some quantifiable but not (easily) monetisable (What price a member of a rare species?); and some monetisable but not normally monetised (What price a decibel of noise?).

Figure B.1: Impacts classified by monetisability and quantifiability
COMMENTARY C: TRANSPORT MODELS

Traffic forecasting is usually required where traffic is diverted from one route to another, or one mode to another; or where a significant amount of new traffic is generated (also see Part 3). On dense or congested networks it is rarely obvious how traffic flows will be affected by transport projects, and the ramifications of the project throughout the network are typically extremely complex. For this reason, transportation models are widely used to forecast traffic changes on urban networks, and are not uncommon on the far simpler rural networks.

Four-step models

Despite their shortcomings, so-called four-step models are almost universally used to simulate traffic on complex, usually urban, networks. Most (termed ‘gravity models’) use an analog of Newton’s universal law of gravitation to model trips between every pair of zones in the network; that is, the number of trips is taken to be proportional to the product of a function of the ‘masses’ of the zones (typically their population or employment) and inversely proportional to a function of the ‘distance’ (typically the generalised cost of travel) between them.

The modelling procedure has four steps.

- **Step 1: Trip generation.** The model computes the number of trips produced by, and attracted to, each zone.
- **Step 2: Trip distribution.** Trips are distributed among zone-pairs in such a way as to reflect the generalised cost of travel between each zone-pair.
- **Step 3: Mode choice.** Trips are allocated to alternative modes.
- **Step 4: Route assignment.** Trips are assigned to mode-specific networks.

In most four-step models the number of trips is fixed and only their route is allowed to vary. More sophisticated variants allow mode choice and/or trip distribution to vary as well, usually by means of an iterative procedure that repeats some or all of the preceding steps.

Criticisms of four-step models are generally aimed at their lack of an underlying economic rationale. For instance, they make no allowance for traffic generated by cheaper travel, nor do they allow land-use to vary endogenously in response to changes in accessibility. Instead, aggregate travel demand and land-use changes must be forecast exogenously.

Discrete-choice models

Discrete-choice models were devised expressly to provide the economic rationale that four-step (gravity) models lack. They are essentially specialised econometric models that predict the demand for trips by individuals on the basis of their demographic and other characteristics, the nature of the trip, and the attributes of the mode (including ‘price’).

Unlike four-step models, discrete-choice models are not zone-based, and so do not suffer from aggregation error. But despite their methodological purity (or perhaps because of it) discrete-choice models have proven to be too complex and theoretically demanding for most users, and furthermore have an undistinguished record for accuracy. For these reasons they are seldom used by practitioners.
Land-use interaction models

It is universally accepted that accessibility affects land-use. For instance, a new outer-urban freeway link is almost certain to attract space-intensive industrial applications that demand good access to the urban area, such as warehousing. However, few transportation models are capable of representing such relationships endogenously, and those that do are generally data-hungry, complex, and lacking in robustness. For this reason so-called land-use interaction models tend to be used experimentally and at a strategic level, not for the evaluation of specific links.

C.1 Traffic congestion

Traffic congestion occurs when traffic flow is constrained by the capacity of the network. It manifests itself mainly as increases in travel time and to a lesser extent vehicle operating costs; and as a degrading of freight performance, particularly in the reliability of delivery time.

As congestion begins to bite, the average and marginal social cost of trips rises. But because marginal cost exceeds average cost, consumers over-consume, resulting in a deadweight loss to society. For large projects in dense (usually urban) networks, predicting the amount of congestion usually requires a transport model.

Congestion impacts are distinguished not by their characteristics but because they are externalities. On an uncongested network, travellers impose travel time and VOC only on themselves—known as ‘user-on-self’ costs. But on a congested network, they impose travel time and VOC on others—known as ‘user-on-user’ costs.

Although it is possible to estimate the magnitude of the deadweight loss as a separate category, Part 2 subsumes them under other project headings, mainly VOC and travel time.
C.2 Road pricing

If road users were required to pay the marginal social cost of their road use as and when they consumed it, congestion would be optimal and economic efficiency maximised. Road pricing (sometimes called congestion pricing) is a way of bringing this about. Under road pricing, a charge is imposed for road use which, when added to the pre-existing private costs of road use, brings the total cost borne by the user into line with marginal social cost.

Until now, road pricing has been difficult. Tolls were costly and inconvenient to collect, and since congestion varies greatly by location and time of day, they were inevitably crude in their application. But recent advances in satellite-based systems and in-vehicle electronic tags (generically termed electronic road pricing—ERP) are making sophisticated road pricing possible.

At the same time, growing congestion in our cities is making road pricing politically more acceptable. Congestion is estimated to cost $13 billion annually in Australia, a cost that is expected to double by 2020.
**COMMENTARY D: TRANSMITTED IMPACTS AND MACROECONOMIC MODELS**

Macroeconomic models are integrated modelling systems designed to simulate national and regional economies. They embody inter-industry and intersectoral relationships in a comprehensive mathematical framework. They allow the user to predict how projects will influence economic conditions and to track the impacts over time. Some models also claim to predict how projects affect business expansion and population growth at a regional level.

Though not traditionally used to evaluate project costs and benefits, macroeconomic models have recently been used in this role.

**D.1 Two approaches to estimating benefits**

Partial equilibrium (PE) analysis is the approach underlying traditional BCA, and the one embodied in Part 2. Benefits are estimated by examining only the ‘first-round’ or ‘initial’ impacts of project expenditure. Subsequent rounds of expenditure are ignored on the grounds that (normally) all benefits from this source are balanced by costs.

General equilibrium (GE) analysis is the approach underlying macroeconomic modelling. Benefits are the net present value of consumption increases during project construction and operation, after deducting returns to (non-transport) induced investments.

Both approaches should produce the same result. But analyses of transport projects using a GE approach commonly show an increase in GDP in excess of the benefits under a PE approach. If this change in GDP is interpreted as a net benefit, the conclusion is that a PE approach understates benefits. However, GDP is an inappropriate measure of welfare as it includes returns-to-capital, which are either compensation for past domestic savings (and hence lower domestic consumption) or interest on debt or dividends paid to foreigners; and it excludes non-market welfare effects such as life and limb, and many environmental goods.

**D.2 Economic impact analysis**

Perhaps the usefulness of macroeconomic models is not in the estimation of benefits but in the quantification of changes in national and state economies in response to projects—termed economic impact analysis. But even here the Luskin (1999) is dubious:

- Estimation of the net benefit can almost always proceed without [models]. An estimate derived from a [macroeconomic] model may incorporate a broader range of effects. But some of these effects do not matter much, and many, such as the impact on aggregate employment, are anyone's guess.

- Popular macroeconomic indicators, such as real GDP and the current account deficit, are of questionable relevance. An investment could benefit society greatly and yet increase the current account deficit, certainly during the construction phase and perhaps in the longer run.
COMMENTARY E: ANNEX TO PART 2 – RISK ANALYSIS

Risk assessment enhances the decision process by enabling decision makers to make use of the full extent of their knowledge and experience. As Hardaker et al. (1997) state, in the presence of risk ‘the task is how to manage risk effectively, within the capacity of the individual, business or government to withstand adverse outcomes’. Risk analysis is an essential component of the provision of infrastructure services and the use of risk management techniques is likely to lead to improved sustainability of outcomes and not just a capacity to withstand adverse outcomes.

E.1 Defining risk

In terms of project evaluation, risk arises when certain ‘events’ occur that can impact on the successful completion of a project. Risk analysis involves identifying these ‘events’ and assessing the probability of occurrence as well as the level of impact (or consequence) on the project. These ‘events’ are not necessarily physical events but can relate to assumptions made within a model, or to different perceptions or forecasts associated with a project. In simple terms, for example, forecasts may be overly optimistic or pessimistic. Overly optimistic forecasts are usually associated with ‘downside risk’ as explained below.

Therefore, risk arises when there is uncertainty in outcomes or future events and the consequences of those outcomes. Risk implies that there is more than one possible outcome, in fact a whole range of outcomes are possible.

An estimation of how likely unfavourable consequences are can be very useful in determining whether that risk is acceptable or whether changes need to be made to lessen the risk of an unfavourable outcome.

In terms of project evaluation, risk occurs when there is uncertainty in the values of variables used in the analysis. Greater uncertainty in the value of a variable can result in a greater range of possible values for the economic outcome of the project.

The assessment of a risk can be subjective or objective. The range of probabilities for an outcome may be determined objectively by using observations, statistical data, or previous experience. This may be thought of as the situation of flipping a coin, where you are uncertain what the result may be, but based on previous experience and statistical knowledge, you know the probability of a head facing up is 50 per cent. If, however, there is a lack of quantifiable information to work with, the situation is more uncertain. Deciding on the probability of different outcomes becomes subjective, and the decision maker has to rely on an informed opinion instead of data, to form the range of probabilities.

Different terms are used in the literature to describe various types of risk. BTRE (2005) refers to two main types of risk, that is, pure risk and downside risk. Pure risk is described as the variability of a random variable about the mean, commonly split into systematic and idiosyncratic categories of risk. Idiosyncratic risk is explained as random variation about an uncertain variable, which is likely to be small and can be ignored for practical purposes. Systematic risk arises from project benefits being correlated with each other or with movements in the economy as a whole.
However, it has been found that there is little to be gained from detailed consideration of systematic risk in project evaluation, as the adjustment estimated is likely to be small (BTRE, 2005). However, it may be good practice for the practitioner to consider it and understand it as part of the evaluation process before it is dismissed from the analysis. The other main type of risk (i.e. downside risk), normally results from over-optimistic evaluations, meaning that the probability of a below-forecast outcome is greater than for an above-forecast outcome. Efforts should be mostly concentrated on identifying and assessing the complete range of possibilities to eliminate downside risk related to project evaluation decisions.

E.2 Risk and uncertainty

Uncertainty is defined here as a state of imperfect knowledge, in comparison to perfect knowledge being a state of certainty. In turn, risk is defined as a state of uncertainty where the practitioner has some reason to be interested in the outcome (a chance of some amount of loss or gain).

Making a hard distinction between risk and uncertainty does not normally offer much too economic decision making. Raftery (1994) explains that uncertainty simply represents a ‘greater unknown’ than a quantified risk attached to the same event. In any case, the analysis of projects under uncertainty requires the specification, implicit or otherwise, of probability distributions for the states of nature (Quiggin in BTRE, 2005). Probabilities for uncertainties may be built up from observations on the relative frequency of the various events that characterise the state of nature. Alternatively, they may represent the informed judgement of those undertaking the analysis (Quiggin in BTRE, 2005).

E.3 Risk management process

Risk management is ‘the culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects’ (AS/NZS 4360:1999). An overview of the complete risk management process is shown below. Risk management is an iterative process, as shown by the feedback loops, helping to continually improve the management of risk.

Positioned within the wider framework of an organisation’s strategic, organisational and risk management context, there are two key steps that are the particular concern of project evaluation. These are:

- risk identification (identification of risk factors that are key sources of uncertainty)
- risk assessment (analysis and evaluation of risk factors as shown by the shaded area on the figure below).

---

8 The Risk Explorer Tutorial developed for Part 2 of the Guide has been designed to assist the practitioner in considering all types of risk related to project evaluation.
Risk identification is a very important part of the process of recognising risks, both internal and external to a project. Checklists of factors or variables can be used to identify the key sources of uncertainty in the evaluation of projects. For example, this may include variables whose uncertainty may have significant effects on outcomes, variables unique to a project, or sources of uncertainty related to model inputs, model coefficients and model specification.

Risk analysis provides information necessary to determine the likelihood of a risky event occurring as well as the impact associated with this occurrence. The impact may be considered, for example, as the amount of loss or additional benefit that could result from the identified risks. Spreadsheet-based applications for analysing risk are practical, mostly where outcomes relate to input factors through relatively straightforward mathematical formulae. Simulation techniques (such as Monte Carlo analysis) are a popular approach in analysing overall project risk comprehensively. However, where projects are complex, such as in an intricate road network model, even Monte Carlo analyses can quickly become intractable. A more selective approach that identifies a limited number of key factors which most influence risk can, however, reduce both the cost and the complexity of simulation technique applications (Austroads 2002).

Risk evaluation takes place after the analysis has been performed. This involves comparing the level of risk found during analysis with set criteria to judge the viability of the project. Risk evaluation aims to determine whether a project should proceed (or perhaps which option should proceed), whether risk treatment is required, and ranking risks for treatment.

Risk treatment follows the identification and assessment (analysis and evaluation) stages. The decision maker can then consider potential risk mitigation measures or treatments that can reduce, or avoid adverse impacts associated with risky events.

All of these steps in the risk management process, except risk treatment, are the subject of development in this Annexe to Part 2. Risk treatment is often considered as a customised process for each agency/organisation dealing with managing risk consistently with organisational objectives.
E.4 Methods of identifying sources of risk

Various methods of identifying risks may be useful in project evaluation. Some ways of identifying potential impacts on a project are:

- brainstorming in a group environment: include a variety of people involved with the project to cover risks across different areas
- comparison with similar projects: the risks experienced in other similar, recent projects may provide a good indication of potentially risky areas. Post-implementation evaluations of past projects may provide valuable information.
- use of comprehensive checklists that contain many areas of potential risk common to transport projects.

E.5 Qualitative risk analysis

Qualitative analysis is a simple method of identifying and describing risks. It is useful as an initial screening tool to prioritise risks and identify risks that will require more detailed analysis. Qualitative analysis describes the impact of events and the likelihood of the event occurring. Many transport authorities have their own standard methods for this type of analysis. In this section, some different methods of qualitative analysis are described that may be used in project evaluation.

Likelihood and impact analysis

One way to perform qualitative analysis is to combine the measures of likelihood and impact to give a measure of risk. The descriptions of likelihood and impact can be varied for different types of risks, such as financial risk, environmental risk, political risk or safety risk.

An example of this approach, adapted from AS/NZS (HB203:2000), is shown in the tables below. As highlighted in these tables, if an event is unlikely to occur but its occurrence could have major consequences for the project, this risk may be considered to be high.

<table>
<thead>
<tr>
<th>Level</th>
<th>Descriptor</th>
<th>Description</th>
<th>Example description-impact on project costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Almost Certain</td>
<td>Is expected to occur in most circumstances</td>
<td>&gt;$75,000</td>
</tr>
<tr>
<td>B</td>
<td>Likely</td>
<td>Will probably occur in most circumstances</td>
<td>$50,000-$75,000</td>
</tr>
<tr>
<td>C</td>
<td>Possible</td>
<td>Could occur</td>
<td>$25,000-$50,000</td>
</tr>
<tr>
<td>D</td>
<td>Unlikely</td>
<td>Could occur but not expected</td>
<td>$10,000-$25,000</td>
</tr>
<tr>
<td>E</td>
<td>Rare</td>
<td>Occurs only in exceptional circumstances</td>
<td>&lt;$10,000</td>
</tr>
</tbody>
</table>

Table E.2: Qualitative measures of impact

<table>
<thead>
<tr>
<th>Level</th>
<th>Descriptor</th>
<th>Description</th>
<th>Example description-impact on project costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Catastrophic</td>
<td>Catastrophic impact</td>
<td>&gt;$75,000</td>
</tr>
<tr>
<td>2</td>
<td>Major</td>
<td>Major impact</td>
<td>$50,000-$75,000</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Noticeable/ concerning impact</td>
<td>$25,000-$50,000</td>
</tr>
<tr>
<td>4</td>
<td>Minor</td>
<td>Slight/tolerable impact</td>
<td>$10,000-$25,000</td>
</tr>
<tr>
<td>5</td>
<td>Insignificant</td>
<td>Unnoticeable impact</td>
<td>&lt;$10,000</td>
</tr>
</tbody>
</table>
### Table E.3: Combining likelihood and impact

<table>
<thead>
<tr>
<th>Levels of likelihood</th>
<th>Levels of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Almost Certain</td>
<td>E</td>
</tr>
<tr>
<td>Likely</td>
<td>E</td>
</tr>
<tr>
<td>Possible</td>
<td>E</td>
</tr>
<tr>
<td>Unlikely</td>
<td>E</td>
</tr>
<tr>
<td>Rare</td>
<td>H</td>
</tr>
</tbody>
</table>

#### Numerical values for risk rating

Likelihood and consequence can also be assigned numerical values to allow a risk rating to be calculated by multiplying the likelihood rating by the consequence rating. The table below shows an example of a template that could be used for the purpose of listing and rating risks.

### Table E.4: Risk identification and rating table

<table>
<thead>
<tr>
<th>Risk</th>
<th>Likelihood (0-5)</th>
<th>Consequences/ severity (0-5)</th>
<th>Risk rating: likelihood * consequence</th>
<th>Mitigation strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of ecological damage to plant life surrounding creek. This may result in additional costs to solve as yet unidentified issues.</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>Understand all issues and incorporate affordable solutions to preserving ecology into project design.</td>
</tr>
<tr>
<td>Risk of project delay due to dealing with community concerns.</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Maintain close working relationship with community groups to resolve issues early and effectively.</td>
</tr>
</tbody>
</table>

#### Classification ratings

Another method of qualitative analysis is to develop standard tables of risk variables and descriptions that indicate the circumstances under which risk ratings would be low, medium or high. This method is used in the New Zealand *Guidelines for Risk Analysis of Major Projects* (SKM, 1999). This method is also utilised in the Risk Explorer Tutorial (see separate pdf files accompanying Part 2 of the Guide).

Qualitative classification tables could be tailored for a particular organisation and can be developed to give further information on how the risk should be rated. These tables may also help to identify how risks may be reduced, for example, how to reduce a risk rating from ‘high’ to ‘medium’. An illustration of a classification table is shown below.
Table E.5: Example of classification ratings for Base Travel Demand uncertainties

<table>
<thead>
<tr>
<th></th>
<th>1 (Low)</th>
<th>2 (Medium)</th>
<th>3 (High)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of data</td>
<td>Counts &lt; 1 year old</td>
<td>Intercepts/count 2-3 years.</td>
<td>Intercepts/count &gt;3 years.</td>
</tr>
<tr>
<td></td>
<td>Household &lt; 5 years old</td>
<td>Household 5-10 years</td>
<td>Households &gt; 10 years.</td>
</tr>
<tr>
<td>Data scope</td>
<td>Count and intercept sites in project corridor</td>
<td>Acceptable data coverage.</td>
<td>Count and intercept sites not in close vicinity of project and thus not encompassing most (&gt;80%) of the relevant traffic.</td>
</tr>
<tr>
<td>Data quantity and statistical reliability</td>
<td>5 or more years continuous count data. Intercept data. Strategic model: one-day household travel diary with either a sampling rate greater than 3% of population or a sample of at least 5,000 households.</td>
<td>Count data providing 95% confidence levels ± 10%. Household one day travel diary with sampling rate of 1.5-3% or 2,500-5,000 households.</td>
<td>A few weeks count data in context of seasonal traffic patterns, such that the 95% confidence level for annual traffic exceeds ±10%. Strategic model based on one day household travel diary with either a sampling rate less than 1.5% of population or a sample of less than 2,500 households.</td>
</tr>
<tr>
<td>Travel demand validation to counts</td>
<td>Very comprehensive count program with close fit of matrix to counts.</td>
<td>Reasonable coverage and fit to counts.</td>
<td>Limited scope count program, no more than adequate fit of matrix.</td>
</tr>
<tr>
<td>Traffic composition (models based on counts alone)</td>
<td>Derived from classified vehicle counts for an adequate sample of annual traffic.</td>
<td>Standard values used with local validation.</td>
<td>Standard values used without local validation.</td>
</tr>
</tbody>
</table>

Source: SKM (1999)

### E.6 Quantitative risk analysis

The next stage of risk analysis is quantitative analysis. Once the high risk variables have been identified, probability distributions for each of these variables can be determined to quantify risk. Assigning probability distributions to the variables is a difficult step in the analysis, and the subjective judgement of experienced professionals is useful to define the form or shape of the distribution.

Quantifying each variable individually makes it clearer to see what the largest concerns are and what effect they could have on project outcomes. Probability distributions of uncertain input variables can then be generated with computer software packages (such as @Risk). These give the decision maker information on the full range of possible values and the probability of any particular outcome occurring.

**An example of a normal probability distribution**

A *normally* distributed PDF (bell curve) has a central peak indicating the most likely value (or *mode*) of the uncertain quantity and with low-probability ‘tails’ on either side of the peak stretching out to the upper and lower extremes. The PDF for an uncertain variable $x$ is conventionally denoted by $f(x)$. The figure below shows a distribution with a minimum value of $a$, a maximum value of $b$ and with a *mode* at $m$. The area under a PDF curve measures the probability that the value of the uncertain quantity $x$ will lie in the range from $a$ to $b$. For example, the shaded area $A$ shows the probability that $x$ will lie in the range of $a$ to $X$ (Austroads 2002).
The figure below shows a cumulative distribution function for the PDF above. CDFs are easier to draw than PDFs, as with PDFs it is difficult to ensure the area under the curve is equal to 1.0. The CDF is s-shaped for a typically bell-shaped PDF, and the CDF point of inflection corresponds to the mode of the PDF. CDFs illustrate the cumulative probability of an x axis value along the y axis. As an example of the relationship between PDF and CDF, the shaded area A shown in the previous figure shows the probability that x will lie in the range of a to X. The probability A is shown in the following figure as point A on the Y-axis.

![CDF and PDF diagram](source_image_url)


**Figure E.3: Cumulative distribution function corresponding to PDF**
An example of use of a triangular distribution

The cost of a proposed project is thought to be a high risk, since little is known about the ground conditions. It has been calculated that the earthworks and associated costs are likely to be $30k (most likely value). In discussion with experts involved with this project and other similar projects completed recently in the area, it is agreed that there is a possibility that these costs could be as low as $10k (minimum value) or as high as $100k (maximum value), depending on the ground conditions experienced. The effect of this variable can be described as a triangular distribution for input to the computer simulation of the project’s estimated BCR. Here, the distribution function is RiskTriang(10,30,100) (see figure below from @Risk 2002).

Using the results of a risk analysis simulation we can show how the uncertainty surrounding the project cost (as influenced by unknown ground conditions) affects the range of expected BCR values for the project. If that turns out to be significant, the practitioner may decide to advise of the need to perform more ground condition testing to reduce the uncertainty of the project’s economic performance.

![Distribution for RiskTriang(10,30,100)](image-url)
Combining variables using computer simulation

Once variables have been defined as distribution functions, the next step is to use a computer software package to generate a probabilistic description of results, based on the identified risk variables selected as inputs. Probability distributions can be directly incorporated into spreadsheet models using custom distribution functions available with software programs such as @Risk. Separate ‘what if’ scenarios can be calculated by drawing a sample from each input distribution, normally based on several thousands of simulation executions. The simulation produces a probability distribution for each output variable (such as BCR or NPV) that describes the range of possible outcomes along with a probability weighting of occurrence (FHWA, 1998). The sampling techniques that can be used to perform this simulation include Monte Carlo and Latin Hypercube simulation techniques, discussed in the body of Annex 2 above.
COMMENTARY F: DOCUMENTATION AND QUALITY CONTROL OF BENEFIT-COST ANALYSIS

This Commentary presents a BCA checklist on how assumptions, tasks, key parameters and measures can be applied in project evaluation. The checklist can be adopted for use by transport planners and managers to substantiate the results of any BCA in general. The checklist will also seek to address the common pitfalls encountered in the BCA estimation process amongst Australian jurisdictions. The checklist is based on the work undertaken in Austroads (2011).

F.1 Common Pitfalls of the BCA Process

The Bureau of Infrastructure, Transport and Regional Economics (BITRE) project entitled *Ex post Evaluation of Major Road Projects* has exposed some serious deficiencies in the way BCA for road projects have been documented and implemented in the past. The common pitfalls of the BCA process have been identified from the BITRE case studies and British Department of Transport documentation.

An examination of the BITRE case studies pointed to differences in ex ante analyses and ex post evaluation in terms of BCA and Net Present Value (NPV) results. Numerous pitfalls were identified below in terms of assumptions and modelling inputs, risk estimation and quality control.

F.1.1 Assumptions and Modelling Inputs

The case studies pointed to inconsistencies and deficiencies in a number of areas ranging from model assumptions to input parameters on road user costs, as listed below.

- using inappropriate discount rates
- using different models to provide input to BCA for the same project
- combining related projects into a single large project so that the BCA results for the combined project conceal poor results for some component projects
- underestimation of crash cost savings
- confusing real and nominal values
- providing insufficient detail to allow in-depth cost analysis and revision
- using inconsistent traffic flow and overestimation of traffic growth forecasts
- overestimation of population forecasts leading to high Average Annual Daily Traffic (AADT) figures
- inconsistent applications of speed-flow curves
- overestimation of travel time savings following from overestimation of traffic growth and different assumptions of queuing speeds
- congestion effects not accounted for leading to overestimation of traffic growth
- inappropriate use of AM peak hour traffic to model traffic for all peak hours
- inappropriate interpolation/extrapolation (of benefits) methodologies

---

9 Source studies will not be quoted for confidentiality reasons.

10 Linear interpolation is not consistent with the expectation that as congestion builds, road user cost in the base case and hence time savings from the project will rise at an increasing rate. Non-linear extrapolation of travel time savings (e.g. 1% per annum) beyond 2016 appears to be arbitrary. Better estimates will be obtained by reducing the time...
• obsolete IT software used resulting in loss of data
• incorrect assumption that growth in traffic demand is the same for base and project cases
• ignoring fuel price increases in VOC estimates mainly due to their unpredictability
• excluding environmental impacts
• underestimation of road capacity leading to an overestimation of travel time savings
• inappropriate aggregation of different vehicle-type traffic levels and growth that affects overall traffic growth estimates
• ignoring travel time savings for freight
• double-counting of safety benefits
• not accounting for reduced road length in calculating safety benefits
• ignoring generated/diverted traffic when it is a significant factor.

The lessons for each of these have been incorporated in Table F.1.

F.1.2 Risk Estimation

Risk and uncertainty in the project outturn cost and benefits ought to be considered. Adding a risk premium to a risk-free rate is not an effective way to adjust for optimism bias in forecasts. Risks should be taken into account by developing alternative forecasts for individual costs and benefits, with probabilities attached. Section F.2.4 provides some discussion on risk estimation.

F.1.3 Quality Control

A series of inconsistencies in terms of data entry, verification and project scope has been identified from the case studies as follows:
• data input entry errors
• data inconsistency - significant variances in the same data item used for different stages of the project
• project scope unclear or there are changes owing to legislation and environmental processes
• project timing changes due to scope changes which affect timing and delivery
• reporting dated or different BCRs for the same project when the BCA process is sometimes repeated over a period of time and by different analysts
• ignoring change in construction costs leading to lower NPVs and BCRs
• incorrect inclusion of road user benefits when the project is still in the construction stage.

Some of the lessons to deal with these issues are included in Table F.6.

F.1.4 UK Experience

From the UK experience, the more general pitfalls in the process of project appraisal (NERA 2006) include the following:
• failing to have a clear understanding of the objectives of the proposed project/plan

periods over which results are interpolated or extrapolated by individually estimating more years, and using non-linear relationships for interpolation and extrapolation.
• difficulties in reaching clear agreement on the purpose of evaluation between the parties/agencies involved
• poor understanding of the limitations of the data
• poor interpretation and documentation of the results of the evaluation
• failing to adopt a consistent methodology across projects
• disrupted planning owing to insufficient time and resources, low management priority or, inadequate response to unforeseen events.

The UK process is of a more general nature. It is recognised that addressing the issues listed in Table F.1 to Table F.6 should reduce the inadequacies encountered in developing and reporting BCA results.
F.2 BCA Checklist

The underlying methodology adopted in project appraisal is crucial in determining the economic viability of the project. For each project, a detailed report of the appraisal methodology used, including all assumptions made, input parameters and values, algorithms specified, discount rate, and any sensitivities involved, should be provided. In particular, the catalogue developed for the purposes of this document provides guidance (in the form of ‘templates’) on the following:

- the checklist of assumptions and key variables used (Table F.1)
- the proforma for the BCA estimation process (Table F.2)
- presentation of the appraisal results (Table F.3)
- risk estimation and sensitivity testing (Table F.4)
- presentation of any non-monetised benefits and costs (Table F.5)
- quality control checklist (Table F.6).
- delivery assessment (Table F.7)

It is assumed that the components contained in the templates should already be available in economic analyses as part of the normal infrastructure planning process. In other words, any credible economic appraisal would address the matters set out in this document and have considered the information required in the tables that follow.

It should be noted that a substantial portion of this document is obtained from Infrastructure Australia (2009) and a series of case studies conducted across Australian jurisdictions.

F.2.1 Checklist of Assumptions and Modelling Inputs

Levels of travel demand and their forecasts are crucial to the economic viability of infrastructure projects. To understand the basis upon which demand estimates have been shaped, information on the assumptions, and derivation for each input parameter should be provided for each project initiative (e.g. base case plus project case/options) as set out in Table F.1 and summarised as follows:

- comprehensive list of the detailed assumptions regarding the key demand drivers and how these vary over the appraisal period, e.g. population growth, employment growth, travel demand (e.g. private cars, light commercial and heavy vehicles), public transport demand and demand for cycling and walking
- details of changes in land use (residential density, commitments to rezoning, or other planning changes), and population, employment and traffic projections
- demand modelling outputs including the transport model used, how ‘knock-on’ and wider network effects are calculated including travel demand changes, explanation of the independence of forecasts and the degree of external or independent scrutiny of the forecasts
- general economic model parameters on the project costs (e.g. year of construction, discount rates, appraisal period, cost estimation and project outturn costs) and benefits (e.g. timing, stream of benefits involving user cost savings)
- capital cost, residual value, asset maintenance and replacement costs as well as operating costs
- economic benefits (savings) in terms of the value of vehicle operating costs (VOC), travel time costs, crash costs, and environmental and other externalities.
### Table F.1: Checklist of assumptions and modelling inputs

<table>
<thead>
<tr>
<th>Component</th>
<th>Assumptions/modelling inputs</th>
</tr>
</thead>
</table>
| **Demand modelling, assumptions and results** | • Identify and outline the key drivers of demand.  
• Describe the situation ‘without’ the proposed project initiative, i.e. the base case, including future works and associated capital, maintenance and operating costs (clearly distinguish between the ‘do nothing’ state and the base case). |
| **Land use, population and employment forecasts** | • Describe and/or list the policy statements and plans which support land use forecasts and existing commitments regarding any necessary rezoning; and the party responsible for undertaking the forecasts.  
• Review historical data and estimate employment and residential population growth rate for the area in question.  
• List scenarios for population and employment projections, i.e. low, medium and high over the forecast period. Compute the annual employment and residential population growth rates implied by these land use forecasts.  
• For specific land use forecasts, estimate the difference between residential population and employment, and compare this to the base case land use estimates. Examine the redistribution of jobs and residents, including underlying assumptions.  
• Legislation changes. New legislation affects land area availability and use; update prior estimates to reflect new laws and legislative costs, and document the changes accordingly. |
| **Demand modelling outputs including travel demand** | Identify:  
• the demand model used to generate the forecasts and the party responsible for undertaking the modelling  
• the time period modelled, e.g. a one-hour AM peak of an average weekday, 24 hour period on an average weekday. Ensure the adoption time period is representative e.g. avoid use of AM peak-hour as proxy for all other peak hour traffic.  
• the expansion factor used to translate the daily observation to an annual observation and the sources and logic underpinning the expansion factor  
• new or generated trips (as opposed to using a fixed trip matrix) have been calculated  
• the demand model deals with induced demand  
• traffic forecasts. For urban areas, adopt an urban transport model which caters for network and congestion effects, traffic flow during peak hours, and generated and diverted traffic to avoid underestimating travel demand. |
| **Travel demand growth** | Establish if the assumed traffic growth rates are linear or non-linear from past data.  
• Apply correct formula in extrapolating future road benefits and embark on sensitivity testing on growth rates if there is uncertainty.  
• Ensure assumptions about population growth are realistic.  
• Estimate traffic growth by vehicle-type wherever possible.  
• Source and estimation methods should be well documented. |
| **Economic model parameters – costs** | Establish the:  
• first year of construction/last year of construction period  
• real discount rates used (e.g. 4% or 7%). These rates are normally set by Treasury Departments. BITRE recommends use of the long-term bond rate in real terms for public sector projects obtainable from the yield of Treasury Capital Indexed Bonds from the RBA. This rate does not include a risk premium. Whatever discount rate is used, it is important to be consistent across projects.  
• appraisal period in years, and basis for its selection, for example, using an x-year period for a short- or medium-term project life. A 30-year time horizon is often used for road infrastructure projects.  
• remaining life of the project till the end of the appraisal period  
• basis for cost estimation (base case and project case). Estimate the confidence level (P50, P90, P95) and the basis for this estimate, magnitude of contingency (as a % of total costs), escalation rate over the construction period, profile of the capital cost expenditure (e.g. year 1 – 10%, year 2 – 70%, year 3 – 20%); and parties responsible for estimating and verifying cost estimates (P50 represents a 50% probability of estimate to equal actual costs; similarly for P90, P95).  
• project outturn costs ($, nominal, undiscounted). |
### Component Assumptions/modelling inputs

**Economic costs:**
- Construction costs. The P50 value should be used in BCA. P90 and P95 estimates may be required for government budgeting purposes and may also be used for sensitivity testing in the BCA.
- Project justification. Describe and justify any adjustments made to the project outturn costs to generate an economic project cost for BCA.
- Economic cost – $, nominal/real, undiscounted and $, real, discounted (using a real discount rate e.g. 7%).
- Residual value. State size of the residual value, economic lives of the assets included in the residual value and the methodology adopted.
- Maintenance costs. Describe the basis for estimating all costs, including growth rates over time (for base case and project case).
- Replacement costs. Establish if there is a need to replace or refurbish major components of the infrastructure/rolling stock during the appraisal period, and how these replacement or refurbishment costs are to be captured.
- Operating costs. Describe the basis for estimating all operating costs, including growth rates over time (for base case and project case). Take note of the party responsible for estimating and verifying these costs.

**Economic model – benefits**

**Economic benefits:**
- Benefit components. List the value and source of all benefits relevant to the appraisal. Describe the estimation basis for each benefit component, including growth rates over time.
- Cost and benefit time streams. Attach an appendix showing the time stream for each benefit and cost component ($, real, undiscounted).
- Generalised trip cost (GTC). Calculate the user cost savings on an origin/destination basis within the demand model, or use aggregate outputs from the demand model.
- Timing of benefits. Include economic benefits after project delivery; incorrect inclusion of benefits prior to project delivery results in overestimation of benefits(1).
- Growth of benefits over time. Describe the benefit estimates over the appraisal period, e.g. years 1 to 30, noting assumptions that cause them to grow.
- Related initiatives. Examine the close relation between benefits and costs, their dependence or potential influence by other project initiative(s). Account for how they are related in BCR estimation.

**Value of travel time:**
- Commuter travel. Estimate value of travel time for the project and the differences in value between modes of travel. Decide if the value is based on resource cost estimates or a willingness-to-pay approach.
- Business travel. Identify the specific value applied to business travel.
- Escalation rate. Clearly describe any escalation rates that may have been applied to these values.
- Queuing speed. Use consistent speed-flow curves in evaluation. Ensure the most up-to-date calibration curves are used and assumptions are consistent across projects. Provide supporting explanation for base and project cases. Undertake sensitivity analysis if there is uncertainty(1).
- Travel time savings. Compute the difference in travel time cost between the base and project case. Avoid linear interpolation and non-linear extrapolation methods. Ensure realistic assumptions on traffic growth, road capacity and travel speeds are used, and consistent discount rates are applied across projects as these affect the value of travel time savings(1).
- Travel time for freight. Where appropriate, include freight time savings in terms of freight benefits, e.g., mean/variability of delivery time, damage in transit by vehicle-type and price(1).
- Source. Document the source and assumptions incorporated into estimating travel time savings.
- Wait/access/egress. Take note of the weighting method applied to egress time and the corresponding source transfer penalty. Establish the transfer penalty applied and the corresponding source.
- Boarding penalty for freight carriers. Identify if a boarding penalty has been applied in the estimation of travel time for freight. If so, take note of the magnitude of this boarding penalty (minutes) and the difference between modes.

**Vehicle operating costs:**
- Estimate for all vehicle classes; adjust for increases e.g. fuel prices(1).

**Crash cost savings:**
F.2.2 Proforma for BCA Process

The BCA process involves the application of unit values for each benefit and cost item, and the estimation of volume measures for benefits and costs. A quick guide on obtaining the unit values and estimation of volume measures is as described below.

F.2.2.1 Establish Unit Values

The unit dollar values for benefits and costs should be established. Each component in BCA of a project should be monetised. Table F.2 shows a list of the potential unit values for the costs and benefits that can be monetised and included in a BCA of any project initiative.

The benefits and costs to both users and non-users of a project should be included. For the user, these mostly cover the changes in trip cost (vehicle operating costs, time costs, crash risks) and other private costs directly borne by users. For non-users, these often include the costs of congestion, noise impacts, air pollution, and GHG emissions (i.e. social costs not often directly borne by the user) (Austroads 2012).

F.2.2.2 Estimate Volumes

Having completed the detailed checklist of assumptions and obtaining the unit dollar values for benefits and costs, estimating the volumes/outputs of benefits and costs can take place. For each proposed project initiative (i.e. base case plus project case/options), the number of trips, average journey time, transport mode/fare and number of kilometres travelled should be estimated.

Where possible, the results should be disaggregated by vehicle-type (i.e. car, bus, light commercial vehicles, heavy vehicles) or transport mode (bus, rail, car, cycle, and pedestrian).
Table F.2: List of monetised BCA unit values and volume measures

<table>
<thead>
<tr>
<th>BCA unit values and volume measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Monetise unit values of benefits/costs</td>
</tr>
<tr>
<td>Economic user benefit/costs</td>
</tr>
<tr>
<td>• changes in generalised trip cost (vehicle operating costs, travel time costs, crash risks)</td>
</tr>
<tr>
<td>• changes in other private costs directly borne by users.</td>
</tr>
<tr>
<td>Economic benefit/costs to non-users</td>
</tr>
<tr>
<td>• changes in the cost of congestion</td>
</tr>
<tr>
<td>• noise impacts</td>
</tr>
<tr>
<td>• air and water pollution</td>
</tr>
<tr>
<td>• GHG emissions</td>
</tr>
<tr>
<td>• health/physical fitness impacts.</td>
</tr>
<tr>
<td>2. Provide estimates for volume measures on:</td>
</tr>
<tr>
<td>• number of trips</td>
</tr>
<tr>
<td>• average journey time (total trips/total hours travelled)</td>
</tr>
<tr>
<td>• public transport mode share (where relevant to the proposed project)</td>
</tr>
<tr>
<td>• freight mode share (where relevant to the proposed project)</td>
</tr>
<tr>
<td>• public transport fare revenue (where relevant to the proposed project)</td>
</tr>
<tr>
<td>• number of vehicle kilometres travelled.</td>
</tr>
</tbody>
</table>

Note: Information in this table should be broken down where relevant, e.g., by car, bus, light commercial, heavy vehicle, light rail and heavy rail, and ‘softer’ modes.

Source: Infrastructure Australia (2009).

F.2.3 Presentation of Appraisal Results

F.2.3.1 Presentation of BCA Results

Table F.3 provides a template which practitioners can use in undertaking a BCA to assist reviews in project appraisals. It is assumed that practitioners are familiar with BCA concepts and methodologies. This table provides a way in which the BCA results could be presented. This includes:

- brief summary BCA indicators in the form of project NPV, BCR, IRR and FYRR at the suggested discount factor
- detailed list of each monetised benefit and cost elements throughout the project life for the base case and the project case (or each project option)
- details on the methodology used to calculate each benefit and cost.
### Table F.3: Presentation of BCA results

#### BCA result

Complete the following table:

<table>
<thead>
<tr>
<th>Discount rate (a 4, 7, and 10% sensitivity analysis example)</th>
<th>4%</th>
<th>7%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project NPV (of net benefits in current dollars)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project BCR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV / $</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRR (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FYRR (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Detailed monetised cost and benefits

Complete the following table:

- **Column 1:** List all monetised cost and benefit elements.
- **Column 2:** State the $ value of each cost and benefit element ($, real, discounted).
- **Column 3:** Include the % contribution of each cost and benefit element – adding to a total of 100% across costs; and 100% across benefits.

<table>
<thead>
<tr>
<th>Monetised costs and benefits</th>
<th>Value</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs (broken down by element)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Cost N</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Total</td>
<td>(sum of above) ($, real, discounted)</td>
<td>100%</td>
</tr>
<tr>
<td>Benefits (broken down by element)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefit 1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Benefit N</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Total</td>
<td>(sum of above) ($, real, discounted)</td>
<td>100%</td>
</tr>
</tbody>
</table>

#### Monetised benefits

Complete the following table and set out the value of each benefit (in $, real, undiscounted values) for each forecast year. Reproduce this table for all modes.

<table>
<thead>
<tr>
<th>Base case</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>20XX</td>
<td>20XX</td>
</tr>
<tr>
<td>Benefit 1 ($, real, undiscounted)</td>
<td>...</td>
</tr>
<tr>
<td>Benefit N ($, real, undiscounted)</td>
<td>...</td>
</tr>
</tbody>
</table>
**Monetised costs**

Complete the following table and set out the value of each cost (in $, real, undiscounted values) for each forecast year. Reproduce this table for all modes.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Base case</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20XX</td>
<td>20XX</td>
</tr>
<tr>
<td>Cost 1 ($, real, undiscounted)</td>
<td>....</td>
<td>....</td>
</tr>
<tr>
<td>Cost N ($, real, undiscounted)</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

**Details on methodology for each benefit**

Complete the following table by providing full details on the methodology used to calculate each benefit. Reproduce this table for each benefit item for one forecast year.

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Base case</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecast year (20XX)</td>
<td>Forecast year (20XX)</td>
</tr>
<tr>
<td>Volume measures</td>
<td>(e.g. wait time, vehicle kilometres travelled)</td>
<td>(e.g. wait time, vehicle kilometres travelled)</td>
</tr>
<tr>
<td>Unit values used and source</td>
<td>(e.g. value of travel time, value of serious injury) Source?</td>
<td>(e.g. value of travel time, value of serious injury) Source?</td>
</tr>
<tr>
<td>Algorithm used to calc. total benefit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ (undiscounted)</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

**Details on methodology for each cost item**

Complete the following table by providing full details on the methodology used to calculate each cost item. Reproduce this table for each cost item for one forecast year.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Base case</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecast year (20XX)</td>
<td>Forecast year (20XX)</td>
</tr>
<tr>
<td>Volume measures</td>
<td>(e.g. wait time, vehicle kilometres travelled)</td>
<td>(e.g. wait time, vehicle kilometres travelled)</td>
</tr>
<tr>
<td>Unit values used and source</td>
<td>(e.g. vehicle operating costs, value of travel time, value of serious injury) Source?</td>
<td>(e.g. vehicle operating costs, value of travel time, value of serious injury) Source?</td>
</tr>
<tr>
<td>Algorithm used to calc. total cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ (undiscounted)</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

*Source: Infrastructure Australia (2009).*
F.2.4 Risk Estimation

The common approaches to incorporating risks in the project outturn costs and benefits are sensitivity analysis and probabilistic risk modelling.

F.2.4.1 Sensitivity testing

Sensitivity analysis is a key element of a BCA process. The purpose of the sensitivity testing is to better understand the risks associated with a proposed project initiative.

There are uncertainties surrounding all key variables in a proposed project initiative. Typically, the sources of uncertainty refer to the following elements entering a BCA process:

- Capital costs. Capital costs refer to costs incurred during road construction, covering materials, equipment, land and buildings. These costs can vary depending on technical problems, weather, changes in wages and prices, and changes in project scope.
- Construction duration. Construction duration covers the period from the project identification stage to project delivery. The duration of projects can vary especially for projects which take a long time to develop and deliver.
- Operating (including maintenance) costs. Operating costs refer to the recurring expenses for a project, primarily maintenance.
- Under and over-estimation of the benefits - this could arise from:
  - changes in global oil prices. Unpredictability in the movement of energy (fuel) prices will affect the vehicle operating cost estimates, which in turn, will alter the benefit/cost estimates
  - different population and economic activity growth/decline scenarios. Changing population growth and fluctuations of economic activity can affect project benefits.

A template for the conduct of the sensitivity testing for the purposes of BCA is set out in Table F.4. Sensitivity testing could be applied via a number of key input variables that influence the BCA results/indicators such as BCR, NPV, IRR (Internal Rate of Return) and FYRR (First Year Rate of Return) (see Table F.4).

Table F.4: Sensitivity testing

<table>
<thead>
<tr>
<th>Sensitivity test #</th>
<th>Variation</th>
<th>NPV and BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Starting result without discount rate</td>
<td>....</td>
</tr>
<tr>
<td>1</td>
<td>Discount rate 4%</td>
<td>....</td>
</tr>
<tr>
<td>2</td>
<td>Discount rate 7%</td>
<td>....</td>
</tr>
<tr>
<td>3</td>
<td>Discount rate 10%</td>
<td>....</td>
</tr>
<tr>
<td>4</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Source: Infrastructure Australia (2009).
The main drawback of sensitivity analysis lies in its subjectivity. Often the analyst relies on subjective and arbitrary estimates of change to one or more uncertain factors. Another drawback lies in the absence of estimation of the likelihood of the cost being higher or lower. There is an added limitation in the number of input variables, as this number results in numerous combinations which are confusing for a decision-maker. This is not discounting the fact that some input variables may be closely correlated (e.g. road usage and maintenance costs) which may produce meaningless results (Campbell & Brown 2003).

Nonetheless, sensitivity analysis is a useful first step in determining the sensitivity of the variables and whether they should be included.

**F.2.4.2 Probabilistic risk modelling**

Probabilistic risk modelling is a formal technique catering for a range of possible values (e.g. low, medium, high) as in sensitivity analysis, but goes beyond by introducing the probability factor of the project cost being higher or lower. Different software packages can be used to undertake probabilistic risk modelling e.g. @RISK, Risk Explorer, and Risk Simulator.

For larger projects, analysts should undertake a probabilistic risk modelling. Depending on project complexity and data availability it would be easy to use available risk analysis software to apply appropriate probability distributions. A popular distribution often chosen for its simplicity is the triangular distribution, which assigns higher probabilities to values near the expected value and lower probabilities to values near the boundaries of a range. This distribution can be described in terms of the estimated maximum value (high), minimum value (low) and modal value (most likely).

**F.2.4.3 P50 and P90 cost estimation**

Individual projects are considered at the mean of a simulated cost distribution, typically the P50 estimate. The P50 cost value is an estimate of the project cost based on a 50% probability that the cost will not be exceeded. The P90 value is an estimate of the project cost based on a 90% probability that the cost will not be exceeded (Evans & Peck 2008).

Owners (and their management) often prefer to have less commercial (and political) exposure in respect of capital budgets and often look for a P90 figure (or equivalent if done deterministically), meaning the contingency allowance on top of the base cost estimate to ensure that there is a 90% chance that the amount will not be exceeded.

Government funding agencies may require transport planners and practitioners to provide a P90 cost estimation for financial budgeting.

**F.2.5 Non-monetised Benefits and Costs**

Ideally, a BCA would include all benefits and costs carefully assessed. However, in some cases benefit and cost categories are difficult to monetise or quantify. They include visual/landscape, social amenity, social cohesion, biodiversity and heritage or cultural impacts. Non-monetised benefits/costs should be carefully assessed and entered to produce an ‘Adjusted BCA’ (ATC 2006) by employing an appropriate set of weights which can represent the non-monetisable cost or benefit factors. A rating scale consistent across these factors could for example be employed as follows:

- **highly beneficial** – major positive impacts resulting in substantial and long-term improvements or enhancements of the existing environment
- **moderately beneficial** – moderate positive impact, possibly of short, medium or longer-term duration. Positive outcome may be in terms of new opportunities or outcomes which enhance or improve on current conditions
- **slightly beneficial** – minimal positive impact, possibly only lasting over the short-term. May be confined to a limited area
- **neutral** – no discernible or predicted positive or negative impact
- **moderately detrimental** – minimal negative impact, probably short-term, able to be managed or mitigated, and will not cause substantial detrimental effects. May be confined to a small area
- **highly detrimental** – moderate negative impact. Impacts may be short, medium or long-term and impacts will most likely respond to management actions.

Each non-monetiseable benefit/cost item could be rated using a rating scale as described. This rating scale could be viewed as the weights attached to the non-monetary objectives.

**Table F.5: Presentation of non-monetised BCA results**

<table>
<thead>
<tr>
<th>Cost/benefit</th>
<th>Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 1: Visual amenity</td>
<td>Inclusion of a nature strip on a roadway in a suburb will lead to an improvement in visual amenity?</td>
<td>Moderately beneficial</td>
</tr>
<tr>
<td>Example 2: Social cohesion</td>
<td>Addition of a bus lane will lead to greater social cohesion?</td>
<td>Neutral</td>
</tr>
</tbody>
</table>

Source: Infrastructure Australia (2009).

A variety of Multi-Criteria Analysis (MCA) techniques, which are sometimes presented as independent alternatives to a proper BCA and, which score impacts on a numerical scale and calculate weighted totals, are not good practice. They should be avoided. They can be manipulated to justify bad projects. The ATC Guidelines present a type of MCA called the Appraisal Summary Table (ATC 2006). The Appraisal Summary Table summarises monetised and non-monetised impacts, with the latter assessed on a qualitative assessment scale. Project impacts are presented and discussed, but not assigned numerical scores and combined using largely arbitrary weight schemes.

The ATC Guidelines also describe an ‘adjusted BCA’ approach as mentioned above. It provides flexibility to apply appropriate weights to specific benefits and costs in a BCA to reflect the relative importance governments place on different objectives such as freight transport and safety. This avoids many of the difficulties associated with ‘independent quantitative’ MCA techniques.

The ATC Guidelines warn that adjusted BCA can lead to highly wasteful initiatives being implemented. As a safeguard, adjusted BCA results should never be reported separately from the corresponding unadjusted BCA. This ensures that the potential efficiency losses from decisions based on adjusted BCA results are transparent. The same warning applies with greater force against using ‘independent quantitative’ MCA applications.

**F.2.6 Quality Control**

At each stage of the appraisal process, quality checks should be undertaken to ensure that errors (if any) are rectified during the appraisal process. This applies to data entry, data verification, documentation of information sources, indexation and version control. Version control refers to having a consistent approach to recording all alterations to BCA that affect the bottom-line results. Details in BCA that are likely to change as the draft BCA develops include the scope, design and timing of projects, assumptions, benefit estimation methodology, and the particular costs and
benefits included. A defined system of quality checks should be in place that involve peer and supervisor review.

Table F.6 provides a list of possible quality control checks that should be embedded during the evaluation stage.

<table>
<thead>
<tr>
<th>Quality assurance for BCA checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data entry</strong></td>
</tr>
<tr>
<td>• Check input data are entered correctly on a regular basis.</td>
</tr>
<tr>
<td><strong>Data verification</strong></td>
</tr>
<tr>
<td>• Verify that the same data items for versions of the BCA are the same.</td>
</tr>
<tr>
<td>• Check for correct and consistent use of BCA decision rules.</td>
</tr>
<tr>
<td>• Ensure BCR and NPV are estimated with the most up-to-date parameter values.</td>
</tr>
<tr>
<td>• Ensure road user benefits are not included during project construction stage (before the project has been completed).</td>
</tr>
<tr>
<td><strong>Documentation</strong></td>
</tr>
<tr>
<td>• List and detail the sources of information used in this economic appraisal.</td>
</tr>
<tr>
<td>• Document the sources of the parameters used to estimate benefits and costs.</td>
</tr>
<tr>
<td>• Document the derivation methodologies for benefits and costs.</td>
</tr>
<tr>
<td><strong>Real and nominal prices</strong></td>
</tr>
<tr>
<td>• Ensure that costs and benefits are expressed in real terms for the same price year.</td>
</tr>
<tr>
<td><strong>Changes in scope</strong></td>
</tr>
<tr>
<td>• Scope changes. Identify if there are changes to the project's scope. Re-estimate the BCA if necessary.</td>
</tr>
<tr>
<td>• Timing and delivery. In conjunction with scope changes, adjust the timing and delivery of a project's timeline. Re-estimate the BCA if necessary.</td>
</tr>
<tr>
<td>• Project assumptions. Identify if there are any changes in project assumptions associated with any changes in the project scope.</td>
</tr>
<tr>
<td>• Project methodology. Identify if there are any changes to the project methodology associated with any change in the project scope.</td>
</tr>
<tr>
<td><strong>Version control</strong></td>
</tr>
<tr>
<td>• When a new version of the BCA has been completed and the results changed, ensure all material reporting or referring to the results has been updated.</td>
</tr>
<tr>
<td>• Technology upgrades, e.g. migration of IT platform in organisation, new software versions. The BCA model and results should be readable and replicable in the new platform or the latest version of software.</td>
</tr>
<tr>
<td><strong>System of quality checks</strong></td>
</tr>
<tr>
<td>• Peer and supervisor review. Implement a system of quality checks, i.e. peer review, supervisor review and finance audits (if necessary) for new transport project initiatives. It is noted that 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 BCA.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
</tbody>
</table>

Source: Case studies across Australia.

F.3 Delivery Assessment

Preparation and management of an evaluation requires a comprehensive assessment of the project deliverables, including risk management, needs assessment to qualify for federal government funding, delivery strategy and a governance model. Table F.7 provides a checklist on the key items required to complete a deliverability assessment as developed by Infrastructure Australia (2009).
F.3.1 Risk Management

A good evaluation design will incorporate an assessment of risks in the project evaluation stage. Risk management should cover the identification of risks, construction risks, environmental risks and other risks e.g. social, political risks.

Risk identification should be undertaken formally and the project should be staged such that the identified risks are reduced and managed properly. Construction risks pertaining to location, geology, design, labour expertise, delivery, scale and costs of project, environmental approvals and land acquisition should be identified and included in the project cost estimate. With regards to environmental risks, community engagement, land use/environment/planning/licence approvals should be sought. Other risks refer to significant social or political risks which should be reflected in the project cost estimate.

F.3.2 Project Funding

Critical to any project are funding needs and requirements. The evaluation should consider whether there is a need for government funding or Commonwealth funding. If there is a need for government funding, the key questions asked are whether the project should be publicly funded, privately funded or based on a user-pay model. If it is an issue of Commonwealth funding, the project is normally regarded as a project of national importance and there could be consideration as to whether a mix of funds should be sought from the state or local government.

F.3.3 Delivery Strategy

The delivery strategy should provide confidence that the project benefits are delivered. Issues pertaining to delivery strategy include the source of finance, contract type, procurement process, operations and maintenance of infrastructure, identification of risks and project milestones.

F.3.4 Governance Model

The project governance model should provide confidence that the project is administered, operated and delivered in a consistent manner. The key areas are mainly about the governance arrangements, commitment, role of the Commonwealth, role of key stakeholders in the governance arrangements and a comprehensive review process. The review process can consist of either an independent review of the governance plan or a series of independent reviews of the project.
### Table F.7: Deliverability assessment

<table>
<thead>
<tr>
<th>Component</th>
<th>Questions, documentation and responses</th>
</tr>
</thead>
</table>
| 1. Is the risk being managed appropriately? | **Key questions on risk management:**  
- Have risks been formally identified, assessed and addressed through a risk management strategy?  
- Can the project be staged to reduce risks / improve manageability?  
**Information and documentation to provide includes:**  
- risk assessment reports  
- risk management strategy  
- peer review of risk assessment and management strategy  
- analysis of staging options  
  - factors taken into account – economies of scale (for procurement and usage)  
  - best time to deliver relevant stages – taking into account future demand forecasts, flexibility for other stages of the project.  
**Key questions on construction risks:**  
- Does the project pose any significant construction risks due to its location, geology, design?  
- Are those risks reflected in the construction cost estimate?  
- Is there sufficient capacity (including relevant skills and expertise) to ensure the delivery of the project and realisation of benefits?  
- Are there any significant consequential risks to the wider network?  
- Are those risks reflected in the project’s cost estimate and cost/benefit analysis?  
- Will delivery require associated works to enable the new project to succeed in practical terms?  
  - What is the scale and cost of likely works?  
  - Who will fund the works?  
  - How will they be delivered?  
- How will interface risks with the project be managed?  
- What requirements will need to be satisfied prior to construction of the project, including relevant planning and environmental approvals, land acquisition?  
**Information and documentation to provide includes:**  
- detailed engineering report  
- peer review of engineering report  
- detailed construction cost estimate, including probabilistic modelling, that reconciles with the risk assessment  
- independent review of construction cost estimate.  
**Key questions on environmental risks:**  
- What are the significant environmental risks?  
- Are they reflected in the project cost estimate?  
- What community engagement/consultation has been undertaken?  
- What land use/environmental/planning approvals need to be obtained?  
- What approvals/licences have already been obtained?  
**Information and documentation to provide includes:**  
- environmental reports (e.g. noise, amenity)  
- environmental impact statement  
- conditions of approval.  
**Key questions on other risks**  
- Are there any significant social or political risks?  
- Are there any significant risks posed by (or for) other levels of government?  
- Are there any other significant risks?  
- Are they reflected in the project cost estimate?  
**Information and documentation to provide includes:**  
- political risk analysis  
- MOUs with other levels of government. |
<table>
<thead>
<tr>
<th>Component</th>
<th>Questions, documentation and responses</th>
</tr>
</thead>
</table>
| 2. Is there a need for government funding? | **Key questions:**  
  - Does a market exist or can a market be introduced, i.e. where users pay for services?  
  - Can the private sector partially or fully fund the project in return for revenue from users or government?  
  - Can the private sector add value by financing and delivering the infrastructure and related services?  
  - If so, is private financing proposed?  
  - Where private financing is envisaged, is a competitive market for the provision of private capital likely given the location and type of project?  
  - If a mix of private and public financing is proposed, what are the market failures that require this?  
  - If public financing is proposed, what are the public policy objectives being pursued or market failure being addressed?  
  - Information and documentation (e.g. a detailed business case) to be provided includes:  
    - analysis of scope for private sector financing (e.g. feasibility of recovery of full or partial costs from users, potential for value add from private financing), information on market soundings undertaken  
    - analysis of potential delivery models  
    - value for money assessment of the delivery model. |
| 3. Is there a need for Commonwealth funding? | **Key questions on the case for Commonwealth funding:**  
  - Why should the Commonwealth rather than state/territory or council fund the project – what is the national interest?  
  - Is Commonwealth funding likely to lead to a displacement of state/territory infrastructure spending?  
  - What is the proposed state/territory/council funding contribution for the project?  
  - What other sources of Commonwealth funding are being provided for the project?  
  - Where a mix of funding sources is envisaged, does the mix reflect the respective interests of the funders and is risk allocated appropriately?  
  - What is the proposed timing of cash flows for each contributor and what will each contributor’s funds be used for (include details of the inflator used to derive nominal amounts)?  
  - Where Commonwealth funding is being sought how is it envisaged that funding would be provided, e.g. grant, equity, loan?  
  - Information and documentation to provide includes:  
    - where Commonwealth funding is sought, projected state infrastructure spending with and without Commonwealth funding  
    - financial model of the project’s cash flows, including real, nominal and discounted dollars. |
| 4. Does the delivery strategy provide confidence that the project benefits will be delivered? | **Key questions on delivery strategy issues:**  
  - What is the proposed delivery strategy, including source of finance, contract type and procurement process?  
  - What is the proposed strategy for operations and maintenance of the infrastructure?  
  - Does the delivery strategy effectively deal with the risks identified?  
  - Does the delivery strategy introduce new risks, e.g. design, construction or operation interfaces?  
  - At what stage is the project in its development, e.g. one option to address a need, preferred option, concept design, business case, committed funding, inclusion in strategic infrastructure plan or similar, procurement.  
  - What are the project’s key milestones?  
  - Information and documentation to provide includes:  
    - procurement strategy report, including analysis of options considered  
    - results of market soundings on:  
      - level of interest in the project  
      - proposed delivery strategy  
      - proposed financing/ownership model  
    - timing and staging of the project. |
| 5. Does the project governance model provide confidence that the project benefits will be delivered? | **Key questions on project governance include:**  
  - What are the proposed governance arrangements for the project? What has been used until now, and what is proposed between now and commitment to proceed, during procurement and delivery, during operations?  
  - What role is envisaged (if any) for the Commonwealth if it contributes to the project?  
  - Who are the key stakeholders and what role will they play in project governance?  
  - Is the project subject to a larger plan or similar review process?  
  - Information and documentation to provide includes:  
    - governance plan  
    - independent review of governance plan  
    - reports from independent reviews of the project, e.g. gateway reviews. |

Source: Infrastructure Australia (2009).
F.4 Summary

BCA results are expected to form an integral part of the business cases for project initiatives submitted for funding. A series of ex post examinations of BCA of major road projects submitted for national funding have brought to light some serious deficiencies and inconsistencies in the way BCA was performed. To improve the quality of BCA of projects, it is recommended that appraisals are developed and performed by experienced analysts and are reported in a transparent and easy-to-duplicate format. The discussion and associated checklists presented in this document are designed to assist in that direction. Practitioners are encouraged to provide completed templates as set out in Table F.1 to Table F.7, as part of the full business case with supporting documentation. The documentation should include:

- a detailed report on the economic appraisal methodology, including a full listing of all parameters used and sensitivity tests applied
- a ‘checklist’ of assumptions, key variables, and models used in BCA, a key input is the predicted demand and associated demand drivers
- a report that provides cost estimates primarily based at the P50 level of expected values
- the proforma for the BCA estimation process
- the presentation and discussion of the BCA results
- a quality control ‘checklist’ referring to the tasks of data entry, data verification, documentation of information sources, indexation and project version control.
- a checklist on the key items required to complete a deliverability assessment.

The BCA checklists will assist jurisdictions around Australia to avoid the common pitfalls in the BCA process and lead to a greater consistency between ex ante and ex post estimates, and a more robust way of undertaking BCA.
COMMENTARY G: SMALL TRAVEL TIME SAVINGS

Valuing travel time savings (VTTS) has major implications for evaluating transport investments and understanding travel time savings is one of the key concerns of transport economics, analysis and modelling. Travel time is also used as a cost/benefit indicator for road transport projects. The value individuals place on the time spent in travel determines the productivity of a road network, making time savings desirable.

In Australia and New Zealand, current practice does not distinguish between small and substantial travel time savings in project evaluation. A review of the international literature was undertaken to identify, review and compile existing literature on small travel time savings, and consider current practice on the inclusion of small travel time savings in project evaluation.

The Commentary summarises key findings from the international literature search and is organised along the following lines:

- definitions of small travel time savings
- valuation of small travel time savings and underlying theoretical framework
- treatment of small travel time savings in project evaluation
- concluding remarks and recommendations.

Further information can be obtained from Austroads (2011b).

G.1 Definitions of small travel time savings

Small travel time savings can be defined, broadly, in proportional or absolute terms. An absolute definition provides the actual measure of the time savings in minutes, while the proportional definition supplies the time savings as a percentage of the whole trip.

G.1.1 Absolute definition of small travel time savings

An absolute definition of small travel time savings provides the actual number of time units saved. The definition of 'small' is generally based on evidence that individuals impose 'perception thresholds' when dealing with the concept of time. Due to the non-transferability and non-storability of time, users have a certain minimum level from which they consider the time savings worthwhile (Hensher 1976). This threshold varies with individuals, traffic conditions, trip length, travellers' comfort and purposes. Some authors argue that a greater proportion of the population will not perceive time savings if they are small, but as the size of the savings increase, a larger proportion of the population will adjust their behaviour to match this increase (Richardson in McKnight 1982).

Due to the subjectivity of time perceptions, an alternate and more consistent definition of small travel time savings is gained by measuring travel time savings in terms of the proportion of trip time that users account for, rather than in terms of the absolute size of time saving.

G.1.2 Proportional definition of small travel time savings

Small travel time savings can be defined in terms of the percentage of the trip the time savings account for. This is useful as it provides a standard measure of size even when trips of different duration are involved. For example, it would be difficult to compare a ten minute travel time saving made on a 30 minute trip to a ten minute saving made on a two-hour trip when trying to measure utility and assign a value.
With a proportional definition of small, there can be consistent valuation of a specific size of time saving whether the trip is twenty minutes or five hours long. Measuring and valuing travel time savings on the basis of proportionality could remove the variable of trip duration (see Cherlow 1981 and Hensher in McKnight 1982 for some examples). Moreover, as small travel time savings are valued lower for inter-urban than for intra-urban travel, it should be evaluated in relation to the overall travel time of the trip (Ramjerdi et al. 1997).

There are debates, however, as to how the value of travel time savings varies in relation to trip length. The studies mentioned in Cherlow (1981) have differing conclusions on this point. Kato (2006) found that the value of travel time savings decreases as travel time increases, but did not elaborate on the specifics of the study vis-à-vis the size of the saving and the length of the trip.

G.1.3 Summary

The evidence in the literature on the way ‘small’ travel time savings are defined is mixed. This evidence provides stronger support for defining small travel time savings in terms of the percentage of the trip time savings account for. In comparison, the absolute definitions of small travel time savings are regarded as difficult to interpret and can be misleading. Nonetheless, there is a consensus in the literature that the way one defines small travel time savings affects the valuing and outcomes of project appraisal.

G.2 Valuation approaches to small travel time savings

There has been debate on the appropriate value to be assigned to travel time savings of different magnitudes, focusing on whether small travel time savings should be measured at: (i) constant or non-zero unit value approach; or (ii) lower unit value approach or zero value approach.

G.2.1 Constant or non-zero unit value approach

Under a constant unit value (CUV) approach to the valuation of small travel time savings, each unit of time saving is given the same value, regardless, in this case, of magnitude of the time saving. For example, under this approach every minute of travel time saved will be awarded a value of ‘x’, regardless of whether the total time saved is three minutes or 30 minutes; the value of a three-minute saving will be 3x, and the value of the 30 minute saving will be 30x.

Two main arguments for the adoption of a CUV surface from the literature, termed as the distributional argument and the decompositional argument.

The distributional argument

The distributional argument assumes that travellers on the same part of a route all have some amount of slack time for which they cannot find a purpose (Sharp 1973 and Fowkes 1999 in Mackie et al. 2001a). Additional time savings can be added to these amounts of unusable slack time, and for some travellers, the result will be an amount of slack time large enough for productive use. The slack time will be uniformly distributed and ranges from zero to the threshold time (minimum).

With this distribution, any given time saving will push some travellers over this threshold and their total time saving would be useful and therefore valuable. Fowkes and Wardman (1988) and Fowkes (1996) (both in Welch and Williams 1997), find that valuation of small travel time savings using this method is equivalent to valuing them at a constant unit value (CUV).

The distributional argument may not hold in the long-term, but when considered in the context of small travel time savings on different stages of a single journey, it indicates how a small travel time saving made at one stage may contribute significantly to an overall time saving for the entire
journey. Since the valuation of the time saving for travellers who are pushed over the threshold was previously equated to the value of the sum of the time savings made by all of the travellers, a CUV approach is preferred.

The decompositional argument

The decompositional argument relates to small travel time savings made at different stages of a trip being added to arrive at a larger total travel time saving for the entire trip, or aggregating small travel time savings from different links on a network to arrive at a larger total time saving for the entire journey. The logic is that ‘the whole’ should equal the sum of the parts. To allow the addition of the parts, the CUV approach should be adopted.

Gunn and Worsley (1999) recommended the use of averages for the valuation of travel time savings, which amounts to advocacy of the CUV approach. The reasoning relates to the long-term value of small travel time savings, which is likely to be greater than the short-term value because of the ability of travellers to reschedule over the longer term, so that eventually, even very small time savings can be put to productive use. However, Leitch (1977) indicates that it is inconsistent to value the overall time saving differently from the sum of its parts.

Following a literature survey, the U.S. Department of Transportation (DoT) found that most evidence given in support of valuing approaches, which discount or otherwise reduce the value of small travel time savings below that of larger travel time savings, is found in early papers which are no longer deemed reliable. Neither the underlying theory nor empirical evidence provides reliable guidance for identifying a threshold to distinguish between small and large time savings (Department of Transportation 1997).

G.2.2 Lower unit value approach or zero value approach

Under a discounted unit value (DUV) approach to valuing small travel time savings, a threshold is determined, below which, time savings are given a discounted value, relative to a time saving of a size above the threshold, or a value of zero, depending on the DUV function.

Welch and Williams (1997) summarise the main approaches for discounting the unit value of small travel time savings by providing descriptions of the main functions. For all of these functions, a threshold is defined as \( z^* \). If the time saving, \( z \), is greater than or equal to the threshold, it is deemed ‘not small’ and therefore is given a unit value of 1.0 which signifies a ‘full’ unit valuation. When \( z < z^* \), the travel time saving is deemed ‘small’ and will be given a unit value of zero (step function), or a unit value which is a proportion of the ‘full unit value’ awarded to time savings of a size greater than \( z^* \) (wedge function, general linear discounting function and multiple step function). The function which those authors appear to favour is the wedge function, for which the value of a travel time saving is equal to \( \frac{z}{z^*} \), if \( z \leq z^* \), or 1.0 (100% of the possible unit value) otherwise.

Generally, arguments supporting the adoption of a reduced or zero unit value (DUV) approach to small travel time savings revolve around the establishment of a threshold, below which the travel time saving is not noticed or valued by individual travellers, or it is assumed that the travel time saving is not substantial enough to be re-allocated efficiently to other productive use. Such arguments revolve around the belief that if the traveller does not fully perceive the time saving, or does not see it as useful, time saving should not be valued.

G.2.3 Current practice

There has been a significant move to the CUV approach. Although shortcomings in the use of CUV have been noted, it is still the preferred approach in cost-benefit analyses (Table G.1).
### Table G.1: Current practice – for valuing small travel time savings

<table>
<thead>
<tr>
<th>Country</th>
<th>Study</th>
<th>Approach</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>• None</td>
<td>• NA</td>
<td>The CUV approach is generally adopted in project appraisals. However, some of the empirical evidence in a number of studies found that the unit value of small travel time savings is lower than larger time savings. These findings tend to be based on assumptions about user perceptions of ‘small’ in travel time savings.</td>
</tr>
<tr>
<td>Norway</td>
<td>• Ramjerdi et al. (1997)</td>
<td>• Analyses both the discounted unit value (DUV) and the constant unit value (CUV) approaches</td>
<td></td>
</tr>
<tr>
<td>British approach</td>
<td>• Powell and Davis (1996) - small travel time savings main element of benefits under the current COBA methodology • Bates and Whelan (2001) • Welch and Williams (1997) • Waters (1992)</td>
<td>• CUV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CUV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CUV - they advocate the discounted unit value approach</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CUV approach</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>• Fosgerau (2005)</td>
<td>• CUV</td>
<td>Formerly, different levels of government applied different methodologies, both DUV and CUV in use.</td>
</tr>
<tr>
<td></td>
<td>• Welch and Williams (1997)</td>
<td>• CUV</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>• Hultkrantz and Mortazawi (2001)</td>
<td>• CUV</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>• Welch and Williams (1997)</td>
<td>• CUV, used DUV for a while</td>
<td></td>
</tr>
<tr>
<td>Other European countries</td>
<td>• HEATCO Deliverable 2 (2006)</td>
<td>• EU-25 plus Switzerland excluding Germany use the CUV approach</td>
<td>Germany uses DUV for non-work trips</td>
</tr>
<tr>
<td>United States of America</td>
<td>• Department of Transportation (1997) • Welch and Williams (1997)</td>
<td>• CUV</td>
<td>• Previously used DUV</td>
</tr>
</tbody>
</table>

Source: Austroads (2011b).

### G.3 FACTORS IN VALUING SMALL TRAVEL TIME SAVINGS

There have been longstanding debates on the factors affecting the value of time savings, including:

- perspective taken when valuing travel time savings
- consistency of the occurrence and size of the travel time savings
- whether the value required is a short-term or long-term value
- mode of travel
- nature of the journey purpose.

#### G.3.1 Objective vs. subjective approach

Two possible approaches to valuing small travel time savings exist: the objective approach and subjective approach. An objective perspective gives small travel time savings significant unit values and avoids some complications relating to individual travellers’ perceptions and conceptualisation abilities which undervalue small travel time savings. Deriving a value of a small travel time saving from the valuation of that saving by travellers themselves produces a subjective
An objective valuation produces rationally determined economic values according to defined, consistent methods of value measurement. In contrast, a subjective valuation might reflect the undefined and widely varying methods of measurement employed by travellers valuing the same travel time saving under contexts that may be unique to the individual’s situation and subject to errors in learning and perception.

G.3.2 Nature of journey purpose

The nature of the journey purpose could have a large impact on the usefulness of small travel time savings made, from both an objective and subjective perspective. It could be determined by its characteristics, which are suggested as being the flexibility or inflexibility of scheduling, the value of the journey purpose (either objective or subjective) and the routine or non-routine nature of the purpose. The extent of flexibility surrounding the trip purpose might affect the value that small travel time savings would have, but larger values would be gained from an objective measurement of the economic benefit gained from small travel time savings.

G.3.3 Time horizon

Small travel time savings differ depending on whether they are valued in the short-term or in the long-term (Gunn & Worsley 1999, Mackie et al. 2001a, Mackie et al. 2001b and Ramjerdi et al. 1997). In the long run, some adjustment of schedules or activity patterns in response to small travel time savings occurs. The value of longer-term adjustments to activity patterns (Gunn & Worsley 1999) has a positive effect on the valuation of small travel time savings, but is not reflected in the subjective valuations of the travel time savings of individual travellers, because the mental exertion required for them to consider the utility of small travel time savings in the future is significant. In the short term, the traveller might have some difficulty putting it to productive use. However, if the travel time saving occurs regularly, there will most likely be a gradual subconscious adjustment made to activity patterns, so that even small amounts of time are re-assigned to other activities.

G.3.4 Consistency

The value of small travel time savings depends on the consistency of occurrence and size of time savings especially where the journey is taken on a regular basis. The U.S. Department of Transportation (1997) argues that when small travel time savings occur predictably or regularly, they can be used productively as travellers adjust their schedules. It would appear then, that arguments for significant or equal valuation of small travel time savings hinge on (amongst other factors) the consistency factor as it relates to those time savings. If it is accepted that, in the long-term, full or productive use can be made of travel time savings because of gradual rescheduling on the part of the individual, then it must be acknowledged that for this to happen, small travel time savings should occur regularly for a particular journey, and that there is a low degree of variability in the size of the travel time saving.

G.3.5 Mode of travel

It is important to consider the mode of transport that the travel time saving relates to, as all of these impose different conditions on the traveller and their ability to put travel time and travel time savings to productive use. It is suggested that the mode for which travellers have the highest value of travel time savings is airplane, followed by rail and automobile (Kato 2006 and Ramjerdi 1997). Hence, the less flexible time budget for car travellers will benefit from a small travel time saving than the more flexible time budget of air and rail travellers.

Small travel time savings for journeys made on public transport should be considered separately from those made on private transport. Public transportation journeys have two distinct categories of travel time: (i) in-vehicle and (ii) out-of-vehicle travel time savings in which are likely to have
different values. Furthermore, public commuters have to make connections, in which case, a small travel time saving may be valuable because it reduces the chance that the traveller will miss their connection, an outcome which would have a high disutility associated with it. A larger travel time saving may also reduce the chance of missing a connection, but then the traveller may arrive too early. In the event that a small travel time saving reduces the chance of a missed connection and the associated disutility, small travel time savings for public transport journeys may have significant unit values even when considered in the short-term.
GLOSSARY

Accessibility. The accessibility of a location reflects the generalised cost (time, money, discomfort and risk) needed to reach desired goods, services, activities and destinations (together termed ‘opportunities’) from that location. It is normally expressed as an ‘accessibility index’ (for which various mathematical definitions exist) and is calculated within transportation models.

Accounting ratio. A quotient obtained by dividing one stipulated monetary item to found on a company’s financial statements, by another. Accounting ratios measure company performance, financial status, and investment potential. There are about a dozen commonly used accounting ratios; they include the current ratio (current assets divided by current liabilities) and P/E ratio (share price divided by earnings).

Base year. The year to which all values are discounted when determining a present value.

Base case. The base case reflects the circumstances likely to prevail in the absence of the project. It is generally defined as the existing condition (or service standard) and its continuation over the evaluation period.

Benefit–cost analysis (BCA). An economic technique for gauging the value of economic decisions in terms of their capacity to satisfy the totality of individual wants of all members of society.

Benefit–cost ratio (BCR). The ratio given by discounted benefits divided by discounted costs.

Consumer and producer surplus. The difference between the price that a consumer is willing to pay for a particular good or service and the price the consumer actually pays. Producer surplus is the difference between the price at which a producer is willing to supply a particular good or service and the price the producer actually receives.

Consumer sovereignty. The doctrine that consumers themselves are the best judges of their own economic preferences.

Deadweight loss. The net loss in social welfare when the benefit generated by an action differs from the foregone opportunity cost. It usually consists of a combination of lost consumer surplus and lost producer surplus.

Depreciation. (Financial): The allocation of the cost of an asset over a period of time for accounting and tax purposes. (Economic): A decline in the value of an asset due to general wear and tear or obsolescence.

Discounting. A means of adjusting monetary impacts that are expected to occur in the future to allow for the time value of money.

Discount rate. A percentage by which benefits in one period would have to increase to retain the same value, were they to arise a period later instead.

Discounted cash flow (DCF). An analytical technique for converting a monetary impact at one point in time to a monetary impact at another so as to allow for the time value of money; the family of project performance measures (including IRR and NPV) are based on the foregoing technique.
**Dose-response function.** A mathematical relationship between the amount of corrective ‘treatment’ and its outcome; for instance, the effect of the number of speed cameras (the dose) and changes in the social cost of road casualties (the response).

**Economic efficiency.** An economy that is perfectly efficient leaves no unexploited opportunities to improve everybody’s welfare.

**Economic impact analysis.** A form of project analysis aimed at establishing the effect that a project will have on the structure of the economy, usually expressed in terms of employment and income broken down by economic sector.

**Equivalent annual worth (EAW).** The EAW of a project is the per-period amount of an annuity whose NPV equals that of the project, where the duration of the annuity is the economic life of the project.

**Escalation index.** A number by which a base-year real price must be multiplied in order to obtain the real price in the year of the index.

**Externality.** Externalities are impacts that are not borne by those who produce or consume the good or service which causes the externality.

**Farm-gate price.** The price of agricultural produce received by the producer net of all transport and related handling costs.

**Financial statements.** Accounts normally found in a company’s annual report, being balance sheet and income statement (profit and loss account).

**Financial analysis.** A form of analysis applied to private companies and their projects with the underlying objective of maximising shareholder wealth.

**Free-rider problem.** A problem encountered by producers of ‘non-excludable’ goods, that is, goods for which it is impractical or impossible to exclude consumers on the grounds that they have not paid (for instance, free-to-air broadcasts).

**Game theory.** A branch of mathematics first devised by John von Neumann with direct applications in economics, sociology, and psychology. So-called games can range from simple personal or small group encounters or problems to major confrontations between corporations or superpowers. One of the principal aims of game theory is to determine the optimum strategy for dealing with a given situation or confrontation. This can involve such goals as maximising one’s gains, maximising the probability that a specific goal can be reached, minimising one’s risks or losses, or inflicting the greatest possible damage on adversaries.

**Hurdle rate.** The minimum IRR required for a project to be accepted.

**Impact.** A generic term to cover both economic costs and economic benefits.

**Internal rate of return (IRR).** The discount rate that produces a project NPV of zero.

**Intertemporal choice, theory of.** A branch of economics concerned with effect of delay on consumer preferences.

**Levelised cost.** Discounted costs of a project divided by discounted physical output.
Market failure. When markets allocate resources inefficiently, they are said to exhibit market failure. There are four main causes: abuse of market power, typically monopoly; externalities, where the market does not take into account the impact on outsiders; public goods, which are non-rivalrous and non-excludable; and asymmetry of information or uncertainty, where one side systematically knows more than the other.

Net present value (NPV). The difference between discounted benefits and discounted capital costs over the life of the project.

Network good. One whose value to a consumer changes because the number of people using it changes. For instance, owning a phone becomes more valuable as more people are plugged into the network.

Nominal. Nominal prices, unlike real prices, include the effect of inflation.

Numéraire. The numéraire is the common unit of value into which all economic impacts are converted so that they may be later summed.

Opportunity cost. The opportunity cost of a resource is its value in its highest alternative use.

Option. An option, like a project, is characterised by impacts, but only in a particular context. When evaluating a project, it is necessary to compare its net benefit stream with the stream that would pertain in its absence. Because both streams are no more than potential choices at this stage, they are called options. One is the base case option and the other the project option. Indeed, there may be more than one project option, all representing variants of the project that are considered to be worth analysing. In the Guide the terms ‘option’ and ‘project’ can often be interchanged without materially changing the meaning. This is because an option is a project—but before it is selected, not after.

Option value. The value that consumers place on being able to keep an option available, even though they may never in fact choose it. For instance, habitual air travellers may be willing to subsidise a competing train service in order to be in a position to use it if the need arises.

Parameter. A parameter is a mathematical quantity that is constant for a given case but varies between cases. The parameters in the Guide are mostly unit costs of impacts (such as shadow prices) and other data inputs (such as the discount rate) used in computing the present value of impacts.

Payback period. The period required for a project’s net recurrent benefits to equal its initial capital cost.

Planning horizon. The period over which the costs and benefits of a project are compared.

Perpetuity. An annuity with an infinite life.

Price year. The price year is the year in which the prevailing prices are used in the analysis for the valuation of impacts.

Project, policy and program. Projects typically consist of one or more capital outlays accompanied by a stream of benefits, for instance the construction and operation of a road. Policies are goals, plus the coordinated actions designed to achieve them and decision rules to determine what to do when, for instance undertaking to achieve a particular road safety target. Programs are integrated sets of projects aimed at effecting policy goals, for instance a set of projects designed to achieve a particular road safety target.
**Public-private partnership (PPP).** Projects that are undertaken jointly by the private and public sectors.

**Road pricing.** A form of ubiquitous road tolling that is (normally) designed to cover the costs of the entire network.

**Real.** Real prices, unlike nominal prices, exclude the effect of inflation.

**Residual value.** The value of an asset at the end of the planning horizon. It is included in BCA calculations as a negative cost occurring at the end of the planning horizon.

**Sensitivity analysis.** A technique to assess the effects on project performance of changes over time in the values of influencing variables. Variables important to the BCA outcome are first identified (such as traffic volume and growth rate, construction costs, discount rates). Ranges of values of these variables are specified, and the effects of those ranges on NPV or BCR are tested.

**Shadow price.** Shadow prices are imputed where the market price does not reflect the marginal value or the opportunity cost of a good or service.

**Social welfare.** The sum of consumers’ preferences as measured by the BCA techniques.

**Sunk cost.** Sunk costs are one cost that cannot be retrieved by resale in the market. More specifically, a sunk asset is one which, once constructed, has no value in any alternative use. Bridges and railway tunnels are typically sunk assets.

**Sustainability.** Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

**Transfer payment.** Transfer payments are exchanges of value from one economic agent (firm or person) to another where no new net economic activity is generated. Most taxes and subsidies are transfer payments.
REFERENCES


Austroads 2011a, Documentation and quality control of benefit-cost analyses, AP-R390/11, Austroads, Sydney, NSW.

Austroads 2011b, Small travel time savings: treatment in project evaluation, AP-R392/11, Austroads, Sydney, NSW.

Austroads 2012, Guide to project evaluation: part 4: project evaluation data, 4th edn., AGPE04/12, Austroads, Sydney, NSW.

Australian Transport Council (ATC) 2006, National guidelines for transport system management in Australia: 3: appraisal of initiatives, 2nd edn, Australian Transport Council, Canberra, ACT.


BTRE 2005, Risk in cost-benefit analysis, report 110, Bureau of Transport and Regional Economics, Canberra, ACT.


Department of Transportation 1997, The value of travel time: Department guidance for conducting economic evaluations, DOT, Washington DC, USA.

Evans & Peck 2008, Best practice cost estimation for publicly funded road and rail construction, Department of Infrastructure, Transport, Regional Development and Local Government, Canberra, ACT.


Fosgerau, M 2007, ‘Using nonparametrics to specify a model to measure the value of travel time’, *Transportation Research: Part A: Policy and Practice*, vol. 41, no. 9, pp. 842-56


Government of Western Australia 2002, *Project evaluation guidelines*, Department of Treasury and Finance, Perth, WA.


Infrastructure Australia 2009, *Reform and investment framework templates for use by proponents: templates for stage 7: solution evaluation*, Infrastructure Australia, Canberra, ACT.


Powell, M & Davis, A 1996, Aggregating small time saving in trunk road scheme appraisals, discussion note E96/02, Leeds University Business School, UK.

QDMR 2003a, ‘Project risk management guidelines’, draft version 1.0, April, Queensland Department of Main Roads, Brisbane, QLD.

QDMR 2003b, ‘Benefit cost analysis: version 5.0: the project evaluation process’, Queensland Department of Main Roads, Brisbane, QLD.


Richardson, AJ 1978, A general theory of travel time savings, working paper 78/6, Monash University, Department of Civil Engineering, Clayton, Vic.

RTA 1999, Risk management manual, Roads and Traffic Authority of New South Wales, Sydney, NSW.


World Bank 1999, INFRISK: a computer simulation approach to risk management in infrastructure project finance transactions, policy research working paper, 2083, World Bank, Washington DC, USA.

Superseded and no longer available from Austroads


Austroads 2005, Guide to project evaluation: part 2: project evaluation methodology, AGPE02/05, Austroads, Sydney, NSW.