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Ex-post Economic Evaluation of National Road Investment Projects

Volume 1 Synthesis Report

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Ex-post Economic Evaluation of National Road Investment Projects

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Foreword

The Bureau of Infrastructure, Transport and Regional Economics has undertaken two rounds of ex-post evaluations of national road investment projects: one in 2005–2007 and the other in 2014–2016. The purpose of this report is to synthesise the ex-post evaluation results and draw systematic lessons. Findings are expected to inform ongoing updates of the Australian Transport Assessment and Planning guidelines, and to improve future cost-benefit analyses.

The Bureau wishes to thank staff from the relevant State road agencies who helped collect information and data, implement ex-post cost-benefit analyses, and commented on the draft case studies included in this report. The Bureau also thanks Anna Chau (Infrastructure Australia) for commenting on the draft report.

Dr William Lu, a key researcher for the past two rounds of ex-post evaluations, was the principal author of this synthesis report. Raymond Lau contributed to the earlier draft. Raymond Lau was also the principal investigator for the Western Australia Dampier Highway upgrade and Victoria Nagambie Bypass case studies. Dr Mark Harvey provided valuable advice and comments at various stages of the project.

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Executive summary

The Bureau of Infrastructure, Transport and Regional Economics (BITRE) undertook two rounds of ex-post evaluations of road investment projects on the National Land Transport Network: one in 2005–2007 and the other in 2014–2016. This report synthesises the ex-post evaluation results to draw out lessons to help improve future project appraisals.

Cost–benefit analysis (CBA) has long been the preferred way to assess transport infrastructure investment projects in Australia. However, CBA, as applied in practice, is prone to errors. Available evidence suggests that there is much room for improvement in the quality of practical Australian road CBAs if they are to be used as an effective tool for option ranking and project prioritisation.

Based on the case study results (though with a small sample), a few observations can be made:

- The net present value (NPV) was over-estimated by significant margins in most of the selected case study projects.
- Over-estimation in NPV was largely caused by over-estimation of road user benefits, with errors in travel time cost saving estimates accounting for 60 per cent of the total absolute variation between the NPV from the ex-ante CBA and that from the ex-post CBA.
- Inaccurate traffic forecasts and methodology errors were mostly responsible for the over-estimated road user benefits.
- There was no systematic evidence of cost overruns for the projects selected for ex-post review.

It should be noted that the ex-ante CBAs included in this report were not necessarily representative of CBA practices in each State at the time. Assessment of a much larger sample of projects would be required before general conclusions can be drawn about the quality of past CBAs in each State. Furthermore, since the ex-ante CBAs were undertaken some 10 or 20 years ago, they should not be taken as representative of appraisal practices in each State today.

A number of lessons can be drawn from the past two rounds of ex-post evaluations.

CBA documentation

- The quality of CBA documentation varied between projects and jurisdictions. It improved for the second round of evaluations but there remains further room for improvement.
- For any large project (>$25m), it is essential for a detailed self-contained CBA report to accompany the Project Proposal Report (PPR).
- Good documentation and transparent CBA calculations facilitate review of the ex-ante analysis as well as ex-post economic evaluations.

- Austroads (2011c) published a report detailing requirements for documentation and quality control of CBAs. This showed common pitfalls in CBAs and provided a checklist for quality control. The checklist could be updated and included in the Australian Transport Assessment and Planning (ATAP) guidelines to improve the quality of CBAs.

CBA review

- The ex-post review found significant errors in the ex-ante CBAs. Some of these were simple and could have been avoided had a peer review process been in place. At the time the ex-ante CBAs were undertaken, there was no formal expert review process at the federal level for such analyses of national road investment projects.
- The situation may have changed with adoption of an integrated project assessment framework after Infrastructure Australia was established in 2008. The improved assessment framework published by Infrastructure Australia (2017) and its role in assessing infrastructure project proposals (including CBAs submitted as part of the proposals) for project prioritisation, are expected to provide timely feedback on, and improve the quality of, the ex-ante CBAs.
- Infrastructure Australia encourages project proponents to have their economic appraisals and business cases reviewed externally, but the lack of resources and a formal review process (including a detailed workable checklist) may impede these reviews and their independence.
- For urban road projects, the credibility of CBAs depends critically on the quality of the traffic modeling used in the economic evaluation. Independent review of traffic modeling results should be mandatory for any CBA review, particularly for urban road projects.

Traffic forecasts

- Traffic forecasts have been identified as requiring significant improvement.
- For non-urban national highways, trend extrapolation has been the primary forecasting methodology for predicting traffic demand. This methodology tends to produce optimistic traffic forecasts in good times and pessimistic ones in bad times. Efforts should be made to understand the nature of the observed trend and sound qualitative judgment must be applied to determine whether the historical trend will continue in the forecast horizon.
- Forecasting errors have also arisen by not allowing for change in the vehicle mix over time. Change in traffic composition has an important bearing on evaluation results. Where possible, separate forecasts should be made for different vehicle classes, at least separating out light and heavy vehicles.
- Forecasting traffic for roads in urban areas is more challenging due to the complexity of congestion and network effects. Outputs from network models should be checked, not just at the aggregate network level, but also for road sections of immediate concern. This would help assure reasonableness of traffic assumptions used in CBA.

Estimation of road user benefits

- A common error found in the road CBAs was making the base case worse than it should have been. The plausibility of any chosen base case should be carefully checked.
- For the projects selected for case studies, over-estimation of travel time cost savings was caused in part by over-optimistic traffic forecasts, and in part by the travel time estimation

methodology (mostly in relation to the base case travel speed/time). Using inappropriate speed-flow curves (interchanging between stop-start and free flow models, and assumptions about the shape of speed-flow curves within models) led to significant biases in travel time cost saving estimates.

- Vehicle operating cost (VOC) saving estimates can also be subject to errors if vehicle kilometres travelled (VKT) or unit VOCs are miscalculated. Unit VOCs vary with speed, road conditions and vehicle type. Great care should be taken to select the most appropriate unit VOC values relevant to the base and project cases.
- There was significant room for improvement in the quality of safety benefit estimates. Crash analysis was hampered by lack of good data and analysis. Until crash data and analysis are significantly improved, there may be a case for using model default rates for both the base and project cases, as these are subject to less uncertainty.

Project cost estimation

- For the projects included in Round 2, there was a clear tendency for cost over-estimation. This might be, in part, associated with using P90[1] cost estimates (for budgeting), which are conservative.
- Ideally, expected values (means of probability distributions) should be used in CBAs. A P50 value is the median of the probability distribution of costs. It can be used as an approximation of mean if the probability distribution is reasonably symmetrical.

Residual value (RV)

- Historically, RV estimation has been omitted in road CBAs. More recent CBAs have tended to include RVs as a way to capture additional benefits beyond the evaluation period.
- Currently two types of approaches are used for estimating RV: depreciation of capital costs and projection of net benefits.
- Conceptually, a net benefits approach is more attractive because it estimates the value of an asset from its capacity to generate benefits. In practice, it produces unrealistically high residual values and is prone to errors.
- Straight-line depreciation is most commonly used because it is simple to apply and understand. Based on the results of our case studies, the current version of the ATAP guidelines has recommended use of straight-line depreciation as the main basis for reporting and other methods for sensitivity testing.

Interpolation and extrapolation

- In the case study CBAs, linear interpolation was normally applied for values between the modelled years to evaluate urban road projects. Errors can occur if actual traffic or benefits grow in a non-linear fashion.
- Approaches to extrapolation beyond the last modelled year varied. Some held the extrapolated values constant while others let them grow in line with traffic growth or another arbitrarily specified growth rate. Consistency in the approach used across project appraisals is desirable for extrapolation beyond the last modelled year.

1 The estimated project cost has a 90 per cent chance of not being exceeded.

- Constant or low-growth extrapolation doesn't necessarily imply that the estimates are conservative; the values for earlier years may be over-estimated.

First-year rate of return (FYRR)

- The FYRR metric is essential to inter-temporal maximisation of investment returns, as it informs the optimal time for investment.
- As with RVs, the trend is increasingly to include FYRR as part of the standard CBA output. In future, "all initiatives should be subject to the FYRR test and be reported in the business case" (Transport and Infrastructure Council (TIC) 2016b).

Risk and uncertainty

- Insufficient attention was paid to risk and uncertainty in past CBAs.
- Decision makers should be made aware that the seemingly precise numbers produced—especially the benefit cost ratio (BCR)—are often accompanied by large uncertainties.
- The main assumptions or alternative scenarios should be fully explored and tested in sensitivity or probabilistic risk analysis.
- The latest (TIC 2016b) CBA guidelines illustrate how these could be implemented. In future, reporting of probability distributions of BCR and NPV should be encouraged.

The past two rounds of ex-post evaluations have extended considerably our understanding of factors affecting the accuracy of CBAs for road projects. However, the sample of the projects selected for ex-post review has been very small. Further ex-post evaluations of the type described in the present report should provide more evidence around sources of major inaccuracies in road CBAs. Because carrying out a full ex-post CBA can be time and resource consuming, more strategic orientation (for example, limiting the evaluation to a small number of critical areas such as demand forecasts and time savings) may be useful in future ex-post evaluations.

Ex-post evaluations undertaken so far have focused on road projects in rural or urban approach areas. More effort should be focused on reviewing CBAs for large and complex urban road projects. There are challenges in undertaking such evaluations, both in terms of skills and resources. Use of urban models may be necessary.

1 Introduction

Investing in infrastructure is an Australian policy priority.

Decision makers are faced with increasing funding constraints, tougher accountability requirements and higher user expectations. As a result, they are increasingly interested in feedback on appraisal methodologies, selection processes, efficiency of implementation and the effectiveness of projects in achieving desired outcomes. Post completion evaluation (PCE) allows the lessons learnt from previous projects to be fed back into the process, and benefits future appraisals.

A PCE can be either process or outcome focused (TIC 2016a). A process-focused PCE assesses the efficiency of processes in relation to project appraisal, selection and implementation. An outcome-focused PCE compares outcomes and forecasts or benchmarks. The process-focused and outcome-focused evaluations are inextricably related because a process-focused review can often provide insights into why a project has succeeded or failed.

Another distinct type of PCE is an ex-post cost-benefit analysis (CBA). Ex-post CBA can be considered part of a process review, but given the importance of CBA in decision-making and its complexity, it is desirable to single out and treat this element separately. Ex-post CBA can be used to determine the accuracy or quality of ex-ante CBAs, although it is also increasingly being adopted as a framework for assessing project effectiveness (Pellegrin and Sirtori 2012; and Florio and Vignetti 2013).

Between 2005 and 2007, BITRE conducted the first round of ex-post CBAs that included seven case studies of road projects implemented around the year 2000. Two of the case studies were published as BITRE Working Papers (BITRE 2007a and b).

The second round of ex-post CBAs were undertaken between late 2014 and mid-2016. This was in response to the Productivity Commission's 2014 call for greater effort in reviewing the effectiveness of completed infrastructure projects. Altogether, five projects were selected for review in this round. These were chosen from the list of road investment projects under the Nation Building Program implemented over the five years from 2008–09 to 2013–14.

Table 1.1 lists the projects selected in the two rounds of ex-post CBA evaluations. The base year indicates the likely year when ex-ante CBA was undertaken.

Table 1.1 List of projects selected for ex-post review

Round	State	Project	Nominal cost ($m)	Base year	Opening year
1	QLD	1. Wallaville Bridge	28	1995	1999
	WA	2. Northam Bypass	49	1998	2002
	SA	3. Adelaide Crafers Highway	152	1995	2000
	ACT	4. Federal Highway – ACT/Sutton Road	82	1996	2000
	NSW	5. Yass Bypass	152	1996	1994
	VIC	6. Goulburn Valley Highway	48	1997	2001
	TAS	7. Bass Highway	66	1993	1999
2	QLD	8. Bruce Highway – Cooroy to Curra Section B	440	2008	2012
	WA	9a. Dampier Highway Stage 1B	11	2009	2009
		9b. Dampier Highway Stages 2–6	91	2009	2013
	NSW	10. Bulahdelah Bypass	315	2010	2013
	VIC	11. Nagambie Bypass	170	2009	2013
	SA	12. Northern Expressway	564	2006	2010

The primary objective of these ex-post CBAs was to check the accuracy of the ex-ante (original) CBAs with a view of identifying opportunities for improvement in future CBAs and project appraisals. In the second round, greater emphasis was also placed on assessing the economic performance of the selected road investment projects.

The purpose of this synthesis report is to summarise the ex-post evaluation results and draw some systematic lessons. Findings of this report are expected to inform the future updates of the ATAP Guidelines, and to improve future CBAs.

Note that the ex-ante CBAs included in this report were not necessarily representative of CBA practices in each State at the time. Assessment of a much larger sample of projects would be required before general conclusions could be drawn about the quality of past CBAs undertaken in each State. Furthermore, since the ex-ante CBAs were undertaken some 10 or 20 years ago, they should not be taken as representative of State appraisal practices today.

The next chapter highlights the role of CBA in road infrastructure project evaluation and discusses common errors. Chapter 3 provides an overview of the framework used in the past two rounds of ex-post economic evaluations and describes how projects were selected for case studies. Chapter 4 reports ex-post evaluation results. Lessons learnt are discussed in the last chapter.

II Road infrastructure project evaluation using CBA

Role of CBA in resource allocation

Like many other governments, the Australian Government requires a CBA to help efficiently allocate scarce resources. According to the Notes on Administration released by the Department of Infrastructure, Regional Development and Cities (DIRD 2014):

> *"All projects seeking funding at the development phase or later are required to complete a cost benefit analysis (CBA). CBAs should be completed in accordance with the latest version of the Australian Transport Council (ATC) National Guidelines for Transport System Management in Australia. Projects under $25 million are permitted to complete a rapid CBA. Projects equal to or over $25 million must complete a detailed CBA" (Appendix C of Notes on Administration, page 42).*

CBA has long been an established way to assess investment in transport infrastructure projects in Australia. It aims to:

1. assess the economic efficiency of individual project proposals (NPV > 0)
2. compare options for the same project (maximising NPV)
3. rank projects (by BCR) where there is a budget constraint.

CBA is a systemic process to identify and quantify project impacts and to provide decision makers with a good understanding of the implications of the project.

Since the Australian Transport Council's 2006 *National Guidelines for Transport System Management in Australia* were published, there has been a noticeable improvement in economic appraisal practices. For example, improved CBA reporting and documentation, enhanced model harmonisation and greater consistencies in economic parameters. Despite this, evidence gathered so far (either through ex-post evaluation or review of ex-ante CBAs) indicates further improvement is needed on the quality of Australian road CBAs so they are an effective tool for option ranking and project prioritisation.

Common errors in CBA

CBA is a quantitative analytical tool used to determine the economic worth of a project. A standard CBA would typically consist of the following nine steps (Boardman, et al. 2011):

1. Specify the set of alternative projects
2. Decide whose benefits and costs count (standing)
3. Catalogue the impacts and select measurement indicators (units)
4. Predict the impacts quantitatively over the life of the project

5. Monetise (attach dollar values to) all impacts
6. Discount benefits and costs to obtain present values
7. Compute the NPV of each alternative
8. Perform a sensitivity analysis
9. Make a recommendation based on the NPV and sensitivity analysis.

The CBA's accuracy depends on how well an analyst performs each of the above nine steps, given the constraints of available data/information, modelling tools and resources. Although each step is subject to error, Boardman, et al. (2011) argue that the most important steps for analysts and decision makers relate to:

- specifying the impact categories (omission/double counting errors, step 3),
- predicting the impacts (forecasting errors, step 4), and
- valuing the impacts (valuation errors, step 5).

A review of the projects selected for case studies indicated that specifying the base case (belonging to step 1) was another area that can create significant errors. There also appears to be much room for improvement in sensitivity testing and risk analysis (step 8).

Base case specification errors

A CBA is always a comparison between two alternative states of world: a base case and a project case (TIC 2016b). Usually, the base case reflects the realistic circumstances in the absence of significant additional investment. In practical road CBAs, the base case is often depicted as the 'business-as-usual' or 'do-minimum' scenario. Specifying the base case requires forecasting, as does the project case, and therefore involves uncertainty and the need to make assumptions.

CBA results can be very sensitive to the base case chosen. In the case of the 2007 Wallaville Bridge case study, three scenarios were considered in the ex-post evaluation: bridge completely closed, partially closed, and totally open. The associated BCRs were estimated to be 16.3, 7.2 and 2.6. The ex-post evaluation showed that the latter two scenarios were more plausible (box 2.1).

Misspecification of the base case speed or road length can also lead to errors in CBAs. Under-estimating base case travel speed or over-estimating base case road lengths was found in some of the CBAs reviewed.

For ex-post evaluations, the base case normally becomes unobservable. Uncertainties remain. Establishing a reasonable counterfactual scenario is crucial to having credible CBA results.

Omission or double-counting errors

Impact categories are fairly well standardised for highway projects. For example, the anticipated major beneficial impacts for road users as a result of an upgrade include:

- time saved for travellers on the upgraded highway
- reduced vehicle operating costs for travellers on the improved highway, and
- accidents avoided due to the possibly a shorter, and safer highway.

Box 2.1 Queensland Wallaville Bridge

Specifying a reasonable base case was a key challenge for both ex-ante and ex-post economic evaluation of the Wallaville Bridge upgrade project.

In the ex-ante evaluation, it was assumed that in the base case the Wallaville Bridge would be completely sub-merged due to the construction of a weir across the Burnett River, 11km downstream of the old bridge (BITRE 2007a). The Walla Weir (now called the Ned Churchward Weir) was to be constructed in two stages: the first would increase the time of closure due to flooding and the second would result in inundation of the old bridge. However, due to unexpected prolonged drought conditions, the planned stage two construction of the weir did not occur. This meant that the old Wallaville Bridge would not be inundated by higher water levels and would not be lost as a road asset as originally expected.

In the ex-post evaluation, two alternative base case scenarios were considered: one assuming the existing bridge to remain partially open, the other assuming it would be completely open.

Adoption of these two alternative base cases brought significant changes to project benefits. In view of the sensitivity of CBA results to base case specifications, efforts should have been made in the ex-ante analysis to explore and test alternative base case scenarios that might become relevant under certain conditions.

Source: Based on BITRE (2007a).

In more recent times, improved travel time reliability has increasingly been seen as an additional benefit, notably for projects in urban areas. Available evidence has shown travellers are more likely to choose a longer but more predictable journey than a shorter journey with highly variable travel time (Austroads 2011a). Deloitte Access Economics (2016) recently recommended for interim use a reliability ratio[2] of 0.9. Travel time reliability benefits were not included in any of the rural and urban approach road projects selected for case studies.

The freight travel time saving benefit was first officially introduced in the Austroads (2004) guide to project evaluation. The latest version of CBA 6 and Eval4 have included freight travel time as an additional travel time saving benefit. Freight travel time was not included as a benefit in most of the ex-ante CBAs selected for case studies.

The effect of improved freight performance (as a result of road investment) on logistical management has long been recognised, but rarely included in practical CBAs. This is in part due to difficulties in measurement and the fact that the impact is likely to be small at the project level.

Over the past decade or so, there has been emerging interest in constructing cycle lanes alongside national highways (for example, the Dampier Highway and Northern Expressway). However, the use of these and associated benefits have been omitted from CBAs and the incremental benefits and costs have not been separately identified or quantified. In 2016, the ATAP provided CBA guidance on active travel projects (TIC 2016c).

Residual value (RV) is an important component of CBA which has so far failed to attract sufficient attention in practical road CBAs. Often RV is ignored. Of the 10 projects subject to full or limited ex-post review, only four included an estimate of RV in the ex-ante CBAs (table 4.1 in chapter 4).

2 The reliability ratio is the ratio of the value of one minute of standard deviation of travel time (i.e. value of reliability) to the value of one minute of average travel time.

Impacts on third parties (i.e. non-road users) have now received greater attention in road project evaluation. These impacts could include:

- noise
- air pollution
- nature and landscape
- severance
- climate change, and
- culture and heritage.

Past CBAs undertaken in Australia tended not to include impacts on third parties either because these were small or hard to quantify/monetise. Environmental effects were normally discussed qualitatively in Environmental Impact Statements (EIS) although there has been an emerging trend in incorporating these effects explicitly in a CBA.

Over the past decade or so, the issue of Wider Economic Benefits (WEBs) has attracted increasing attention both domestically and internationally. WEBs arise from infrastructure investment, and include agglomeration economies, increased output in imperfectly competitive markets and higher tax revenues due to better labour market (see Dobes, et al. 2016 and BITRE 2014 for a brief review). While WEBs are relevant to transport project appraisals, the quality of WEB estimates in Australia needs to improve. KPMG (2015) investigated ways to improve WEB parameters and is currently developing a robust set of parameters for Australia for publication in the ATAP Guidelines. WEBs are likely to be small or negligible for projects located in rural areas such as those included in the ex-post case studies.

Impact prediction errors

Once the impacts are categorised, they need to be predicted (or estimated). Central to the evaluation of road user benefits are traffic forecasts, because they directly affect many of the benefit categories. Also, there are issues related to estimation of congestion and its impacts on travel times, VOC and crash costs, as well as project cost estimation (including RV estimation).

Traffic forecasts

Inaccuracies in traffic forecasts are a worldwide phenomenon for transport infrastructure projects. These take the form of large deviations with systematic biases (Nicolaisen and Naess 2015).

Over-estimation of travel demand for toll roads has been widely studied (see BITRE (2011) for a review). As for new untolled roads, the situation is unclear (Flyvbjerg et al. 2005; Nicolaisen 2012; Parthasarathi and Levinson 2010; and Welde and Odeck 2011).

Australia has a poor record in forecasting traffic on toll roads (BITRE 2011). It is not clear whether this also applies to untolled roads. The ex-post traffic review conducted in the past two rounds of ex-post CBA provides useful insight into this important question.

The accuracy of traffic forecasts depends on the quality of data, the adequacy of the chosen model and the assumptions made in forecasting.

The availability of quality data is a prerequisite for sound traffic modelling. Traffic data used in project evaluation are often subject to limitations. For example, most rural traffic data are collected every few years, making it difficult for analysts to use more robust methodologies such as time-series or multivariate econometric analysis. There is also an issue about the currency of the available data. Traffic level for the base year often needs to be forecast and can be subject to significant errors.

Two distinct approaches have been used for traffic modelling depending on the location of the project to be evaluated. In the context of rural project evaluation, where there are limited network effects, simpler methodologies are employed for forecasting. In general, there are three broad categories of methodologies available (TIC 2016b):

- simple extrapolation of past trends
- extrapolation by relating the forecast variable to one or more explanatory variables
- application of informed judgment.

Rural traffic demand modelling nearly always relies on simple trend extrapolation due to the limited availability of data. Our case study results show that this approach tends to produce more optimistic forecasts in good times (see box 2.2) and more pessimistic ones in bad times. For longer-term forecasts, the trend extrapolation method neglects congestion impacts and can lead to systematic bias (over-estimation) in base case traffic forecasts (Nicolaisen and Naess, 2015).

For urban areas where network effects are pervasive, more sophisticated approaches are required involving use of urban traffic models. Traffic forecasts derived from urban network models are far less transparent than those derived from simple rural traffic models. Often, detailed traffic forecasts (mostly in relation to affected roads) are not detailed in CBA reports making it difficult to assess the plausibility of traffic assumptions.

A new transport initiative can cause traffic demand to rise either through diversion of existing traffic or generation of new traffic. Induced (diverted plus generated) traffic is less likely to be a significant consideration for rural road investment projects (apart from diversion of traffic to a town bypass). Estimation of induced traffic demand is necessary for large urban road projects. An urban transport model with sound assignment algorithms and congestion handling capabilities is indispensable for this purpose.

Traffic modelling for the case study projects has been centred on aggregate Annual Average Daily Traffic (AADT) with the 'fixed traffic composition' assumed for the entire evaluation period. Such an approach may over-simplify the real world situation where traffic composition is likely to vary over time and space. In the case of the Yass Bypass project, there was clear evidence of under-estimation of commercial and heavy vehicle traffic over time (appendix A.5). The decision to undertake an aggregate modelling approach with fixed traffic composition or a disaggregate modelling approach with different vehicle classes treated separately depends on data availability.

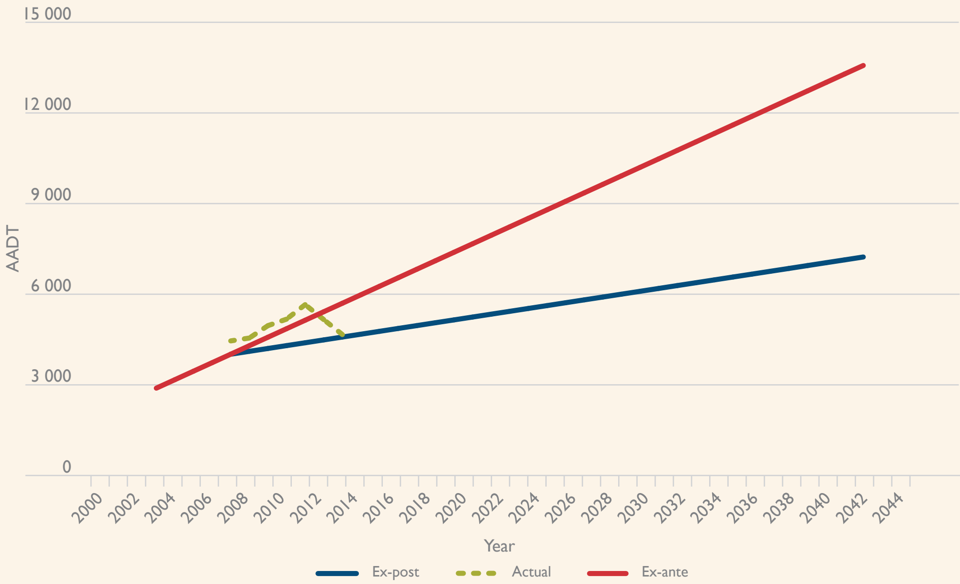
Forecast traffic growth can be linear or compound. For assessment of rural road projects, linear growth is the default assumption. The decision to use a linear or compound growth rate should follow from careful analysis of traffic data combined with informed qualitative judgment.

Box 2.2 Traffic forecasting in a volatile environment

The trend extrapolation method is commonly used for forecasting traffic on rural roads. It may not perform well in a volatile environment. The case study on the Western Australia's Dampier Highway upgrade project is a case in point.

Figure B1 shows both the ex-ante and ex-post traffic forecasts as well as actual historical traffic counts. At the time when the ex-ante CBA was undertaken, there had been a period of strong growth in traffic thanks to the mining boom. It was assumed that this trend would continue for the entire 30-year evaluation period.

Figure B1 Traffic Forecasts: Dampier Highway Stages 2–6



With hindsight, it was not reasonable to assume that the then observed high-growth trend would continue forever. Actual traffic demand has seen significant declines in recent years due to the end of the mining boom, completion of mining projects and non-eventuation of some development initiatives in the area.

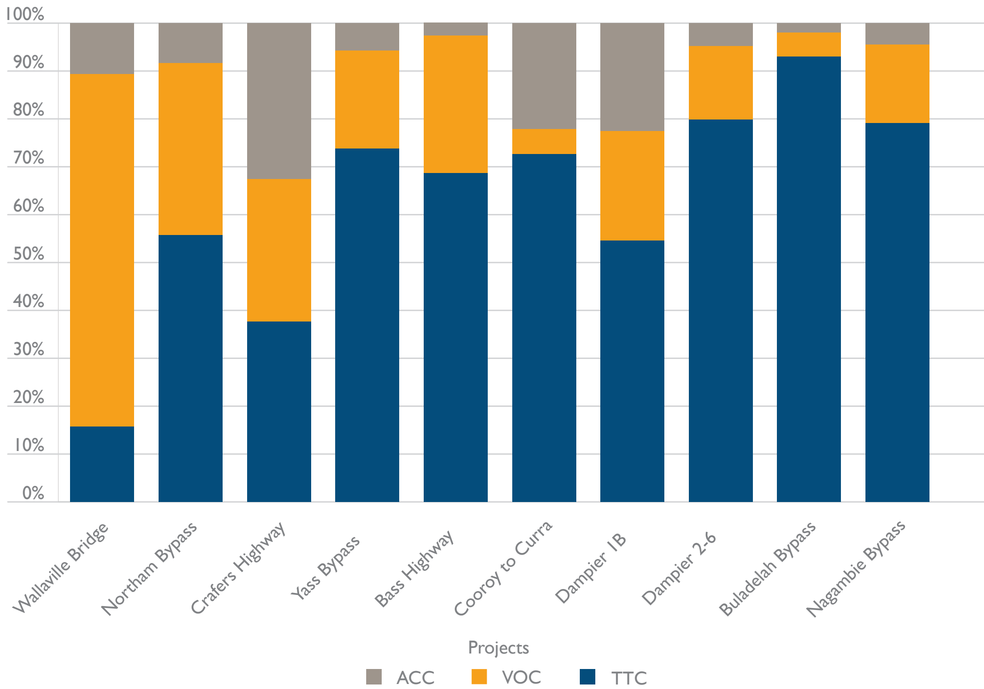
The traffic forecasts for the ex-post CBA were based on a regression model that linked traffic demand to externally forecast population growth. While the forecasts for the ex–post CBA appear more plausible, uncertainties remain in model specifications and parameters due to data constraints. The effects of these uncertainties on the ex-post CBA results were explored via sensitivity tests.

Source: based on the Dampier Highway case study.

Estimation of road user cost impact

An important objective of road infrastructure investment is to reduce congestion, and to save travel time and vehicle operating costs for road users. For most road projects, time saving is the main source of road user benefits (figure 2.1). Therefore, accurate estimation of travel speeds for both the base and project case is critical to obtaining sensible overall CBA results.

Figure 2.1 Sources of benefits (%)



Note: TTC=travel time costs, VOC=vehicle operating costs and ACC=accident costs.

Shares of VOC savings were over-stated for the Wallaville Bridge and Northam Bypass projects due to mis-specified length of the base case road.

Source: BITRE based on the case study results.

For rural road projects, most road user cost models available in Australia relate travel speeds to the volume/capacity ratio (VCR), which is a measure of congestion. This approach has its origin in the National Association of Australian State Road Authorities (NAASRA) Improved Model for Project Analysis and Costing (NIMPAC) and comprises three steps:

1. Estimation of average "free speeds" for both old and new alignments given their gradients and curvatures.
2. Adjustment of free speeds for effects of variations in surface conditions.
3. Further adjustment of speeds for effects of traffic congestion.

Implementation of steps 1 and 2 is relatively straightforward, relying on well-established international models. Estimation of effects of traffic congestion on travel speed/time (step 3) is however handled using simple, locally developed, speed–flow relationships. Within the framework of NIMPAC style models, congestion effects are calculated typically using the following procedures:

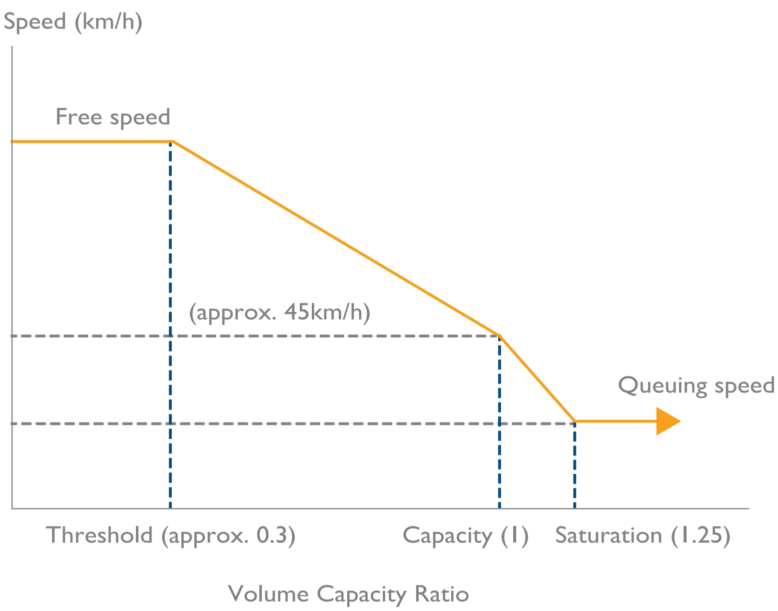
- AADT is converted from vehicle counts to passenger car unit equivalents.
- Annual or daily flows are then allocated to a series of hourly flow categories.
- Volume/capacity ratios (VCR) are computed for each hourly flow category.
- Speeds are estimated by inserting estimated VCRs into an equation that models speeds/travel time as a function of VCRs.

Critical to the last procedure is the establishment of a credible relationship between speeds/travel time and VCR. The general practice in road widening and duplication is to adopt the piecewise linear relationship recommended by Austroads (figure 2.2).

According to figure 2.2, vehicles operate at their free speed, until congestion causes them to slow down. As congestion builds, the operating speed continues to decrease to approximate 45km/h at a VCR of 1. When the traffic reaches saturation (VCR=1.25), vehicles travel at a 'queuing speed' or 'congested speed' (usually 30km/h in rural environments).

Speed-VCR relationships are assumed for different road types and vehicle types. The speed-VCR relationships for both base and project cases should be checked and if possible new data collected for verification.

Figure 2.2 Travel speed and volume-capacity ratio



Source: Austroads (2004), p.50.

Application of the speed-flow relationship could be prone to errors because of uncertainties about the queuing speed on different types of roads for different types of vehicles. Austroads (2011b) suggested that a default queuing speed of 30km/h be adopted at VCR=1.25 for typical rural roads, but did not specify any default queuing speed value for other types of roads. As a result, queuing speeds and speed-flow curves have to be assumed, which causes inconsistencies in CBAs. Different assumptions about the queuing speed can lead to different results for travel time cost savings if the estimated volume-capacity ratio is above one during the evaluation period. In general, the lower the queuing speed assumed for the base case, the higher the estimated travel time cost savings, and vice versa.

For urban road projects, estimation of travel time savings relies on urban traffic models. Often ex-ante CBAs draw outputs from these models without proper explanation and validation. Typical outputs for use in a CBA are vehicle hours travelled (VHT) and vehicle kilometres travelled (VKT) for both the base and project cases at the network level for selected years. This information is insufficient to gauge the realism of forecast project impacts in the immediate vicinity. The South Australian case study (Northern Expressway) is a case in point (Box 2.3). Based on the VHT and VKT provided by the traffic model, the average network travel speed for the opening year was estimated to be 43.1km/h for the base case and 43.7km/h for the project case. While the network travel speed would be expected to increase, it was not clear whether the magnitude of the predicted change was plausible. VHT and VKT estimates from urban network models should be subject to greater scrutiny before they are accepted as valid inputs in a CBA.

Box 2.3 Output of an urban traffic model for use in CBA

Urban traffic models are used to assess projects on large road networks with more congestion. These models use exogenously determined social-economic and land-use variables to forecast the future transport network performance for the base and project cases. Traditionally, four-step multimodal models are used that iterate through traffic generation, distribution, mode split and link assignment.

The output of these models provided for use in CBA typically includes the totals of VHT and VKT at the network level. Using these totals, the average network speed can be derived for the base and project cases. Table B1 uses South Australia's Northern Expressway case study as an example. It shows that there is little difference in the derived speed at the network level between the base and project cases (0.6–1.4km an hour). Without knowing the modelled speeds of traffic travelling on the most affected roads, it is hard to determine whether the estimates reported in table B1 are plausible.

Table B1 MASTEM outputs for the Northern Expressway project

Scenario	Year	Total travel time (hours/working day)	Travel distance km/working day)	Travel speed (km/h, working day)
Base case	2006	499 948	21 829 080	43.7
	2011	562 783	24 275 400	43.1
	2016	608 126	25 952 760	42.7
	2021	679 403	28 218 330	41.5
Project case	2011	557 657	24 358 786	43.7
	2016	598 201	26 159 206	43.7
	2021	662 142	28 376 521	42.9

Source: based on the SA Northern Expressway case study.

Recent CBAs on urban transport projects have made use of outputs from micro-simulation models. While these models can replicate traffic phenomenon in greater detail, they are more complex and require a raft of assumptions that should be assessed as part of the CBA. Microsimulation models were not used in modelling traffic for any of the projects included in the past two rounds of ex-post evaluations.

Modelling travel time savings for urban transport projects also requires assumptions on expansion factors (intra-day and annual expansion). The expansion factors currently in use vary considerably, which could potentially cause bias in the estimated annual road user benefits.

Traditionally, volume expansion factors were used to estimate the annual costs/benefits from *n*-hour peak period traffic modelling. Based on the data for Sydney, Nairn (2004) observed that the peak to daily expansion factor had been increasing over time and was expected to continue. On the other hand, little change was found in weekday to annual expansion factors.

Use of volume expansion factors in project appraisals has been a source for over-estimation of trip costs for the base case due to inappropriate consideration of congestion effects. Orthongthed et al. (2013) showed that the cost expansion factor for the two hour AM peak is about 10% lower than the volume expansion factor.

For urban transport projects, road user benefits are normally modelled for selected years, thereby requiring interpolation for intervening years and extrapolation for years beyond the last modelled year. Interpolation between modelled years usually takes a linear form. There may be some cases where this is not valid, for example, where there are capacity constraints, and this should be checked (EC 2003). If benefits are expected to increase exponentially due to increased congestion, forecasts should be ideally produced at five-year intervals as input to economic appraisal (World Bank, 2005). As for extrapolation beyond the last modelled year, the growth in magnitude of impacts should not be greater than that implied by the results up to the last modelled year (Department for Transport (DfT), 2014). According to the World Bank (2005), beyond 20 years, population and land use forecasts are less reliable and travel demand growth should be frozen.

Inconsistencies in approaches for interpolation and extrapolation were observed in the ex-ante CBAs included as case studies (see Box 2.4).

Project cost estimation

The accuracy of project cost estimates is assessed in ex-post evaluations by comparing actual costs with the costs estimated in the ex-ante CBAs presented for decision making. For all the five projects included in the second round of ex-post evaluations, the ex-ante CBAs used P90 cost estimates. This is inconsistent with the current practice, which is to use P50 values for economic evaluation. Ideally, the expected value or mean of the probability distribution would be used. A P50 value (the median of the probability distribution) can serve as an approximation for the expected value if the probability distribution is reasonably symmetrical. P90 values can be used for sensitivity testing (TIC 2016b).

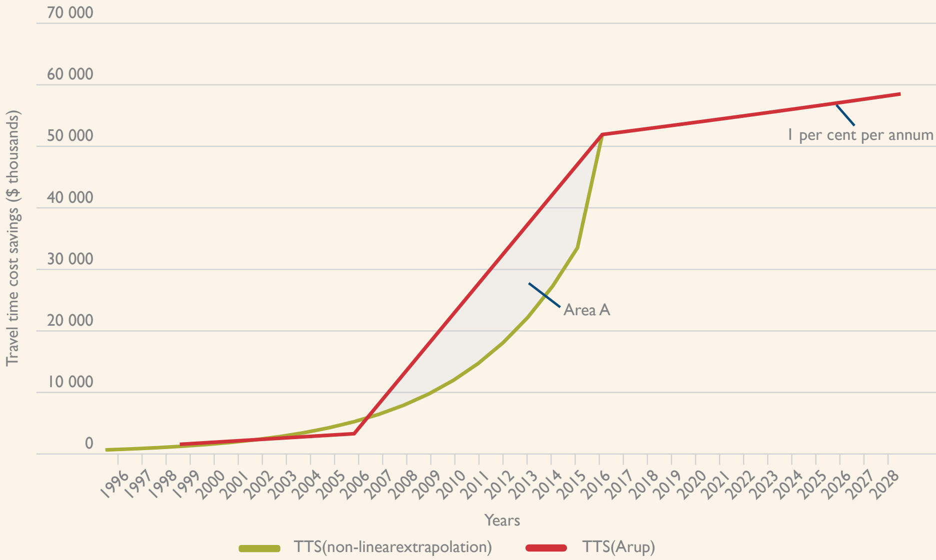
Inaccuracies in cost estimation have been a feature for mega-projects internationally. Flyvbjerg, et al. (2004) found that road projects finished, on average, 24% over budget. Evidence of cost overruns on Australian transport infrastructure projects was reviewed by Terrill, et al. (2016) and found to be smaller. For example, Wood (2010) estimated an average cost overrun across 46 Australian transport infrastructure projects of 5–10.5%. Love (2012) observed average cost overruns of 12% for 58 Australian road and rail projects.

In the past, cost overruns were not uncommon for federally funded highway projects in Australia, as evidenced in the first round of ex-post evaluation results. The situation appeared to have changed with the use of P90 cost estimates as the basis for funding and in CBAs at the time. For the projects included in the second round of case studies, no systematic cost overruns were observed. This was probably due to the overly conservative nature of P90 cost estimates. Comparison of actual costs with P50 cost estimates was not possible because information on the latter was not available for the projects included in the second run of ex-post evaluations.

BOX 2.4 Interpolation and extrapolation of benefits

Linear interpolation is commonly used to derive values between modelled years. This method may not be valid if road user benefits grow non-linearly due to rising congestion. The ACT/Sutton road is a case in point. Figure B2 presents the results for two different interpolation methods, one linear and the other exponential. If the latter is believed to be more appropriate, area A represents the potential linearisation error. One way to reduce the chance of this error occurring is to model an additional year in between.

Figure B2 Interpolation/extrapolation of travel time cost saving (ACT/Sutton Road upgrade project)



Source: Based on the ACT/Sutton Road case study.

Extrapolation methods varied among the projects reviewed, typically taking the following forms:

- keeping road user benefits constant (Bulahdelah Bypass)
- letting them grow in line with traffic growth (ACT/Sutton Road)
- letting them grow at a reduced rate compared with the growth rate in the intervening years (Northern Expressway).

Different methods would lead to different levels of user benefits. Ideally, a decision about the method chosen would be evidence-based. Furthermore, leaving the benefits at the level of the last modelled year does not necessarily mean that estimates will be conservative if benefits are over-estimated in early years.

Since the publication of Evans & Peck's (2008) best practice cost estimation guidelines, the probabilistic cost estimation method has become a standard practice for appraisal of transport projects. A brief overview of this methodology is included in appendix C. The ex-post case studies included in this report did not review how probabilistic cost estimates were obtained in ex-ante CBAs. As a result, it was not possible to draw any systematic lessons in relation to the quality of cost estimates.

Residual values

The ATAP Guidelines (TIC 2016b) define the evaluation period in a CBA as the number of years over which the benefits and costs of an initiative are assessed. The guidelines note that a default value of 30 years following completion of construction is generally used for road initiatives. At the end of the evaluation period, a project may have some remaining economic life over which it still has the capacity to generate benefits. A simple way to resolve the mismatch between the evaluation period and the estimated or assumed economic lifespan of the project is to capture any remaining benefits with a residual value (RV). The RV is counted as a benefit at the end of the evaluation period and represents the present value of net benefits beyond the evaluation period, discounted to the end of the evaluation period.

Two approaches are generally used for estimating RV at the end of the evaluation period: asset depreciation and net benefit stream.

The asset depreciation (notably straight line depreciation) approach is the most commonly used method for estimating RV. Although it is not the best or the most comprehensive method, it can be quickly and easily calculated and can be used as a point of comparison with a more comprehensive and intensive method (Jones, et al. 2013). The net benefit stream approach is conceptually more attractive, but it involves high levels of uncertainty. Appendix E provides a detailed description of the various RV estimation methods.

Being dependent on circumstances far in the future, RVs are subject to high levels of uncertainty. Different estimation methodologies can lead to vastly different RV estimates. Given the current state of knowledge, the best practice, as recommended in current ATAP Guidelines (TIC 2016b) may be to use RV derived from straight line depreciation as the main basis for reporting, and a point of comparison with more complex estimates from various net benefit stream methods.

Valuation errors

Valuation errors occur when assigning monetary values to impacts such as travel time saved, VOC saved, lives saved, environmental and other externalities avoided. Since the mid-1990s, significant efforts have been made by Austroads to harmonise methodologies and values used to estimate road user costs. Austroads has provided regular updates on unit values of travel time, VOCs and unit crash costs for use in economic evaluation. Jurisdictions have been required to use Austroads-recommended unit economic values in their economic appraisals of projects for which federal funding is sought. The responsibility of updating unit road user cost values now resides in the ATAP Guidelines Steering Committee.

Valuation of travel time savings

Travel time savings normally constitute a large portion of the measured benefits of road projects. Getting valuation of travel time right is therefore critically important in CBAs.

In Australia, the common practice has been to choose values of travel time for a given year (when a CBA is undertaken) and multiply them by the total travel time saved for different vehicle types to derive travel time cost savings. In other words, values of travel time are assumed to be constant over the entire evaluation period.

In contrast, value of time is allowed to change over time in some countries (for example, the UK) in line with the changes in income (DfT 2014). The TIC (2016b) sees this as an acceptable approach.

The issue of having a growing value of travel time was raised in one of the ex-ante CBAs selected for case studies. In his evaluation of the Goulburn Valley Highway project, Stanley (1993) allowed the value of time to increase in line with the historical trends in the growth of real income per capita (1 per cent a year).

Inconsistencies in the use of evaluation parameters can arise if there is no clear guidance on what unit value of time should be used in road CBAs, whether they should be allowed to change over the evaluation period and at what rate. This will potentially lead to a loss of comparability between appraisal results. While the Austroads Guide to Project Evaluation in the past and now the ATAP guidelines specify values of time to use for all road projects, there is no recommended growth rate.

Unit value of VOCs

Key inputs into the calculation of basic VOCs include fuel, lubricating oil, tyres, vehicle prices, and repairs and maintenance. Among these inputs, fuel prices have been subject to the greatest uncertainty.

Unit values of VOCs for each vehicle class vary according to road surface and pavement conditions, horizontal and vertical alignments, and average vehicle speed. Unit VOC curves differ between rural and urban roads, and within the latter, between urban freeway and stop-start conditions. TIC (2015) contains the latest information on VOC models used in Australia.

In practical CBAs, selection of a unit VOC value that is based on the right operating environment and vehicle type is critical for obtaining credible VOC saving estimates. Difficulties may arise in deciding typical operating environments (notably in relation to travel speeds) and finding representative unit VOCs for a particular group of vehicles (for example heavy vehicles). Box 2.5 shows an example of how errors can be made.

Box 2.5 Estimation of VOC savings for the Bulahdelah Bypass project

In the ex-ante CBA of the Bulahdelah Bypass project, speed-based VOC models were used to estimate VOC savings. The unit costs for the base case and the existing road for the project case were derived from the urban stop-start model (Austroads 2012b). The unit VOCs for cars and trucks using the bypass were also assumed to vary with speed. These costs were sourced from the RTA VOC look-up tables for rural roads.

Two problems were found in the estimation of VOC savings. First, the base case townsite route was not in a typical stop-start condition for all the sections at all times. While stop-start conditions might apply in the most congested hours such as peak holiday seasons in the vicinity of the town centre, it would not be suitable for most other times and for the approach road that comprised half the total length of the base case road. Applying a stop-start model for the entire length of the road through the town and for all times over-estimates the VOCs for the base case and hence the project's VOC savings.

Second, the ex-ante CBA used rigid trucks as a proxy to represent the "heavy vehicles" category, which resulted in under-estimation of unit VOCs for base case truck operation. As a result, VOC savings were under-estimated, other things being equal.

Source: Based on the NSW Bulahdelah Bypass case study.

Unit value of crash costs

Valuation of accident costs in Australia has been mostly based on values recommended by the Bureau of Transport Economics (BTE 2000). BTE employed the human capital approach supplemented by a cost estimate for pain and suffering. In the latest update of crash costs based on BTE (2000) estimates, ATAP (TIC 2015) recommended $2.0 million in 2013 prices as the average cost per person for a fatal crash.

Over the past decade, there has been a growing momentum towards use of unit crash cost values based on the willingness to pay (WTP) method, which are generally much higher. For example, the Roads and Traffic Authority (RTA 2008) used a WTP approach to produce an estimated value of a statistical life (VSL) of $6.4 million in 2007 prices or $6.96 million in 2010 prices. Abelson (2008) put forward a VSL of $3.5 million ($3.7 million in 2010 prices) by taking into account the different approaches and estimates produced in Australia and internationally. The current action plan (2015–2017) of the Nation Road Safety Strategy recommended a switch to WTP as soon as practical.

The WTP approach measures the amount individuals are willing to pay to reduce the probability of death or injury. Estimates are obtained from either 'revealed preferences' as evidenced in situations where individuals trade off costs against risk of death or injury, or 'stated preferences' whereby people are asked how much they would be willing to spend to reduce the risk of death or injury in hypothetical situations. WTP is more consistent with CBA methodology in that it attempts to base estimates on consumers' valuations.

Efforts are being made to produce more robust national WTP estimates of the social cost of Australian road crashes. Recently, Austroads (2015) completed a project scoping study aimed at producing such estimates. However, given the cost and complexity of the WTP study, it will be some time before new estimates become available.

Sensitivity analysis

Sensitivity analysis is a simple and common way to address project risk. Austroads (2012a) recommended a range of variables to be tested in CBA, mostly in relation to capital costs and traffic assumptions. Of the five projects selected for the second round of ex-post evaluations, only two featured a sensitivity test of alternative capital cost scenarios and one arbitrarily varied the road user benefit by +/-20%. None of ex-ante CBAs took reasonable steps in dealing with uncertainties in traffic forecasts, including the assumptions underpinning the forecasts.

A more formal way to deal with traffic risk for large projects is to adopt a probabilistic approach. Similar to the transition to probabilistic analysis in project cost estimation, traffic forecasting used in CBA should also contain reasonable confidence intervals. This will allow traffic risks to be incorporated in benefit estimations. Appendix D discusses the probabilistic approach in some detail.

III Ex-post economic evaluation framework

The objectives of the past two rounds of ex-post evaluations were to:

- assess the economic performance of the projects examined
- check the accuracy of ex-ante CBA's predictions
- explain differences (if any) in results between the ex-ante and ex-post CBAs
- draw lessons from the case studies to improve future CBAs.

The key question to be addressed is: with hindsight, how accurate was the CBA in informing decision-making? More specifically the following questions were asked:

- Have the forecast road project benefits been realised?
- What are the magnitudes of deviations between forecasts and actual outcomes?
- What caused the deviations?
- What lessons can be learnt to improve future CBAs and thereby make CBA a more effective decision-making tool?

Overview of ex-post economic evaluation framework

The methodology used for ex-post CBA drew upon earlier studies by EC (2011), Odeck (2012) and BITRE (2007a and b). A review of these studies is provided in appendix F. Although these studies had different origins and came from different perspectives, they shared many similarities in terms of the challenges faced in conducting ex-post CBAs and the methodological framework they adopted.

The framework used in the past two rounds of ex-post evaluations comprises the following 10 steps:

1. Provide a description of the project (design, cost, timing and history)
2. Locate and review ex-ante CBAs
3. Identify issues in ex-post evaluation (mostly emerging from the review of ex-ante CBAs)
4. Replicate the ex-ante CBA
5. Collect data for the ex-post CBA (for example, traffic and crash data)
6. Update traffic and crash forecasts
7. Undertake the ex-post CBA (including adjusting model inputs, updating model parameters and making other project-specific corrections)
8. Compare results between ex-ante and ex-post CBAs

9. Explain the difference
10. Draw lessons.

There were difficulties in completing each of the 10 steps listed above with steps 2–6 subject to particular challenges.

Locating and obtaining documentation (step 2) on ex-ante CBAs proved to be difficult and time-consuming in the first round of ex-post studies. The situation improved for the second round with better documentation and archiving. However the quality of documentation still varied considerably across projects (table 3.1). Of the five projects reviewed in the second round, only two had a full separate CBA report detailing CBA inputs and interpreting CBA results. For other projects, CBA results were imbedded in a number of documents, making it difficult to complete ex-ante CBA reviews and ex-post evaluations.

Identifying the focus for the ex-post economic evaluation (step 3) was another challenge. Most of the issues can be identified from the review of ex-ante CBAs and tend to vary across projects. Special attention was paid to issues related to the specification of a proper base case, traffic demand analysis and road user cost estimation (travel time estimation in particular).

Table 3.1 Quality of documentation

	Type of documentation					
	PPR	Summary CBA tables in appendix of PPR	Full CBA report	Proprietary CBA software	CBA Manual	CBA spread-sheet
Bruce Highway Upgrade Cooroy to Curra Section B (QLD)	√		√	√	√	
Dampier Highway Duplication (WA)	√	√		√	√	
Bulahdelah Bypass (NSW)	√		√			√
Nagambie Bypass (VIC)	√	√		√	√	
Northern Expressway (SA)	√	√				√

Source: BITRE.

Replication of ex-ante CBAs (step 4) used to be a difficult task largely due to the unavailability of the original CBA software (or spreadsheet model), or information on model inputs. For the second round of evaluation, this was less of a problem due to improved documentation and better archiving.

Collecting new data for ex-post evaluation (step 5) and updating traffic and crash forecasts (step 6) posed a further challenge. The quality of updated traffic and crash forecasts was often limited by the lack of detailed, reliable long-term time-series data.

As for the performance indicators, NPV and BCR are used to show the overall economic worth of a project. NPV is decomposed into detailed annual benefit and cost streams whenever considered necessary. To assist in determining the optimal timing for investment, the FYRR is also calculated and reported.

Case studies

Two rounds of ex-post evaluations were undertaken by BITRE in the past 10 years—the first in 2005–07 and the second in 2014–16 (table 3.2). Altogether 12 projects were selected for case studies. The seven projects included in the first round were chosen from the program implemented between 1996 and 2002 aimed at improving the then National Highway System. The five projects included in the second round were drawn from the list of road investment projects under the Nation Building Program implemented over five years from 2008–09 to 2013–14 (see appendix G for more detail on the selection of case studies in the second round).

In selecting projects for case studies, consideration would ideally be given to project's size, performance, recurrence of similar projects, risks, strategic importance, geographical distribution, and potential environmental and regional impacts. Actual choice of the case studies for the first round was largely driven by availability of relevant information and data. With better information available for the second round, the selection of case studies was tilted more towards larger projects.

Of the 12 projects selected for case studies, five were upgrades of rural roads, three were upgrades of urban approach roads and four were bypasses (table 3.2).

There were two projects for each of the five states, one for Tasmania and one for the ACT. It should be noted that the original economic appraisals undertaken for these projects were not necessarily representative of CBA practices in each state and territory. A much larger sample would be required before conclusions could be made about the quality of CBAs undertaken in the states and territories.

As for the types of review, nine projects were subject to a full ex-post evaluation, one to review plus limited ex-post evaluation and two to review only. The reason for not conducting a full ex-post review of the ACT/Sutton Road duplication (No. 4) and the Northern Expressway (No. 12) projects was lack of relevant urban traffic models to estimate traffic impacts. The availability of traffic and travel time data after the completion of the Northern Expressway project allowed travel time savings to be re-assessed, the results of which were included in the overall analysis wherever possible. The case study for Goulburn Valley Highway project (No. 6) included a review of the ex-ante CBA and some preliminary ex-post evaluation results and therefore was treated as a 'review-only' case study.

Table 3.2 Profile of projects selected for case studies

	Type of projects			Type of review			Status of case studies
	Highway upgrade						
	Rural (5)	Urban approach (3)	Bypass (4)	Review of ex-ante CBA only (2)	Review of ex-ante CBA plus limited ex-post CBA (1)	Review of ex-ante CBA plus full ex-post CBA (9)	
Round 1 (2005–07)							
1. Wallaville Bridge (QLD)	√					√	Published
2. Northam Bypass (WA)			√			√	Published
3. Adelaide Crafers Highway (SA)		√				√	Unpublished
4. Federal Highway–ACT/Sutton Road (ACT)		√		√			Unpublished
5. Yass Bypass (NSW)			√			√	Unpublished
6. Goulburn Valley Highway (VIC)	√			√			Unpublished
7. Bass Highway (TAS)	√					√	Unpublished
Round 2 (2014–16)							
8. Bruce Highway Upgrade Cooroy to Curra Section B (QLD)	√					√	Included as Appendix B.1
9. Dampier Highway Duplication (WA)	√					√	Included as Appendix B.2
10. Bulahdelah Bypass (NSW)			√			√	Included as Appendix B.3
11. Nagambie Bypass (VIC)			√			√	Included as Appendix B.4
12. Northern Expressway (SA)		√			√		Included as Appendix B.5

A brief description of each of the seven case studies included in the first round is provided in appendix A. The detailed results for the first two case studies can be found in BITRE Working Papers 70.1 and 70.2 (BITRE 2007a and 2007b).

All case study reports for the second round are included in Appendix B of this report.

IV Key findings

Accuracy of ex-ante CBAs – macroscopic view

The formula used to show differences in results between ex-ante and ex-post analyses takes the form:

$$Deviation = \frac{EI_{Ex\text{-}ante} - EI_{Ex\text{-}post}}{EI_{Ex\text{-}post}} \times 100$$

where EI stands for economic indicators such as NPV, road user benefits or project costs. A positive figure indicates over-estimation and a negative figure indicates under-estimation.

Table 4.I summarises the estimated accuracy of the ex-ante CBAs in broad plus and minus signs.

For performance indicators, there was consistent over-estimation of BCR in both rounds. On a nominal basis, projects in the first round featured slight cost over-runs and those in the second round slight cost under-runs. Information on FYRR was mostly missing for the first round, although the situation improved for the second. This concealed evidence that would indicate whether the projects had been implemented before their optimal times.

For traffic forecasts, there was a general change from under-estimation in Round I to over-estimation in Round 2. Over-estimation occurred for both initial traffic levels and forecast traffic growth rates.

Over-estimation of road user benefits appeared to be prevalent for the projects included in both rounds. While methodological errors explained most of the over-estimation in Round I, overly optimistic traffic forecasts were a major contributing factor to over-estimation in Round 2.

Residual values were generally omitted until recently, as seen in Round 2 of ex-post evaluations.

Table 4.1 Summary of findings on accuracy of ex-ante CBAs

	Ex-post evaluations undertaken in 2005–2007 (Round 1)					Ex-post evaluations undertaken in 2014–2016 (Round 2)				
	Wallaville Bridge (QLD)	Northam Bypass (WA)	Adelaide Crafers Highway (SA)	Yass Bypass (NSW)	Bass Highway (TAS)	Bruce Highway Upgrade Section B (QLD)	Dampier Highway Duplication (WA)	Bulahdelah Bypass (NSW)	Nagambie Bypass (VIC)	Northern Expressway (SA)
Performance indicators										
Benefit–cost ratio or NPV	+	+	+	–	+	+	+	+	–	+
Cost (nominal)	–	–	–	–	–	+	–	+	+	Within budget
Ex-ante FYRR (%)	Omitted	Omitted	Omitted	Omitted	Included	Included	Omitted	Included	Omitted	Included
Traffic analysis										
Initial traffic level	–	–	+			+		+	+	+
Heavy vehicle (%)	–		+	–		–			–	–
Traffic growth forecasts	–	–	–	+	+	+	+	+	–	+
Road user cost estimation										
Travel time savings	+	+	–	–	–	+	+	+	–	+
VOC savings	+	+	+	–	+	+	+	+	+	Not reviewed
Crash cost savings	+	+	+	–	+	+	+	–	+	Not reviewed
Residual values	Included	Omitted	Omitted	Omitted	Omitted	Included	Omitted	Included	Omitted	Included

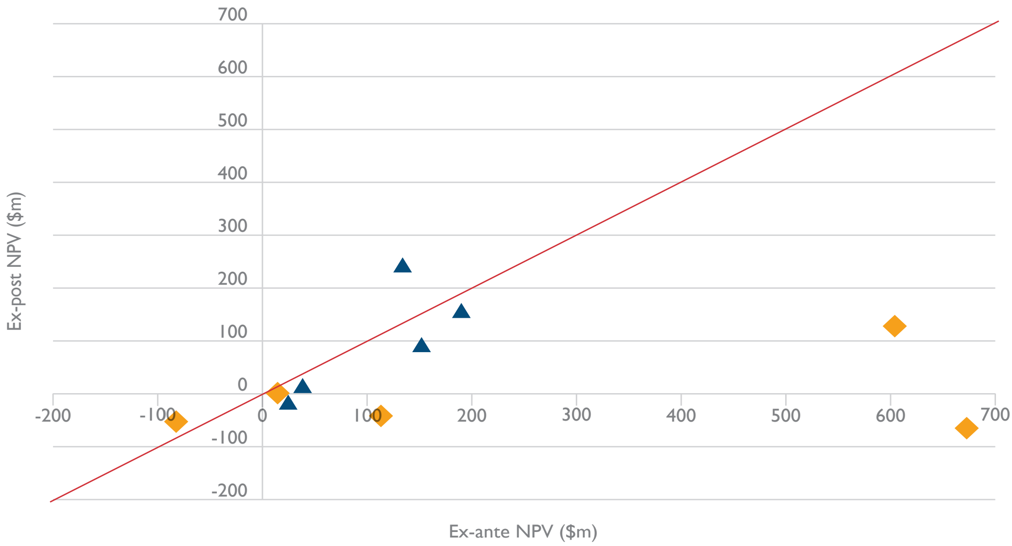
Note: '+' indicates over-estimation by the ex-ante CBA and '–' indicates under-estimation. Blank spaces indicate no change was introduced in the ex-post study either because the ex-ante was accurate or new information was lacking. Results for the Northern Expressway project were based on the preliminary findings reported in appendix B.5.

Accuracy of ex-ante CBAs – microscopic view

Deviation in NPV

Figure 4.1 shows the difference in NPV between the ex-ante and ex-post analyses for the nine projects for which detailed ex-post evaluation results were available (five for the first round and four for the second round). The 45-degree line in the scatterplot shows the match between the ex-ante and ex-post values. Data points below the 45-degree line indicate an over-estimation and vice versa. Overall, the NPVs of all projects except two (Nagambie Bypass and Yass bypass) were over-estimated in the ex-ante CBAs compared with the ex-post CBA. The range of over-estimation was huge—from 19% to 1,135%. There was no clear pattern in the percentage deviation between small and large projects. However, inaccuracies appeared to have increased between the two rounds of ex-post evaluations.

Figure 4.1 Comparison of ex-ante and ex-post NPV



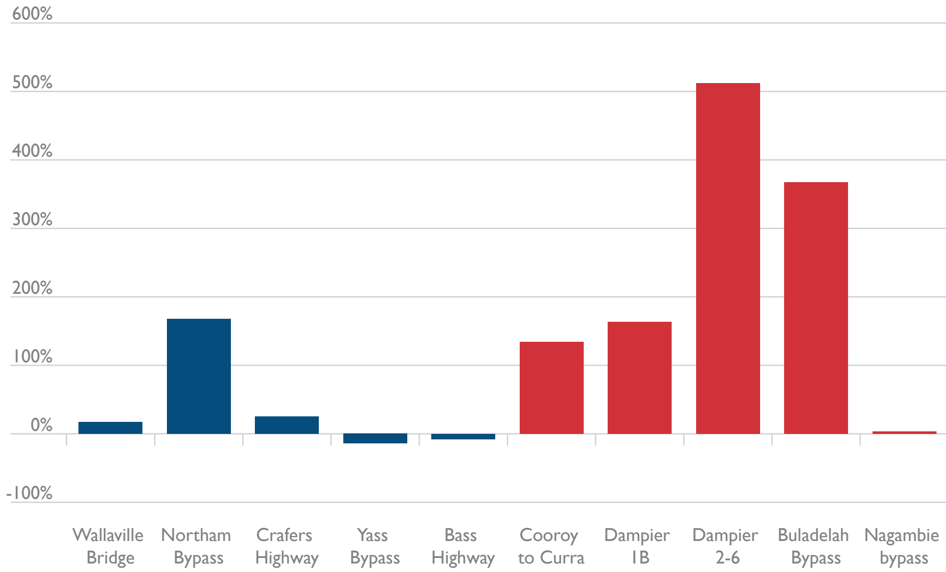
Note: Triangle: first round at 7% discount rate; and diamond: second round at 4% discount rate. The Dampier Highway project has two data points—one for Stage 1B and the other for Stages 2 to 6.

Source: BITRE based on the case study results.

Deviation in road user benefits

Most of the deviation in NPV was caused by deviation in road user benefits. Except for the Yass Bypass and Bass Highway upgrade projects, there was a consistent pattern of over-estimation of road user benefits (figure 4.2). The extent of over-estimation was more serious for the projects included in the second round of ex-post evaluations.

Figure 4.2 Deviation in road user benefits (% ex-ante over ex-post)



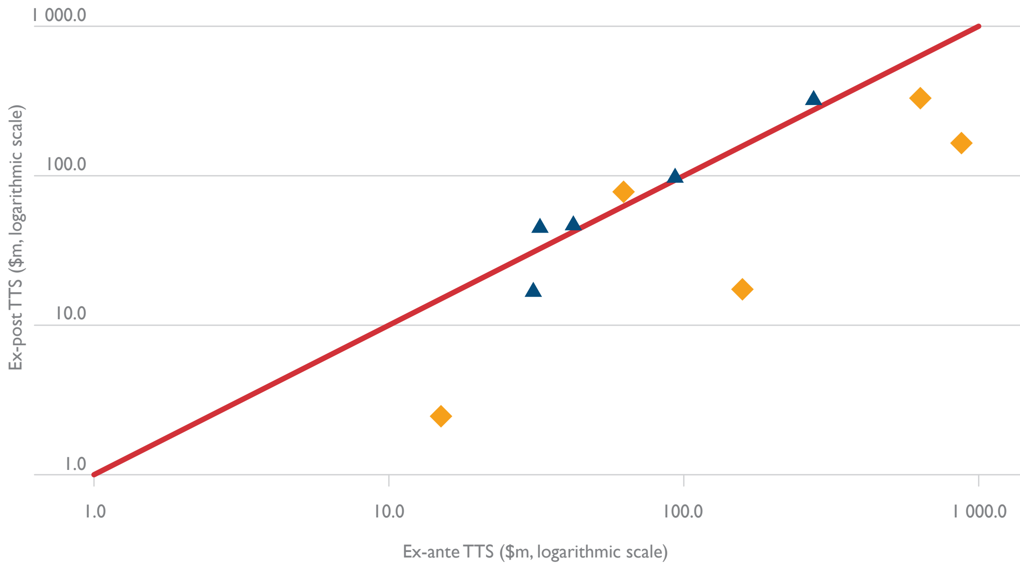
Note: First round: blue; Second round: red.

Source: BITRE based on the case study results.

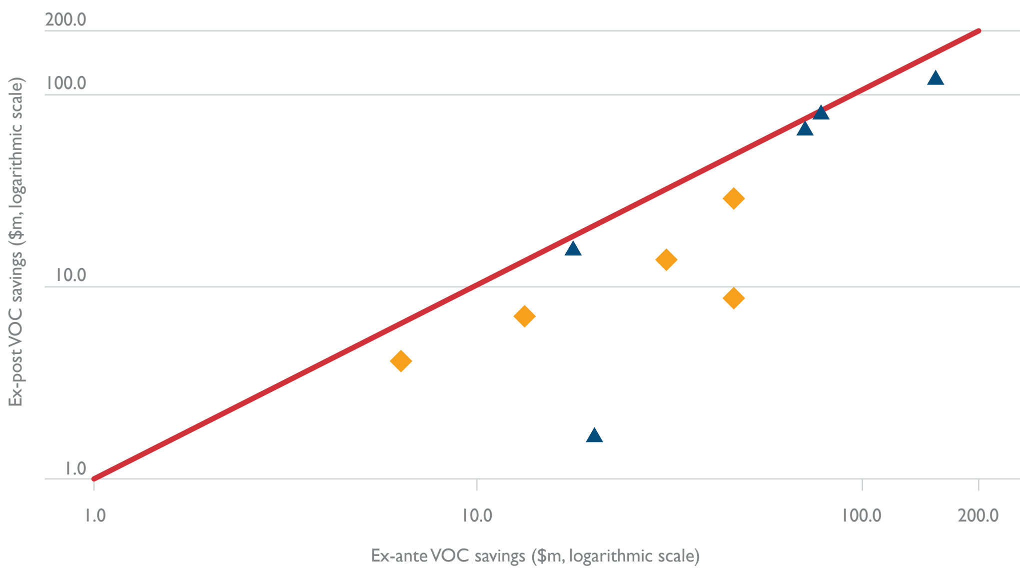
Figures 4.3a-c show the deviation across the major categories of road user benefits using a logarithmic scale. For travel time cost savings, there was a clear tendency of over-estimation for projects included in the second round of evaluations (figure 4.3a). VOC savings were consistently over-estimated for the projects in both rounds of ex-post evaluations (figure 4.3b). Deviations in safety benefits between ex-ante and ex-post results also appear to be large (figure 4.3c), although there were uncertainties surrounding the ex-post estimates due to data problems.

Figure 4.3 Comparison of ex-ante and ex-post road user benefits

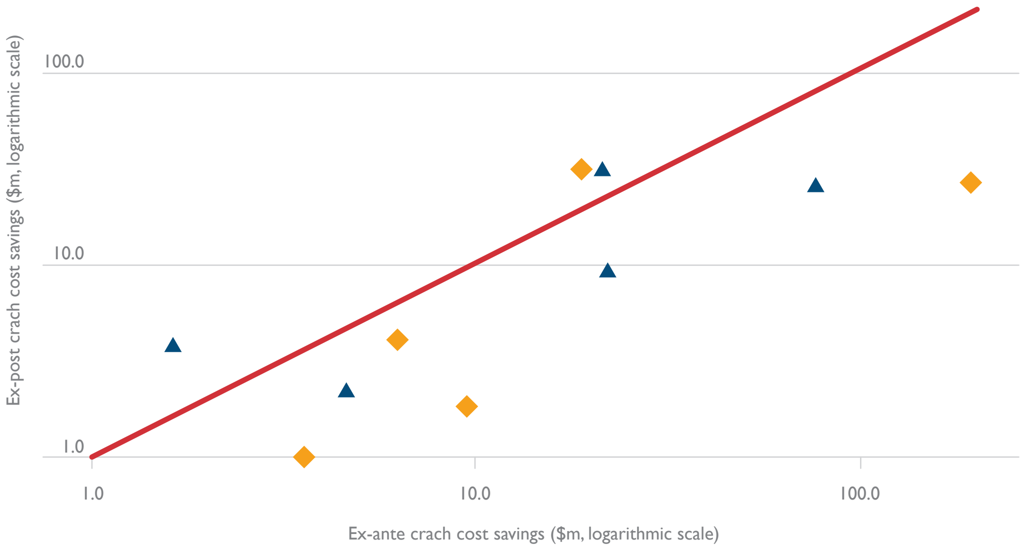
a. Travel time savings



b. VOC savings



c. Safety benefits



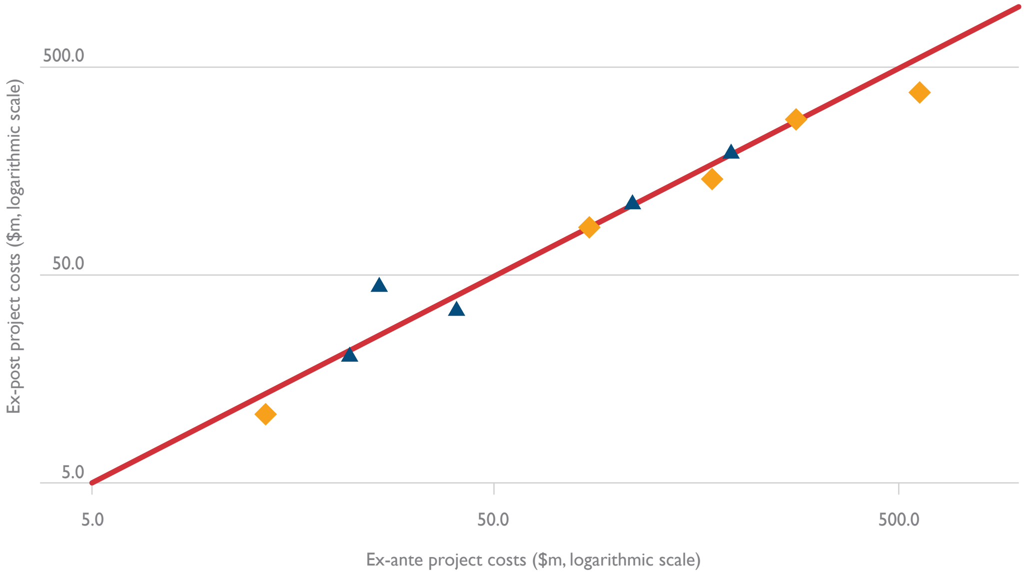
Note: Triangle: first round @7%; and diamond: second round @4%. The Dampier Highway project has two data points – one for Stage 1B and the other for Stages 2–6.

Source: BITRE based on the case study results.

Deviation in project costs

Table 4.2 above points to a general trend of cost over-runs for the projects in the first round, and under-runs in the second round in nominal terms. The deviation in project costs in real discounted terms between the ex-ante and ex-post evaluation is small for most projects (figure 4.4). There were two outliers, both of which are explained by scope changes. Overall, the deviation in project costs was fairly symmetric between over and under-estimation.

Figure 4.4 Comparison of ex-ante and ex-post construction costs



Note: Triangle: first round @7%; and diamond: second round @4%. The Dampier Highway project has two data points – one for Stage 1B and the other for Stages 2–6.

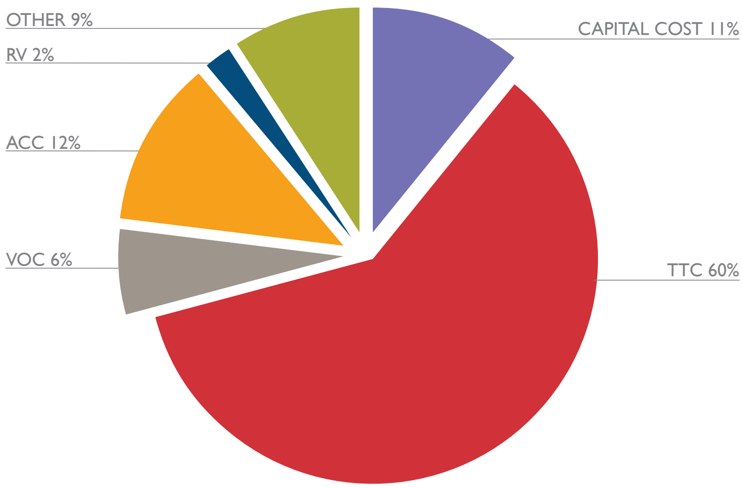
Source: BITRE based on the case study results.

Sources of deviation in NPV: a summary

Figure 4.5 shows the sources of deviation in NPV. Variation in travel time savings was the largest source of deviation in NPV (60%), followed by the variation in crash cost savings (12%) and in capital costs (11%). Together these three components accounted for more than 80 per cent of the total variation in NPV.

It is worth noting that the results for the ex-post analyses should not be viewed as completely definitive, because not all elements have been updated in ex-post CBAs. The results may, however, be used to indicate areas for improvement in ex-ante CBAs.

Figure 4.5 Contribution to the total absolute variation in NPV (%)



Notes: TTC=travel time costs, VOC vehicle operating costs, ACC=accident costs, RV=Residual Value, and Other=maintenance and environmental costs.

The absolute differences in benefits and costs between the ex-ante and ex-post analyses were summed for each benefit and cost category, and in total. The percentages in figure 4.5 are the total for each of the benefit and cost categories divided by the total for all the categories.

Source: BITRE based on the case study results.

Explaining differences

Deviations in NPV between ex-ante and ex-post evaluations were largely caused by differences in the estimated road user benefits (TTC, VOC and ACC), comprising 78% of total variation. Inaccurate traffic forecasts were generally responsible for these differences, but there were other factors including methodological errors in estimating key components of road user benefits as well as sporadic errors.

Traffic forecasts

For the first round of ex-post evaluations, initial traffic demand was under-estimated for four of the five cases, but the forecast growth rates did not show any tendency towards significant over or under-estimation.

Over-estimation of traffic demand was evident for the projects in the second round of ex-post evaluations (table 4.2). Traffic forecasts for some projects were overly optimistic in terms of initial traffic levels or future traffic growth, contributing to the over-estimated road user benefits or NPV. A standout example was the Dampier Highway project for which significant adjustment had to be made to traffic growth forecasts (from 6.0–6.5% to 2.3% a year, linear) in the ex-post evaluation. Initial traffic levels for Bulahdelah Bypass and Northern Expressway were over-estimated by almost a third.

For rural projects, traffic forecasts are largely based on trend extrapolation. This method tends to produce optimistic forecasts in good times and pessimistic ones in bad times. Traffic forecasts for the projects included in the second round were mostly prepared during the boom period leading up to the Global Financial Crisis. The ex-post analysis covered the period after the Global Financial Crisis.

Table 4.2 Forecast versus actual traffic demand

(a) Initial traffic levels (opening year)

Project name	Forecast AADT (A)	Actual AADT (B)	% (A/B-1)x100
First round			
Wallaville Bridge	1 792	2 228	–19.6
Northam Bypass	1 516	1 611	–5.9
Adelaide Crafers Highway	31 824	40 246*	–20.9
Yass Bypass	na	na	na
Bass Highway	31 207	31 766	–1.8
Second round			
Cooroy to Curra	16 000	14 736	8.6
Dampier Highway Stage 1B	5 044	4 550**	10.9
Dampier Highway Stages 2–6	4 296	4 550**	–5.6
Bulahdelah Bypass	17 902	13 379	33.8
Nagambie Bypass	7 259	8 295	–12.5
Northern Expressway	18 300	13 800	32.6

* Ex-post forecast. ** Based on the average AADT for the duplicated Dampier Highway.

(b) Traffic growth forecasts (% a year, linear)

Project name	Ex-ante (A)	Ex-post (B)	Δ=(A-B)
First round			
Wallaville Bridge	2.40	2.70	–0.30
Northam Bypass	2.00	3.00	–1.00
Adelaide Crafers Highway	1.66	1.51	0.15
Yass Bypass	na	na	na
Bass Highway	3.00	2.71	0.29
Second round			
Cooroy to Curra	3.00	2.17	0.83
Dampier Highway Stage 1B	6.00	2.30	3.70
Dampier Highway Stages 2–6	6.54	2.30	4.24
Bulahdelah Bypass	2.60	2.05	0.55
Nagambie Bypass	1.43	2.50 (compound)	–1.07
Northern Expressway	na	na	na

Source: BITRE based on the case study results.

For some bypass projects (for example, the Bulahdelah and Nagambie bypass projects), over-allocation of traffic onto the bypass was also a source of over-estimation of road user benefits.

Methodological errors

In addition to inaccuracies in traffic forecasts, methodological errors were also responsible for the inaccurate estimation of road user benefits.

Modelling of travel time savings

Large deviations were found in the estimated travel time cost savings for some projects (figure 4.3a). While inaccurate traffic forecasts explained part of these deviations, methodological anomalies in modelling were also responsible. A common error was to have the base case made worse than it should have been. A few examples illustrate the point.

Misspecification of base case flooding effects: the assumption about the complete loss of the Wallaville Bridge caused a large diversion of traffic leading to significant over-estimation of the travel time savings for the project (see box 2.1).

Under-estimation of travel speed for the base case: in ex-ante CBA of the Bulahdelah Bypass project, the average speeds for the base case routes were under-estimated (by as much as 24–52% over the evaluation period), leading to significant over-estimation of travel time cost savings (appendix B.3).

For the ACT/Sutton road project, it appeared that there was also an under-estimation of the travel speed for the base case due to over-estimation of traffic demand and use of an unrealistically low queuing speed for an urban approach road that had the characteristics of a rural road (appendix A.4).

Misspecification of base case road length: in the ex-ante evaluation of the Northam Bypass project (BITRE 2007b), the base case through-town road length was increased by 69 per cent to allow for the delay effects caused by intersections. Ex-post evaluation results showed that the increase was too large causing a significant over-estimation of travel time cost savings (BITRE 2007b).

Estimation of VOC savings

For the projects selected for case studies, there was a consistent pattern of over-estimation of VOC savings (figure 4.3b). In addition to overly optimistic traffic forecasts, there were a number of other contributing factors.

Misspecification of base case flooding effects: in the case of Wallaville Bridge project, the assumed closure of the bridge in the base case caused a large detour for traffic via Bundaberg, thereby leading to a significant upward bias in the estimated VOC savings.

Misspecification of base case road length: for both the Northam and Bulahdelah Bypass projects, the lengths of the base case and through-town roads were over specified, though for different reasons. The result was a significant over-estimation of VOC savings for these projects.

Mis-selection of unit VOC values: in selecting unit VOC values for the Bulahdelah Bypass project, two errors were made: (1) use of a stop-start model when a continuous flow model was more realistic, and (2) using rigid trucks as a proxy to represent the entire "heavy vehicles" category. The former caused an over-estimation and the latter an under-estimation (see box 2.5).

Estimation of crash cost savings

Deviations in the estimated safety benefits were large (figure 4.3c). Their contribution to the total absolute variation in NPV also appeared to be relatively large (only after travel time cost savings, figure 4.5).

The quality of crash rate estimates derived from site-specific data for the case study projects was poor because of data limitations. Errors were also made in the selection of unit crash cost values. Inaccurate traffic forecasts added further to the gap in estimated safety benefits between the ex-ante and ex-post analyses.

There were significant uncertainties surrounding crash cost saving estimates, both ex-ante and ex-post. Crash rates used in the ex-ante analyses were based on either site-specific crash data or model default values. There is no evidence to suggest that one approach performs better than the other. However, anomalies can arise if the two approaches are mixed up, for example, using an historic crash rate in the base case and a default value in the project case.

Other errors

Table 4.3 lists other methodological errors, CBA input errors, and spreadsheet errors found in the ex-ante CBAs. Most of these were sporadic and could have been avoided if a peer review had been undertaken. Some of these errors caused significant distortions in the estimated BCR. For example, in the ex-ante CBA of the Crafers Highway project, correcting for three errors (namely, inclusion of benefits for the years when the project was still being built, use of an incorrect extrapolation methodology and double-counting in safety benefits) caused the BCR to drop from 2.43 to 1.45, a 40% reduction, other things being equal.

Table 4.3 Other errors encountered in road CBAs

	Round 1				
	Wallaville Bridge	Northam Bypass	Adelaide Crafers Highway	Yass Bypass	Bass Highway
Other methodological errors	• Incorrect first benefit year and length of evaluation period		• Included the benefits while the project was still being built • Incorrect length of evaluation period • Used compound growth to extrapolate road user benefits which grew in a linear fashion		
CBA input errors		• Incorrect assumption about the induced benefit to the freight industry	• Incorrect length of the project case road, leading to an under-estimation of safety benefits • Under-estimation of road capacity		• Incorrect input for maintenance costs
Spreadsheet errors			• Incorrect formula used to estimate the average accident cost		
	Round 2				
	Cooroy to Curra	Dampier Highway	Bulahdelah Bypass	Nagambie bypass	
Other methodological errors	• Double-counting of savings in road closure costs associated with accidents • Incorrect formula used to estimate residual value	• Incorrect first benefit year and length of evaluation period for Stages 2–6	• Incorrect VOC model for heavy vehicles	• Incorrect length of evaluation period	
CBA input errors	• Incorrect section length • Inconsistencies in the assumptions about the maintenance costs and timing, and associated roughness reduction		• Incorrect (modelled) section length for the base case road	• Overstatement of the length of the base case road • Incorrect road width specification • Over-statement of traffic demand on the bypass	
Spreadsheet errors	• Incorrect formula used to derive the average cost of a fatal crash		• Spreadsheet errors in extrapolating annual travel time savings and safety benefits	• Misalignment of the road user cost stream for the base case causing a large spike in road user benefit	

Source: BITRE based on the case study results.

In the ex-ante CBA of the Nagambie Bypass project, a simple spreadsheet error caused the BCR to be over-estimated by more than 30% (see appendix B.4 for more detail).

In the ex-ante CBA of the Cooroy to Curra Section B project, a combination of errors (incorrect section length, inconsistencies in assumptions about the base case road maintenance, incorrect formula used to estimate the average crash costs, and double-counting of savings in road closure costs) caused the BCR to be over-estimated by 18%.

V Lessons learnt

A number of lessons can be drawn from the past two rounds of ex-post economic evaluations.

CBA documentation

CBA documentation was found to have improved significantly between the first and second rounds of ex-post evaluations. However, the quality of documentation varied across the projects. Of the five projects selected for review in the second round, only two had separate CBA reports that contained detailed information on assumptions, methodology and results. For the other three, the results were imbedded in their respective PPRs. A separate CBA report would have provided greater transparency in CBA inputs and better interpretation of CBA results. For large projects (>$25m), it is essential to have a detailed self-contained CBA report to accompany the PPR.

Proprietary CBA software (for example CBA6 used in Queensland and Eval4 used in Victoria) tended to be accompanied by detailed user manuals and full model inputs. It is usually claimed that spreadsheet models used for CBAs follow particular guidelines, but compliance is less assured compared with CBAs using proprietary software.

CBA reports should be supplemented by the information that is necessary to replicate the original analysis (including CBA tools used and input data). Making the CBA calculations available facilitates the review of the ex-ante analysis as well as ex-post economic evaluations.

Austroads (2011c) published a report detailing requirements for documentation and quality control of CBAs. The report showed common pitfalls in CBAs and developed a checklist for quality control purposes. It is suggested that the checklist be updated and included in the ATAP Guidelines.

CBA review

The ex-post review found significant errors in the ex-ante CBAs. Some of these were simple and could have been avoided had a peer review process been in place. At the time the ex-ante CBAs were undertaken, there was no formal expert review process in place for CBAs of national road investment projects at the federal level. The situation may have changed since then with the adoption of an integrated project assessment framework following the establishment of Infrastructure Australia in 2008. The assessment framework recently released by Infrastructure Australia (2017) and its role in assessing infrastructure project proposals (including CBAs submitted as part of the proposals) for prioritisation, are expected to provide timely feedback on, and improve the quality of, the ex-ante CBAs. Currently, Infrastructure Australia encourages project proponents to have their economic appraisals and business cases reviewed externally, but the lack of resources and a formal review process (including a detailed workable checklist) may impede the number of such reviews and their independence.

For urban road projects, the credibility of CBAs depends critically on the quality of the traffic modelling outputs used in the economic evaluation. While CBA analysts could apply some common-sense tests to traffic modelling results, it is ultimately up to traffic modelling experts to undertake an adequate review. Independent review of traffic modelling results should be an indispensable part of any CBA review, particularly for urban road projects.

Traffic forecasts

Traffic forecasts have been identified as a key area for significant improvement. So far, trend extrapolation has been the primary forecasting methodology for predicting traffic volumes on non-urban national highways. This methodology tends to produce optimistic traffic forecasts in good times and pessimistic ones in bad times. Efforts should be made to understand the nature of the observed trend and sound qualitative judgement applied to determine whether the historical trend will continue during the forecast period.

Forecasting errors have also arisen from neglecting to allow for changing vehicle mix over time. Changes in traffic composition can have an important bearing on the evaluation results. Where possible, separate forecasts should be made for different vehicle classes, at least separating out light and heavy vehicles.

Traffic analysis has been constrained by the availability of good data. Updates of traffic forecasts in the ex-post evaluation have faced no fewer challenges than experienced in the ex-ante analysis. Better data (in terms of both quality and currency) will help improve future traffic forecasting.

Forecasting traffic for roads in urban areas is more challenging due to the complexity in handling congestion and network effects. Reality checks should be applied to modelling outputs from network models, not just at the aggregate network level, but also for individual road sections of immediate concern.

Estimation of road user benefits

A common error found in the road CBAs reviewed was making the base case worse than it should have been. The plausibility of any chosen base case should be carefully checked.

For most road projects, travel time cost savings are the largest source of road user benefits, hence correctly estimating travel time cost savings is fundamental for getting the overall CBA results right. In the past, over-estimation of travel time cost savings was caused in part by over optimistic traffic forecasts, and in part by the methodology employed to estimate travel time savings (mostly in relation to the base case travel speed/time). Inappropriate or inconsistent use of speed-flow curves led to significant biases in travel time cost saving estimates.

VOC saving estimates can also be subject to errors if VKT or unit VOCs are miscalculated. For bypass projects, getting the length of base case road right is crucial (given the traffic level) for obtaining correct VKT estimates. Unit VOCs vary with speed, road conditions and vehicle type. Great care should be taken to select the most realistic unit VOC values.

The case study results show that there is much room for improvement in the quality of safety benefit estimates. Crash analysis was hampered by lack of good data. For ex-ante CBAs, there was a lack of reliable historical crash data making it difficult to determine site-specific crash rates for the base case. For ex-post CBAs, crash data were not available over a long enough period to establish credible crash rates for the project case.

Analysis of crash costs is complex task requiring specialised skills. Significant errors were found in a number of the ex-ante CBAs in relation to both estimated crash rates and unit crash costs. Improving analysts' skills for crash analysis is necessary to improve the accuracy of safety benefit estimates.

Until crash data and analysis are significantly improved, there may be a case for using model default rates for both the base and project cases because they are subject to less uncertainty.

Project cost estimation

For the projects included in Round 2, there was a clear tendency for cost over-estimation. This might have been, in part, associated with the use in CBAs of P90[3] cost estimates for budgeting. Ideally, expected values (means of probability distributions) should be used in CBAs. A P50 value is the median of the probability distribution of costs. It can be used as an approximation of mean if the probability distribution is reasonably symmetrical.

RVs

Historically, estimation of RVs has been omitted in road CBAs. More recent CBAs have tended to include RVs as a way to capture additional benefits beyond the evaluation period.

Currently two types of approaches are used for estimating RVs, the depreciation and the net benefits approaches. Conceptually, net benefits approaches are more attractive because they relate the value of an asset to its capacity to generate benefits. In practice however, depreciation approaches—usually straight line—are more commonly used because they are simpler to calculate and understand. For most projects with a BCR above one, a depreciation approach provides a lower bound for RV estimates and an upper bound for net benefits. Based on the results of our case studies, the current version of the ATAP guidelines recommends use of straight line depreciation as the main basis for reporting and other methods for sensitivity testing.

Interpolation and extrapolation

In the case study CBAs, linear interpolation was normally applied for values between the modelled years for evaluation of urban road projects. Linearisation errors can occur if actual traffic or benefits grow in a non-linear fashion.

Approaches to extrapolation beyond the last modelled year varied for the projects reviewed. Some held the extrapolated values constant while others let them grow in line with traffic growth or another arbitrarily specified growth rate. Consistency in the approach used across project appraisals is desirable for extrapolation beyond the last modelled year. Constant or low-growth

3 The estimated project cost has a 90 per cent chance of not being exceeded.

extrapolation does not necessarily imply that the estimates are conservative; the values for earlier years may be over-estimated.

FYRR

The FYRR metric is essential to the inter-temporal maximisation of investment returns, as it tells decision makers the optimal time for investment. The WA case study showed that if the FYRR had been calculated and reported, the Dampier Highway upgrade could have been delayed until traffic, and hence annual benefits from the project, had grown more, ensuring a better investment return. Similar to RVs, there has been an increasing trend to include FYRR as a part of the standard CBA output. In future, "all initiatives should be subject to the FYRR test and be reported in the business case" (TIC, 2016b).

Risk and uncertainty

CBA is a useful tool for project appraisal. However, decision makers should be aware that the seemingly precise numbers produced (especially the BCR) are often accompanied by large uncertainties. The main assumptions or alternative scenarios should be fully explored and tested in sensitivity or probabilistic risk analysis. The latest TIC (2016b) CBA guidelines illustrate how these could be implemented. Reporting of probability distributions of BCR and NPV should be encouraged.

Directions for future research

The past two rounds of ex-post evaluations have extended considerably our understanding of factors affecting the accuracy of CBAs for road projects. However, the sample of the projects selected for ex-post review has been very small. Further ex-post evaluations of the type described in the present report should provide more evidence around sources of major inaccuracies in road CBAs. Because carrying out a full ex-post CBA can be time and resource consuming, more strategic orientation (for example, limiting the evaluation to a small number of critical areas such as demand forecasts and time savings) may be useful in future ex-post evaluations.

Ex-post evaluations undertaken so far have focused on road projects in rural or urban approach areas. More effort should be focused on reviewing CBAs for large and complex urban road projects. There are challenges in undertaking such evaluations, both in terms of skills and resources. Use of urban models may be necessary.

Appendix A: Case studies – Round 1

Altogether seven National Highway projects were selected for case studies in the first round of ex-post CBAs. Selection was based in part on the size and type of projects and their geographical distribution, however data availability was key to selecting a project within a given jurisdiction. Total value of the projects reviewed in the first round amounted to more than half a billion dollars (in nominal terms).

A.1 Wallaville Bridge on Bruce Highway in Queensland ($28m)

The Wallaville Bridge formed part of the Bruce Highway until the Tim Fischer Bridge replaced it in July 1999 at a cost of $28.3m. The project involved constructing the new bridge and a new 8.3km section of the highway at Wallaville, 40km southwest of Bundaberg. The construction of the new bridge, 5km downstream from the original one, started in December 1997 and replaced the narrow and poorly aligned Wallaville Bridge which was built during World War II.

The replacement of the old bridge did not become a priority for the Federal Government until a weir was proposed across the Burnett River, 11km downstream of the old bridge. The Walla Weir (now called Ned Churchward Weir) was to be constructed in two stages, the first of which would increase the time of closure due to flooding, and the second of which would result in the inundation of the old bridge. However, due to unexpectedly prolonged drought conditions, the planned stage-two construction of the weir did not occur. This meant that the old Wallaville Bridge would not be inundated by higher water levels and would not be lost as a road asset as originally expected.

These events, which were rightly seen to be highly improbable during the concept stage of the project, add significant complexity to this case study and provide a useful demonstration of how to deal with uncertainties surrounding the base case.

In the ex-post evaluation, the following adjustments were made to the re-constructed ex-ante analysis:

E1. Incorporating freight time saving benefits

E2. Change in construction costs

E3. Change in traffic growth

E4. Change in traffic composition

E5. Change in accident rates

E6. Change in average accident costs

E7. Change in length of evaluation period

E8. Change in discount rate

E9. Allowing for non-zero existing traffic on the diversion route.

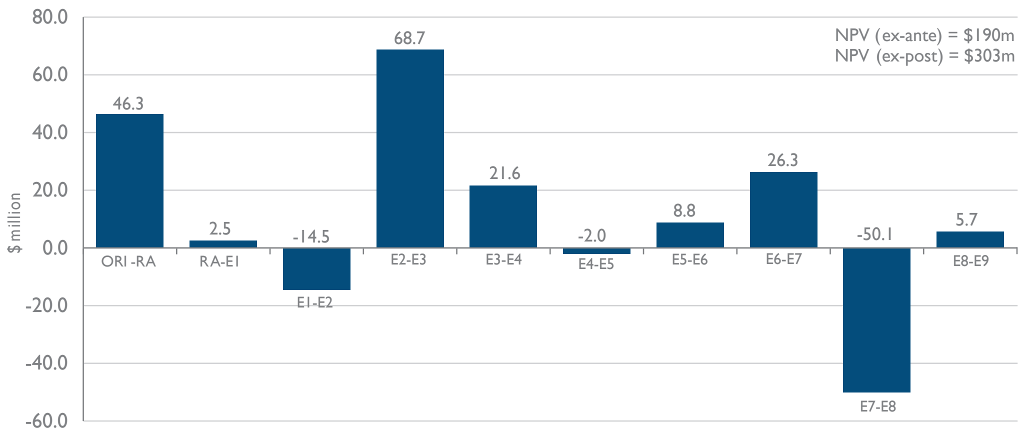
Adjustments made in this ex-post evaluation were based on two different assumed base cases, namely:

Base case 1: This base case retains the original assumption that the Weir construction to stage 2 is completed with a height of 21m resulting in a complete loss of access to the old Wallaville Bridge. This requires all traffic from the Bruce Highway to divert to a longer route via Bundaberg. This base case is labelled as the 'no bridge' option.

Base case 2: This alternative takes, with hindsight, stage 1 construction of the Weir as a certainty, with stage 2 construction treated as uncertain at this stage. Therefore, the old Wallaville Bridge is assumed to be open for light vehicle traffic until the stage 2 construction of the weir or the end of the physical life of the old bridge (say 2010). From this time all light vehicles will have to divert through Bundaberg. All heavy vehicles are assumed to have to divert through Bundaberg from the start of the evaluation period for safety reasons. This base case is labelled as the 'bridge partially open' option.

The ex-post net present value (NPV) based on the first base case was estimated at $303m, $113m (59.5 per cent) higher than the ex-ante estimate (figure A1). Key contributors to this gap included an under-estimation of initial traffic levels and growth ($68.7m), a change from CBA4 to CBA6 methodology (46.3m), an increase in the length of the evaluation period ($26.3m) and an under-representation of heavy vehicles in the fleet ($21.6m). These positive deviations were offset to some extent by an increase in the discount rate (–$50.1m) and an under-estimation of project costs (–$14.5m).

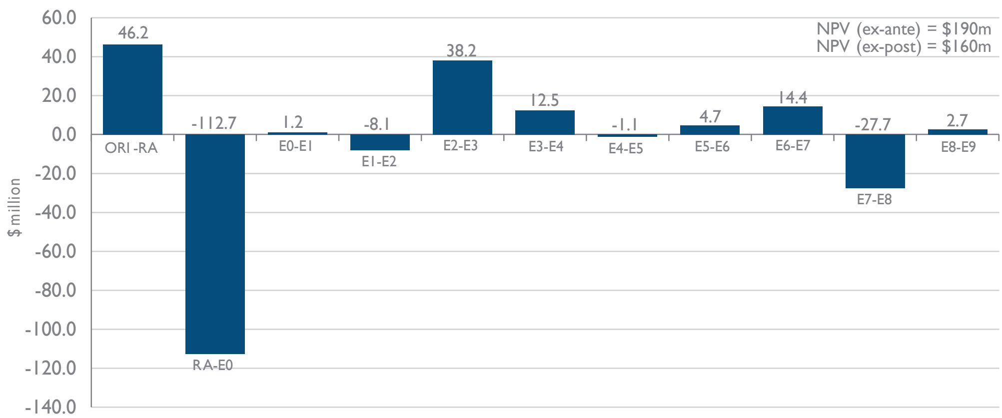
Figure A1 Sources of variation in NPV



Notes: RA: Re-constructed analysis.

The ex-post NPV based on the second base case was estimated at $160m, $30m (–15.8 per cent) lower than the ex-ante estimate (figure A2). Changing the base case to the 'bridge partially open' case decreased the NPV of the project by $143m. This estimate was in contrast with that for the 'no bridge' base case, highlighting the importance of base case specification in determining the economic evaluation outcomes.

Figure A2 Sources of variation in NPV



Notes: RA: re-constructed analysis; E0: Base Case 2.

Given the uncertainties surrounding timing of the stage 2 weir construction and the physical life of the old Wallaville Bridge, a sensitivity analysis was also undertaken to show the worst-case scenario. This scenario assumed that in the base case the old Wallaville Bridge would remain open for the entire evaluation period for all vehicles with a minimum capital expenditure.

The results of the sensitivity analysis showed that while the 'bridge open' assumption led to a further decrease in the NPV ($31m), the project was still economically viable with a BCR of 2.56.

A major lesson learnt from this case study is the importance of base case specification under uncertain situations for mutually dependent projects. If the original study had taken base case 1 (despite it being based on the Queensland Department of Primary Industries' advice) as a possible outcome for the future development of the weir and not a certainty, a sensitivity analysis of 'bridge partially open' and/or 'bridge open' options could have proved useful as it would have provided a range of estimates for the likely economic viability of the project. This form of analysis could be taken further by assigning probabilities to each base case as part of a risk analysis.

(Based on the Queensland case study report (BITRE 2007a)).

A.2 Northam Bypass in Western Australia ($49m)

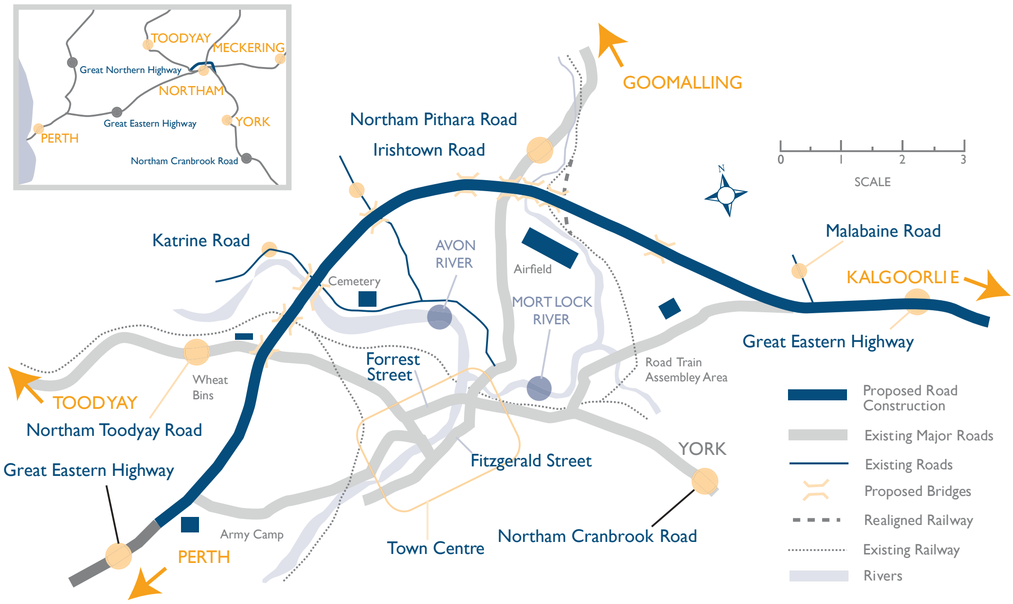
Northam is a town on the Great Eastern Highway (GEH), approximately 97km east of Perth. It has a population of around 7,000 and is a major service and administration centre for the Western Australia central wheat belt region.

Before the Northam Bypass was built, the GEH passed through the centre of the town and heavy vehicles had to negotiate the main shopping area, including two railway crossings, four right angle turns and many busy intersections. These vehicles included B-doubles and truck/trailer combinations up to 67.5 tonnes.

The bypass aimed to divert through-traffic away from the town, overcome the difficulties and dangers of heavy vehicles using the pre-existing route through built-up areas, and improve the safety and amenity of the town's major streets.

The bypass included construction of a new road approximately 14.9km long including eight bridges—two over rivers, two over railways and four over existing roads (figure A3). The bypass starts from the old GEH to the west of Northam near the entrance to the Army camp. Passing north-east, it crosses the Northam-Toodyay Road via an overpass north-west of the Colebatch Road intersection and follows an alignment between the town wastewater treatment ponds and the cemetery. It is then moves across a 230m bridge over the standard gauge railway line, Avon River and Katrine Road. From Katrine Road, the bypass continues in a north-easterly direction, passing over Irishtown Road before heading east to cross the Northam-Pithara Road to the north of the airstrip. From the Northam-Pithara Road back to the existing GEH, the bypass follows a south-easterly alignment, passing north of the racecourse and a road train assembly area. The bypass route connects with the pre-existing highway east of the Katrine Highway.

Figure A3 Northern Bypass



The total budgeted cost for the project was estimated to be $47m (in 1998 prices) in the Stage 3 PPR. Federal Government funding was capped at $40m. The Government of Western Australia committed to cover any additional cost in excess of $40m. The actual project cost was $49.4m (nominal).

The project commenced in January 2001 and was completed in May 2002.

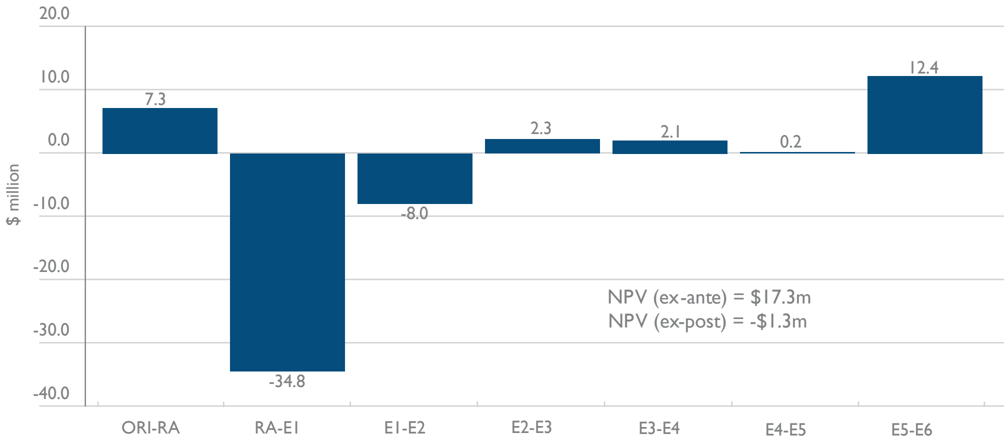
In the ex-post evaluation, the following adjustments were made to the ex-ante CBA:

E1. improving the treatment of intersection effects
E2. removing the $8m savings to the freight industry that have not been realised
E3. changing construction costs and project timing
E4. changing traffic levels and growth
E5. changing average crash costs
E6. changing the discount rate.

The number of adjustments introduced in this ex-post evaluation was fewer than for the other case studies in this series. The freight time benefits recommended by Austroads were not estimated due to the limitations of the RURAL3 modelling software. Because of the complex nature of the Northam road network and the amount of information required, changes in vehicle composition and crash rates were not updated for the ex-post evaluation in this case study.

NPV was used as an indicator to show the contribution of each variation to the total difference between the ex-ante and ex-post evaluation results. The components of the total variation in NPV are illustrated in figure A4. The ex-post NPV was –$1.3m, which was $18.6m lower than the ex-ante estimate. The change in methodology of treating the delay effects caused by intersections (RA-E1) contributed –$34.8m (or 187.1 per cent) to the total $18.6m difference in NPV. The variation in the freight-related benefits (E1–E2) contributed –$8m (or 43.0 per cent).

Figure A4 Sources of variation in NPV



Note: ORI=original analysis. RA=reconstructed analysis.

Of the adjustments that led to an increase in the NPV, lowering the discount rate from 7 per cent to 3 per cent (E5–E6) was the most significant ($12.4m). Changing construction costs and project timing (E2–E3) increased the NPV by $2.3m. Improved traffic data and modelling (E3–E4) lifted the NPV by $2.1m.

The results of the ex-post evaluation reported above should not be viewed as fully definitive because there were a number of factors not updated or calculated — for example, changes in the actual traffic composition and crash rates, incorporating the impact of intersections on VOC savings, inclusion of the Austroads-recommended freight benefits and the improvement in local amenity.

A major lesson was how intersections should be treated in the economic evaluation of a bypass project. In the ex-ante analysis, extra lengths were added to various links to take into account delay effects caused by intersections in the base case. This approach meant travel speeds for the base case were underestimated and travel time savings were overestimated. It also led to a large overestimation of savings in VOCs and crash costs.

A number of alternative approaches could be used to handle the effects of intersection delays. For the ex-post evaluation undertaken in this case study, reducing the maximum speeds through a change in the speed limits along the townsite route was used as a proxy for the impedance of intersections. This approach had two advantages compared with the approach used in the original analysis. First, working on speeds was a more direct approach, which could allow assumptions about speeds to be checked against real world data. Second, it avoided major distortions in the calculated savings in VOCs and crash costs, although the effect on VOC savings of the stop-start nature of intersections could not be captured.

In future town bypass evaluations, extreme care should be taken to select a methodology for modelling intersection delays for the base case. The adequacy of the assumptions made about travel speeds should be cross-checked against real world observations if possible.

Another lesson relates to the inclusion of non-standard road user benefits. The ex-ante analysis included an $8m benefit to the freight industry as measured in savings in travel time costs and VOCs due to the reduced distance travelled by shuttle vehicles between Perth and the road train assembly area.

The construction of Northam Bypass was a necessary but not a sufficient condition to enable road trains to travel closer to Perth. Other complementary works, including the relocation of the road train assembly area, were required. The costs of these works should be included as part of the total project cost before any additional benefits can be claimed.

Other important lessons from the project point to the need for accurate reporting and better documentation of CBA inputs and improved traffic analysis.

(Based on the Western Australian case study report (BITRE 2007b)).

A.3 Adelaide Crafers Highway in South Australia ($152m)

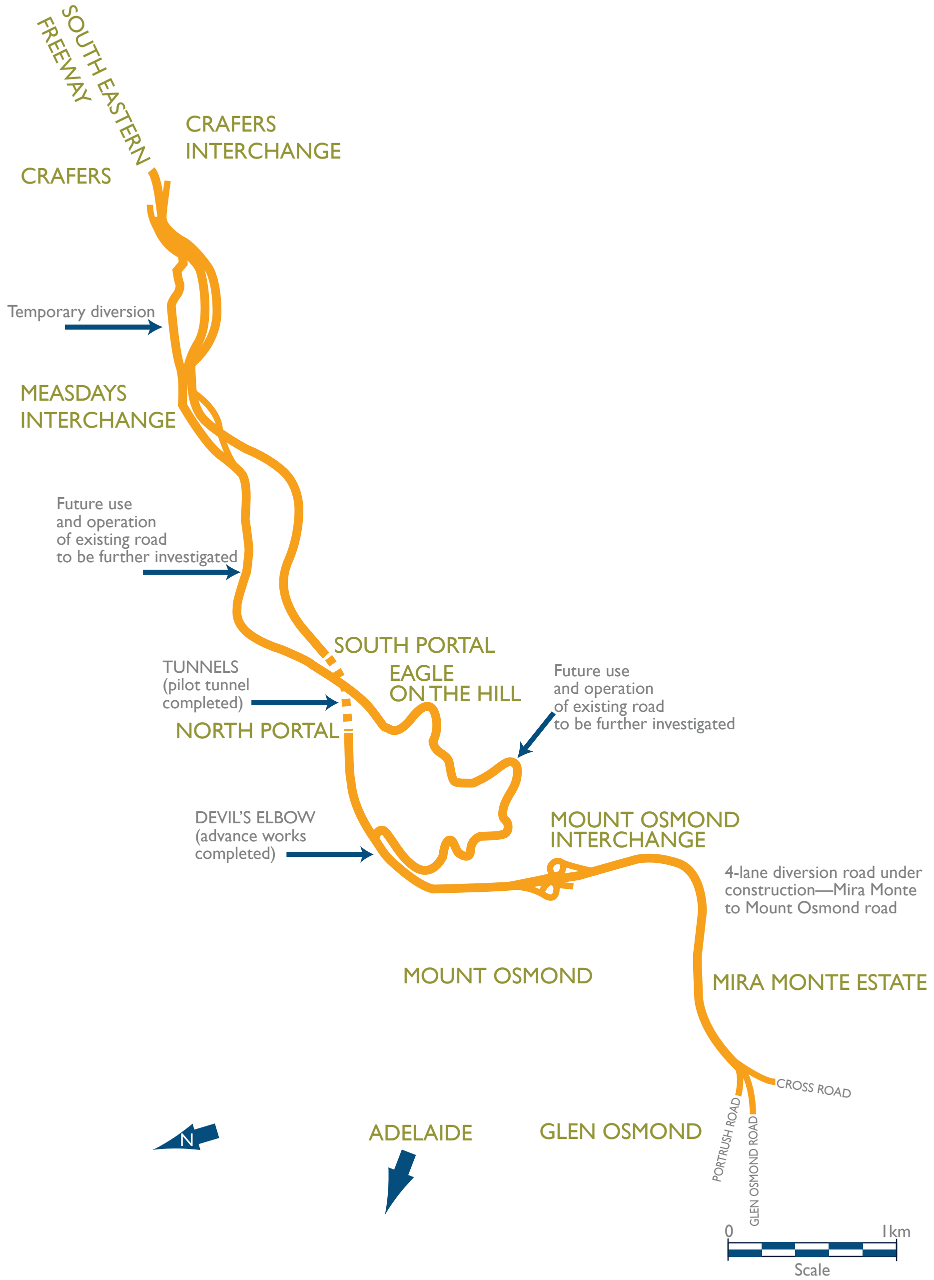
The Adelaide Crafers Highway (ACH) project arose from the inadequacy of Mount Barker Road which was characterised by a relatively narrow alignment, sharp curves and steep grades. These features led to slow traffic speeds (especially for heavy vehicles), congestion at peak times and comparatively high accident rates. The purpose of the project was to reduce road user costs and improve safety, as well as to support economic development with better accessibility for freight traffic.

The ACH project starts south-east of Adelaide at Glen Osmond, traverses the western escarpment of the Mount Lofty Ranges and terminates at Crafers in the Adelaide Hills (figure A5). The project involved upgrading the existing highway from Glen Osmond to the Devils Elbow (3.6km) including an interchange at Mt Osmond Road, additional traffic lanes (from two to three), median barriers and realignment. Improvements to the Glen Osmond/Portrush/Cross Roads intersection were also included.

A new highway corridor (4.7km) was built from Devils Elbow running east of the old route, through a short twin-tube tunnel beneath Eagle on the Hill, then approximately parallel to the old route on the west side for about 2km. The new corridor traces the old road alignment, but at a substantially lower level, for about 1.4km joining up with the existing South Eastern Highway at Crafers Interchange.

The improved Adelaide Crafers section of the South East Highway is 2.1km shorter than the old route between the same points. The nominal design speed limit also increased from 80km/h to 90–100km/h due to increased capacity and improved alignments.

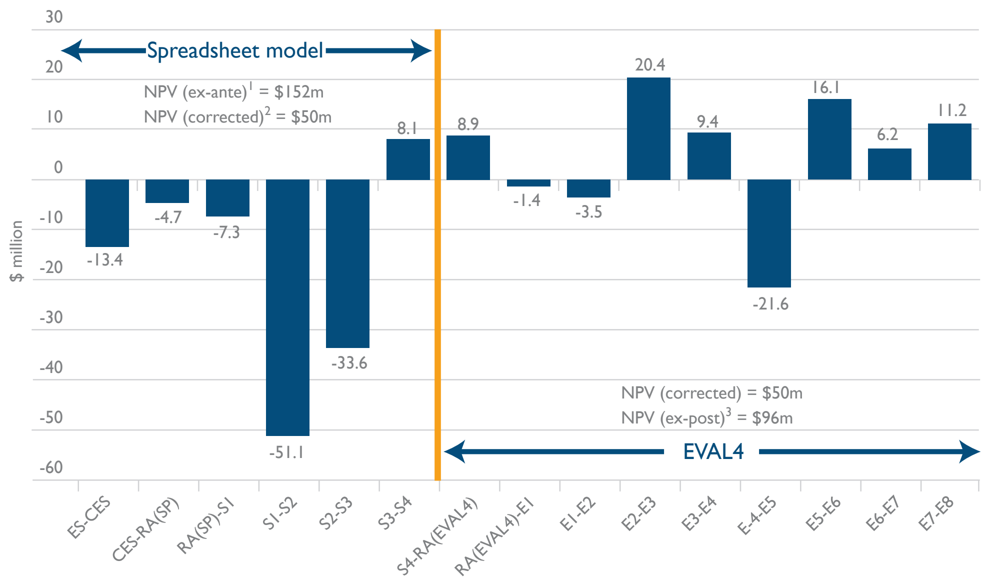
Figure A5 ACH alignment plan



Originally the approved project cost was $136m (in 1995 prices) in September 1996. The project was completed in March 2000 at a cost of $152m ($143.9m in 1995 prices).

The ex-ante CBA of the Adelaide Crafers Highway project reported a NPV of $152m, and a benefit–cost ratio of 2.6. The ex-post evaluation estimates NPV to be at least $96m, which is up to $56m (or 37 per cent) lower than the ex-ante estimate. There were many factors contributing to this difference between the ex-ante and ex-post results. Figure A6 shows the incremental impact that each adjustment has on the NPV of the project.

Figure A6 Sources of variation in NPV



The ex-ante CBA contained a number of errors, leading to overestimation of NPV. Of these, incorrect benefit accruing (S1–S2) and double-counting of safety benefits (S2–S3) were the most important sources of overestimation of benefits. These two corrections alone brought down estimated NPV from $152m to $65m. A system of quality assurance, including peer review and auditing, is required to improve the future CBA of transport initiatives.

In addition to correcting some errors in the spreadsheet model, the ex-post evaluation considered a range of CBA enhancements using the EVAL4 CBA model. These included:

- improved prediction of traffic speed in congested conditions, a feature of the EVAL4 model (S4–RA(EVAL4))
- re-estimation of initial traffic levels and growth rates in the light of post-construction traffic data (E2–E3)
- inclusion of benefits associated with generated traffic (E3–E4)
- re-estimation of the crash rates for both the base and project cases (E4–E5)
- updating unit crash costs (E5–E6)
- starting the 30 year evaluation period from project completion rather than from project commencement (E7–E8).

These enhancements led to an increase of the NPV by at least $46m, offsetting part of the reduction in NPV calculated in the spreadsheet model.

This ex-post evaluation has highlighted scope to improve the original ex-ante analysis, and points to a need to improve the CBA processes, most notably in the areas of traffic and crash analysis. It also highlighted the importance of good documentation at all stages of an economic evaluation, and the key role played by sensitivity testing. Finally, it demonstrated the need to adequately consider generated traffic when assessing projects on urban approaches.

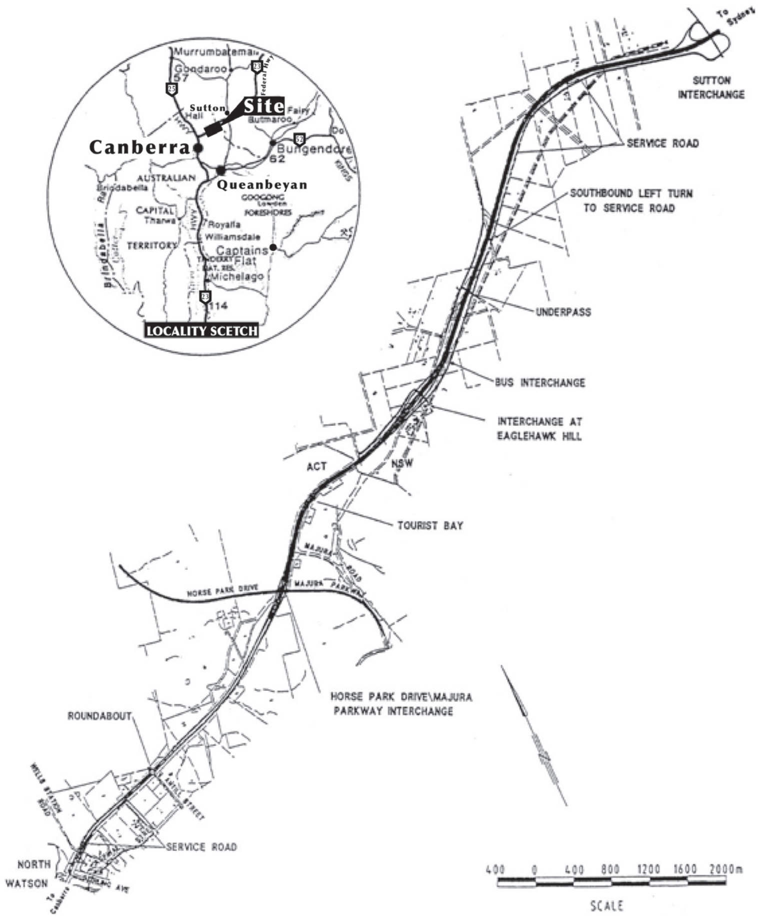
(Based on the South Australian case study report (BITRE unpublished)).

A.4 ACT/Sutton Federal Highway duplication in ACT ($82m)

The ACT/Sutton Road project involved duplicating 10km of Federal Highway between Stirling Avenue (ACT) and Sutton (NSW) (figure A7). Roughly half of the length is in NSW and the other half in the ACT. The project was jointly proposed and managed by the RTA in NSW and the Department of Urban Services (DUS) in ACT.

Unlike other case studies, the ACT/Sutton Road project was subject to a review only. A full expost CBA was not possible due to lack of the detailed information for the ex-ante analysis and unavailability of the tools originally used for traffic modelling.

Figure A7 Site location plan



The review was centred on the traffic analysis and estimation of travel time cost savings. Key findings were that:

- there was a significant over-estimation of traffic growth rates on the ACT/Sutton Road, probably by 100 per cent. Overly optimistic assumptions about population growth appear to be the main cause of the over-estimation

- travel time benefits could have been over-estimated because of over-estimation of traffic growth, an overly pessimistic view of the base case travel speeds, inappropriate use of AM peak-hour traffic as a proxy for all other peak-hour traffic, and inappropriate interpolation methodology.

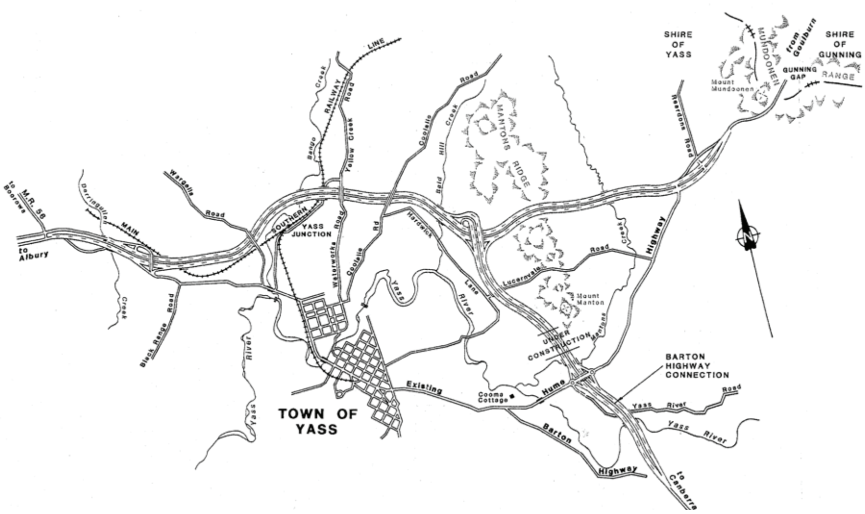
The major lesson learnt from this review was that travel time benefits can be very sensitive to the assumed queuing speeds when the volume-capacity ratio is above one. To make valid comparisons between benefit-cost ratios, it is important to use consistent speed-flow curves in project evaluations. Failure to do so could lead to an incorrect ranking of road projects competing for funds.

(Based on the ACT case study report (BITRE unpublished)).

A.5 Yass Bypass in NSW ($152m)

The Yass Bypass project involved constructing four-lane, dual carriageway roads on a new alignment. The main pair of carriageways became part of the Hume Highway, allowing the National Highway to bypass the town of Yass. The project also featured a grade separated interchange and another pair of carriageways connecting the Hume Highway to the Barton Highway allowing traffic travelling to and from the south to bypass Yass (figure A8).

Figure A8 Yass bypass and Barton connection



Unlike other case studies that aimed to check how well ex-ante CBAs performed, the Yass Bypass was an ex-post analysis of an ex-post evaluation undertaken by RTA in 1996 for the Yass Bypass project. As 10 years have passed since the RTA's 1996 study, less uncertainty about impacts and more accurate estimates of the actual NPV of the project were expected.

The RTA undertook the ex-post CBA modelling work in 2006 in consultation with BITRE. The case study illustrates the importance of allowing for changing traffic composition. Since 1996, the percentage of business cars and rigid trucks has nearly doubled. In the ex-ante study and in most CBAs of non-urban road projects, the composition of vehicles is assumed to stay constant throughout the evaluation period. Correcting the traffic composition in this case study caused noticeable increases in travel time and VOC savings. The case study shows that the possibility of changing vehicle composition over the evaluation period should be allowed for.

(Based on the NSW case study review (BITRE unpublished)).

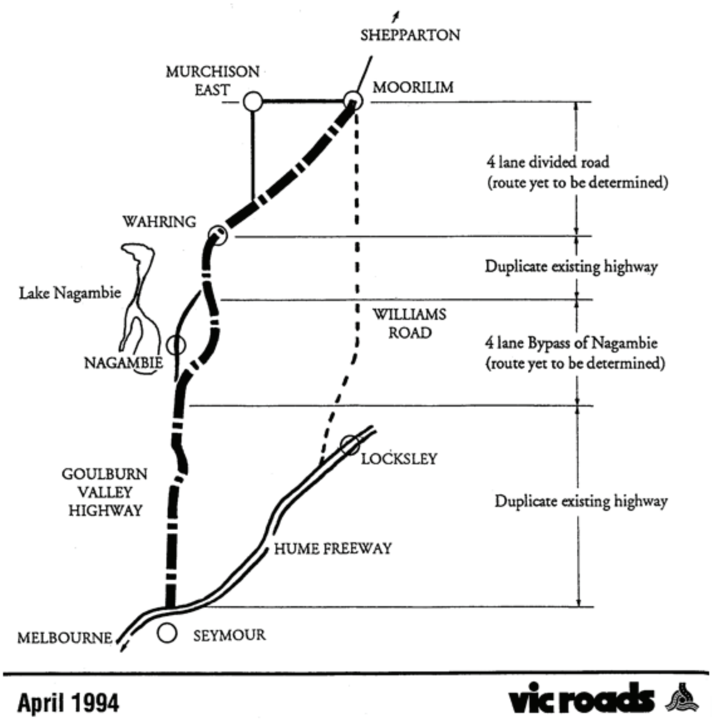
A.6 Goulburn Valley Highway – Hume Highway to Nagambie in Victoria ($48m)

The Goulburn Valley Highway (GVH) is a part of the National Highway linking Melbourne and Brisbane. The project was to duplicate 16km of the GVH from Seymour to Nagambie (figure A9). This was part of the effort to construct a four-lane standard road between the Hume Highway and Shepparton.

The case study comprised a review only of the ex-ante CBA (table 3.2).

The ex-ante CBA was based on the earlier appraisal results for the upgrade of 51km section of the GVH from Seymour to Moorilim. The benefits of the 16km of duplication were simply estimated as a portion of the total benefits for the full upgrade. Because benefits were not distributed equally along the corridor under investigation, the project benefits for the first 16km upgrade were over-estimated. The case study demonstrated that, where practicable, projects should be evaluated individually, rather than at the aggregate level, unless they are directly related (implementing one significantly affects the benefits or costs of the other).

Figure A9 Goulburn Valley Highway: Semour to Moorilim



The ex-ante CBA allowed unit value of travel time cost to vary in line with the growth of real income per capita, although this was not recommended at the time.

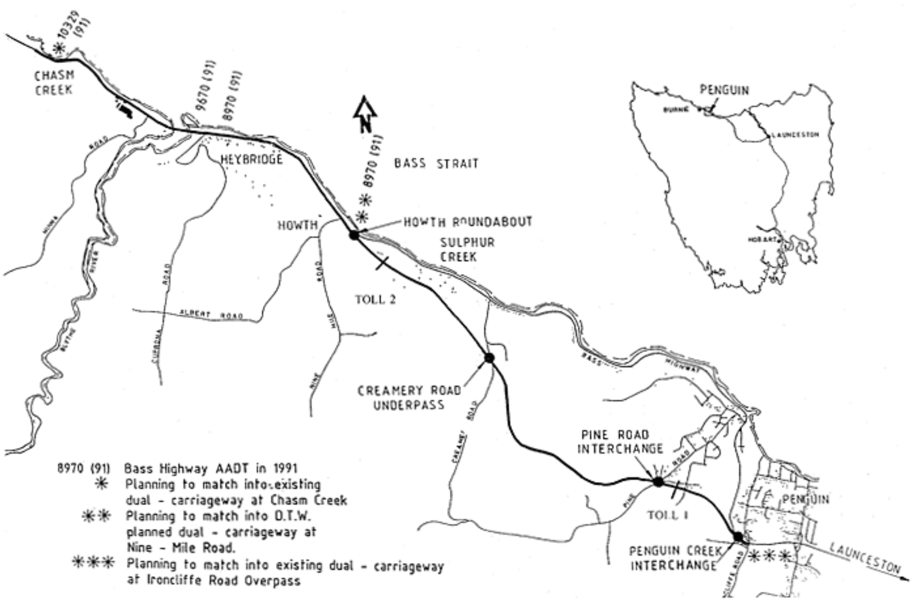
(Based on the Victorian case study review (BITRE unpublished)).

A.7 Bass Highway – Penguin to Chasm Creek in Tasmania ($66m)

The Bass Highway in northern Tasmania was built with poor alignment by today's standards and with very low traffic levels in mind. Planning to improve the route as part of the National Highway System had been underway since at least 1985. In 1994, it was described as a two-lane road with a low standard of alignment, constrained by topography, carrying around 9,000 vehicles a day with a high growth rate and few safe overtaking opportunities. The Penguin-Chasm Creek section was 12.6km long.

The upgrade involved duplicating the existing coastal route for 4.8km in two stages: from Nine Mile Road to Minna Road (2.8km) and then Minna Road to Chasm Creek (2.0km) (figure A10). Another stage was a new inland diversion of 6.9km bypassing 7.8km of the existing coastal route between Penguin and Nine Mile Road. Construction was completed in October 1999.

Figure A10 Bass Highway – Penguin to Chasm Creek



During the detailed design stage, legislative changes in environmental regulations were passed requiring significantly more effort to mitigate the negative environmental impacts of the project. This case study demonstrates that there is a risk of cost overruns for environmental reasons and that this risk should be considered in cost estimation.

(Based on the Tasmanian case study review (BITRE unpublished)).

Appendix B: Case studies – Round 2

B.1 Bruce Highway Upgrade – Cooroy to Curra Section B in Queensland ($440m)

See Volume 2.

B.2 Dampier Highway Duplication in Western Australia ($102m)

See Volume 2.

B.3 Bulahdelah Bypass in New South Wales ($315m)

See Volume 2.

B.4 Nagambie Bypass in Victoria ($170m)

See Volume 2.

B.5 Northern Expressway in South Australia ($564m)

See Volume 2.

Appendix C: Probabilistic cost estimation

Probabilistic or risk-based cost estimation methods are a form of quantitative risk analysis that uses Monte Carlo simulation to estimate a project's cost. Monte Carlo simulation is a computerised technique that allows cost estimators to account for uncertain components of the project cost that are made of inherent and contingent risks (Evans and Peck 2008).

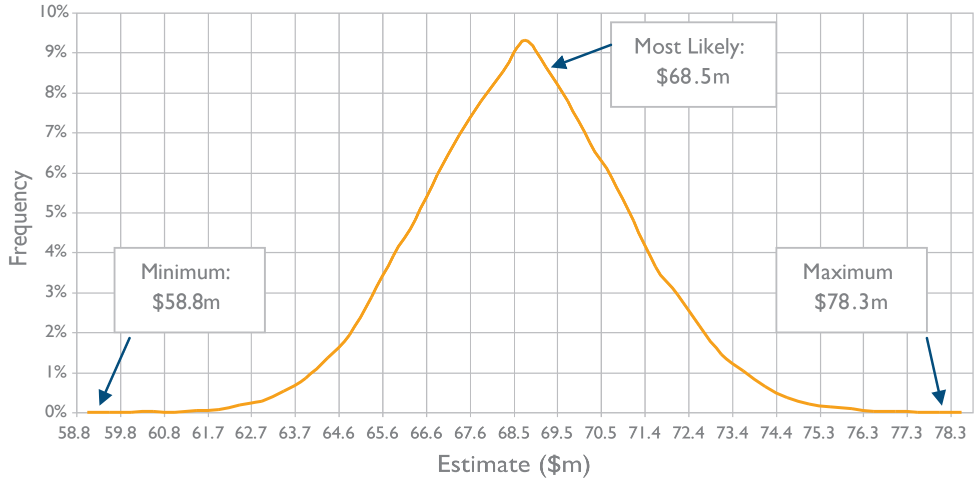
Inherent risk exists for cost items that are certain to occur but contain uncertainty about the size of the cost. This uncertainty is expressed as a range of possible quantities and rates of a cost item. For example, the 'top soiling' cost item is most likely to use 1,099,500m^2 of soil at $3.2 per m^2 (the base estimate), but can range from 900,000–1,500,000m^2 in quantity required and from $2.1–5.3 per m^2 in the rate charged.

While inherent risks are associated with events that are certain to occur, contingent risks are variations in costs due to events that may or may not occur. Typical contingent risks include political, environmental, contractual, weather, safety and industrial issues. An example of a contingent risk is a contractor's claim due to inclement weather that could range from 15 to 160 days at a rate of $61,000 a day with a 50% probability of occurring based on weather forecasts.

Under the probabilistic approach, probability distributions are specified for each cost item for quantities and unit costs. Monte Carlo simulation tests large numbers of values randomly selected according to each of these probability distributions. These random values are used to produce estimates for each cost item and then summed to give the total project cost. Contingent risks are treated in a similar way, however they also have a probability of occurrence, allowing for the possibility of a zero cost.

A typical Monte Carlo simulation iterates tens of thousands of times, each time sampling new random values from the specified probability distributions and producing a new project cost estimate. The large number of total project cost estimates can then be presented as a histogram. An example of this histogram is shown in figure C1 where 50,000 iterations were performed for a cost estimate. This histogram shows that the project cost is likely to range from $58.5m to $78.3m with the most likely outcome of $68.5m.

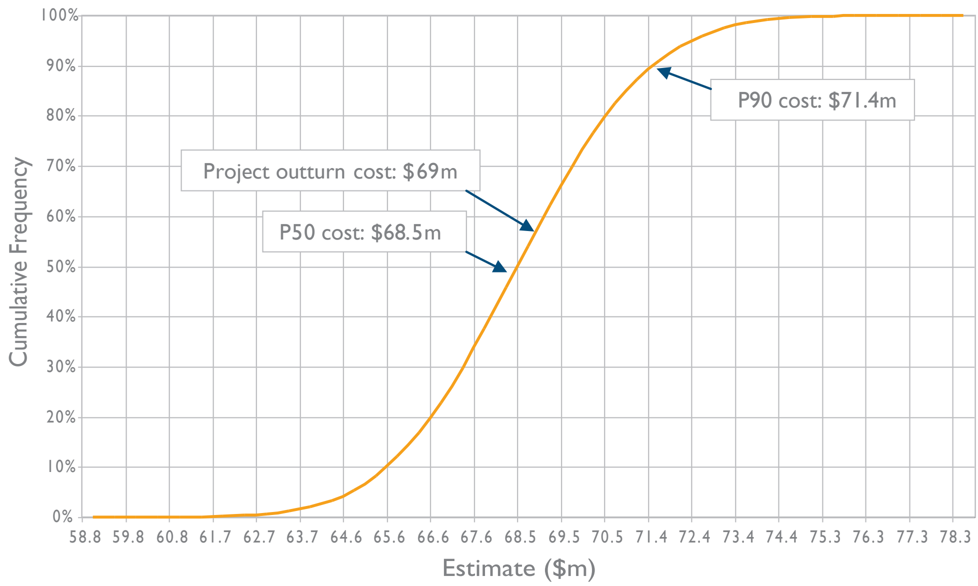
Figure C1 Histogram of probabilistic cost estimates



Source: Tan & Makwasha (2010).

An alternative presentation of the Monte Carlo simulation results is the cumulative probability distribution called an 'S' curve (figure C2) derived from the histogram. This curve provides the cumulative sum of probabilities in the histogram for various cost estimates.

Figure C2 Cumulative probability distribution



Source: Tan & Makwasha (2010).

Using the 'S' curve, a cost estimate can be obtained for a specified 'P' value that reflects the amount of risk allowed. For example, a P90 cost estimate ($71.4m, figure C2), obtained by the intersection of the 'S' curve and the horizontal 90% probability line, represents the project cost that has a 90% chance of not being exceeded. Similarly funding to a P50 level gives a 50% probability that the project cost will not be exceeded. Funding to P50 levels requires less capital to be committed, however, more cost variations are expected. P90 levels set aside an excessive amount of funds but are less likely to be subject to cost overruns.

A P50 cost estimate that has been correctly estimated will have a 50% probability of a cost underrun and 50% probability of a cost overrun. When the P50 level of funding is applied to a portfolio of projects, if the probability distributions are not skewed, it can be expected that, given a large number of projects, the cost overruns and underruns will balance out over time. Proponents of Australian road projects were required to provide both P50 and P90 cost estimates in project proposals but were usually funded to the P90 level. This might be one of the reasons why there were no systematic cost-overruns observed for the projects included in the second round of ex-post evaluations.

For more information on probabilistic cost estimation, refer to the Department's Notes on Administration for Land Transport Infrastructure Projects (Department of Infrastructure, Regional Development and Cities 2014) and the Austroads Guide to Project Evaluation Part 2: Project Evaluation Methodology (2012a).

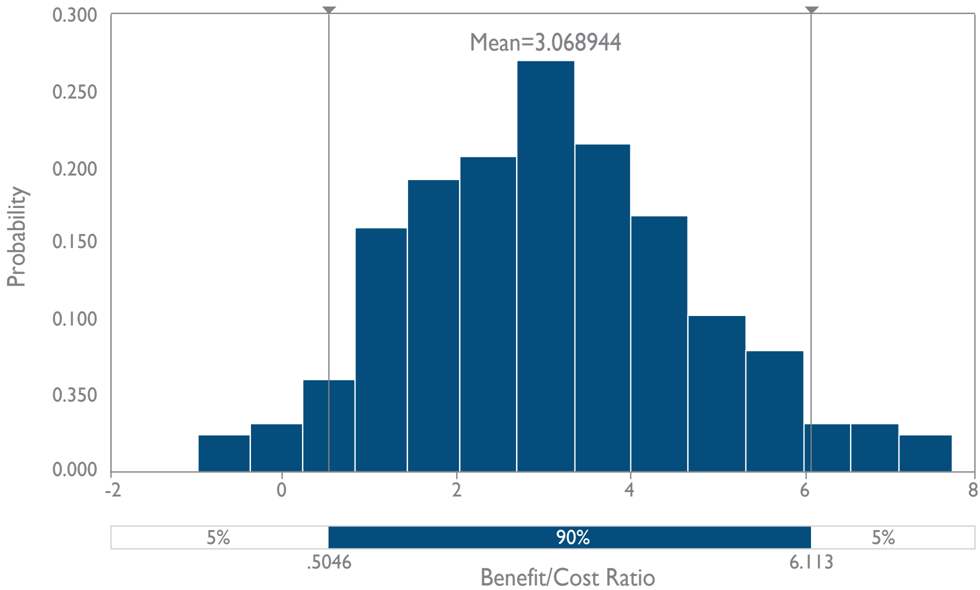
Appendix D: Incorporating risk in benefit estimation

Advances made in cost estimation through quantitative risk analysis should be matched in the estimation of benefits. Given the much greater uncertainty about traffic forecasts due to lengthy time horizons, many estimates of project benefits have large confidence intervals around them that are currently not apparent to the decision maker. Furthermore, the width of these confidence intervals expands over time as the future projection becomes more distant.

Figure D1 shows the range of BCR values a project could have if Monte Carlo simulation was used to estimate both the benefits and costs of the project. This histogram shows that while the BCR is most likely to be around 3, there is the possibility that the BCR would turn out to be as high as 8 or as low as –1. This type of analysis and presentation gives much more useful information to the decision maker than a single BCR figure of 3.07 could give.

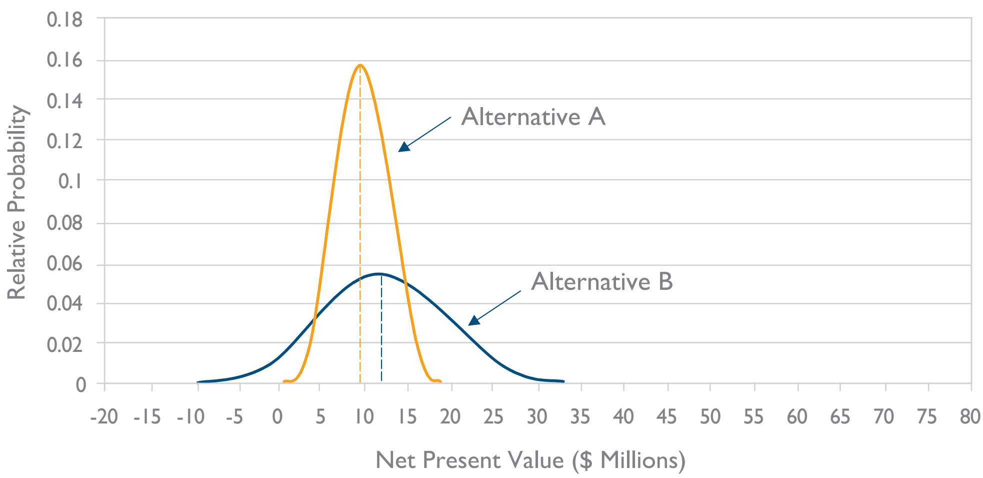
Figure D2 shows another example on how risk analysis can be useful for decision making. Using information such as that illustrated in figure D2, two projects can be compared by looking at their mean NPVs and the spread of possible values. Alternative A has a mean NPV about $2m lower than alternative B, however, it also has less variation in possible NPVs. Although alternative B has a higher mean NPV it also has a lower minimum NPV of –$10m, where Alternative A would never fall below $0m.

Figure D1 Histogram of probabilistic project BCRs



Source: Austroads (2012a).

Figure D2 Comparison of two projects using their NPV probability distributions



Source: FHWA (2003).

Normally, variances of probability distributions of CBA results are ignored because it is assumed that much of the risk associated with individual projects can be diversified away. Individuals stand to benefit by small amounts from a large number of government projects such that under-performance by some projects is balanced out by the over-performance of others. The Arrow–Lind principle implies that decision to implement projects can be made on the basis of expected values alone, without regard to variances (Arrow and Lind 1970).

An exception is where benefits have a significant impact on the economic welfare of a small number of beneficiaries. In such a case, a risk averse decision maker might choose alternative A in figure D2 to minimise downside risk.

The main value of undertaking probabilistic assessments of benefits and costs is not to obtain variance estimates, but that the process forces analysts make a comprehensive assessment of project risks and thereby reduce optimism bias. Where large uncertainties are found, the assessment might suggest additional resources be expended in the CBA to get better information and reduce the variances of probability distributions.

Appendix E: Residual value estimation

This appendix provides a brief review of the RV estimation methods used in road CBAs.

Two categories of approaches are generally used for estimating RVs at the end of the evaluation period:

- asset depreciation, and
- net benefit stream.

Asset depreciation (notably straight line depreciation (SLD)) is the most commonly used method for estimating RV. Although it is not the best or most comprehensive, it can be quickly and easily calculated and used as a point of comparison with a more comprehensive and intensive method (Jones, et al. 2013). Net benefit stream approaches are conceptually more attractive, but involve high levels of uncertainty. RVs derived from the benefit stream approaches should be treated with great caution.

Before describing the above two RV estimation methodologies, discussion on the way the asset life is defined is necessary as it helps explain some of the assumptions made for estimating RVs.

Asset life

There are a number of approaches to determining asset life, but the following two are relevant to the estimation of RVs in road CBAs: design life and economic life.

Following Austroads (2003), the design life for road pavements is defined as the time over which the asset is expected to provide its full service function allowing for maintenance appropriate for the functionality of the structure. Roads will be designed with forecasts of performance of construction materials, traffic load, weather and maintenance in mind.

'Economic life' is defined as the period over which the asset is economically viable. The end of the economic life of an asset would be the stage at which ongoing maintenance and operational costs outweigh the benefit the asset can offer or the cost of the replacing the asset (Austroads 2003).

In estimating RVs for the ex-post case studies, it has to be assumed that economic and design lives are of equal length. In Australia, a road pavement is expected to have an economic life of 40–60 years (QDTMR 2011, TfNSW 2013 and Austroads 2003). In the UK, a maximum of 60 years is taken as the economic life in road CBAs (DfT 2014).

It is also important to consider the effects of maintenance on asset life and how much maintenance is required to maintain a road asset to a certain standard. In practical CBAs, maintenance usually follows a more or less set pattern that is linked to the roughness of the road during the evaluation period. It is questionable whether maintenance costs would remain stable as the road asset enters the later stages of its life. Larger maintenance costs may be required to maintain a given level of standard or to support higher levels of traffic. If a net benefit stream approach is used to estimate RV, these extra maintenance costs should be considered in estimating future benefits beyond the evaluation period.

Asset depreciation

RV for an infrastructure asset can be estimated by assuming a particular form of depreciation. The most common approach is SLD (Jones, et al. 2013, NMF 2012, ATC 2006 and IA 2013). In a CBA for a road asset, RVs based on SLD can be calculated using the formula:

$$\textit{Residual Value}\ (SLD) = \textit{Cost of Asset} \times \frac{\textit{Asset Life Remaining After Evaluation Period}}{\textit{Asset Life}}$$

The SLD method assumes the asset is consumed at a constant rate during its entire life without discounting. It also assumes there is a correlation between the number of years left of the life of the road asset and its ability to generate benefits into the future.

SLD is reasonable for projects with fairly uniform benefit streams over the life of the assets and BCRs around one. It will under-estimate benefits where BCRs are well above one or continue to grow beyond the evaluation period. It will over-estimate benefits for projects with low BCRs or declining benefits after the evaluation period. Therefore the BCR (which indicates the relationship between benefits and capital costs) and the profile of benefits over time are major factors affecting how well SLD performs.

Non-linear depreciation schedules are sometimes assumed or modelled if sufficient information is available.

If data are available, RVs can be calculated for each component of a road asset (Jones, et al. 2013 and 2014; Laurentia 2011), for example, earthworks, bridges and land. This is known as the 'component method' and may provide a more accurate estimate of RV. However, it can be demanding in data and calculations.

Net benefit stream approach

Net benefit stream approaches attempt to estimate the benefits an asset will generate over the remaining life of the asset following the end of the evaluation period. Four alternative methods have been used to estimate RVs:

- annuity method
- decreasing net benefit
- constant net benefit, and
- increasing net benefit.

Annuity method

For assets that have a finite lifespan (excluding earth works), one approach would be to use the annuity method to estimate RVs (Jones, et al. 2013). Adopting a 30-year evaluation period for an asset with 50-year design life requires calculation of the annualised value of net benefits for the first 30 years, and assuming annual benefits are at this level for the remaining 20 years of the asset's life.

The procedure of estimating RV using the annuity approach is as follows:

- take the present value of all net benefits for the first 30 benefit years
- find the 30-year annuity using the formula:

$$A = PV_{30} \times \left[\frac{r}{1 - (1+r)^{-30}} \right]$$

  Where:

  - *A* is the annuity value
  - PV_{30} is the present value of net benefits for the first 30 years, and
  - *r* is the discount rate

- assume benefits continue on at this level until the end of the asset's life, and
- discount these back to the last year of the evaluation period using the formula :

$$RV_{20} = A \times \left[\frac{1 - (1+r)^{-20}}{r} \right]$$

  Where:

  - RV_{20} is the residual value for the 20-year period after year 30.

The annuity approach works best for projects that have a steady net benefit stream over time. For most road projects, this requirement is unlikely to be fulfilled. Benefits from road infrastructure projects tend to increase over time in line with growth in traffic.

Decreasing net benefit

The Norwegian Ministry of Finance recommends letting net benefits reduce linearly to zero from the end of the evaluation period to the end of the asset's life (NMF 2012). The underlying assumption is that the net benefit stream decreases due to increasing maintenance costs and/or decreasing average road user cost savings (as a result of road deterioration). A further possible rationale is that (in the base case) where the project does not exist, society will find other ways to deal with the problem the project aims to address.

If the rate of the decrease in net benefits is a straight line, the residual value can then be calculated as follows:

$$Residual\ value = \sum_{i=1}^{n} \frac{NB_i}{(1+r)^i}$$

$$NB_i = NB^* - i\left(\frac{NB^*}{n}\right)$$

where:

- NB^* = net benefits in the last year of the evaluation period
- NB_i = net benefits in year i of remaining life
- n = remaining years of asset life

The above formulas differ slightly from those recommended in NMF (2012) where annual net benefits are simply summed over the remaining asset life without discounting. Similar to asset depreciation, the profile of the decreasing residual net benefits can vary depending on the available information, however, must reach zero in the final year as per the definition of economic life.

It is the most conservative approach short of assuming zero residual value and would seriously underestimate the RV of a well-constructed and maintained road with growing traffic.

Constant net benefit

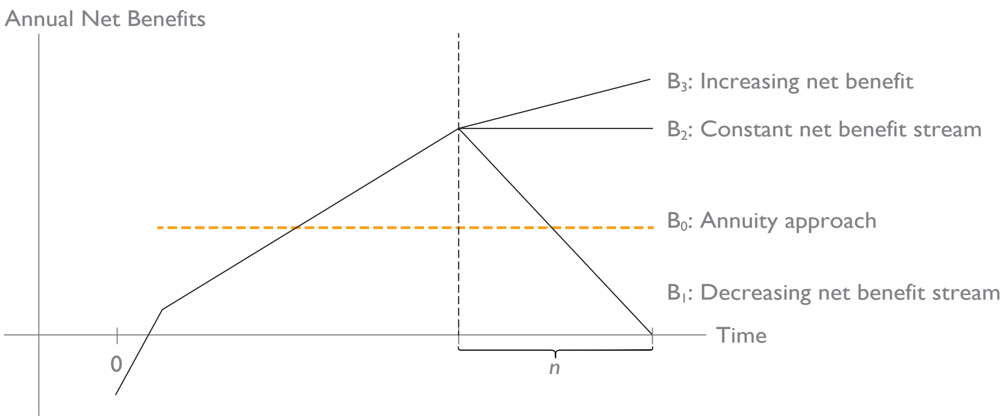
Another approach, which was recommended in EC (2014), is to assume that the net benefits in final year of the evaluation period will continue on unchanged until the end of the asset lifespan. It is similar to the annuity method in that the asset is assumed to continue to perform its function at the required standard without any additional operating or maintenance costs. In a situation where traffic (and hence benefits) continue to grow beyond the evaluation period, the constant benefit approach risks under-estimating the RV.

Increasing net benefit

The third approach is to relate the future benefit flows to the forecast traffic growth. The asset is assumed to remain unimpaired during the residual period without any increase in operating and maintenance costs. This approach produces a RV that serves an upper bound of the RV estimates in cases where the base case infrastructure becomes increasingly congested as traffic grows such that benefits grow faster than the traffic level.

Figure E1 shows the three benefit forecasting methods together with the annuity approach. Depending on assumptions about the asset life, these methods would produce vastly different net benefit streams and hence RVs. If the asset life is defined from the design perspective, the net benefit may be assumed to continue to grow (B3) or remain constant (B2) beyond the evaluation period. On the other hand, if an economic approach is adopted to define the asset life, this naturally leads to the assumption of declining net benefits (B1).

Figure E1 Net benefit forecasting beyond the evaluation period



Selection of RV in road CBA

NMF (2012) specifies three criteria for a sound RV calculation. These are:

- The RV should be capable of being derived from the readily available information such as that from the analysis pertaining to the evaluation period.
- The underlying assumptions are readily comprehensible.
- The derived RV should be the best possible estimate based on available information.

According to NMF (2012), the SLD method meets the first two criteria listed above, but not the third because there is little or no relationship between the project cost and net economic benefits beyond the evaluation period. SLD tends to under-estimate RVs for projects whose benefits are larger than costs, and conversely.

The net benefit stream approaches also meet the first two criteria, but they produce a range of RV estimates depending on the particular approach chosen. The economic life of an asset is likely to be indeterminate, long-term traffic forecasts are likely to be inaccurate, and road user benefits (notably travel time cost savings) are arbitrarily determined for the very distant future. For these reasons, EC (2014) recommended use of a depreciation approach for projects with very long design lives such as often occurs for transport infrastructure.

Appendix F: A review of methodologies for ex-post CBAs

A number of earlier studies were relevant to forming a methodological framework for the latest round of ex-post evaluations. These include European Commission (2011), Odeck (2012) and BITRE (2007a and b). Although these studies had different origins and came from different perspectives, they shared many similarities in terms of the challenges they faced in conducting ex-post CBAs and the methodological framework they adopted. A brief review of each of these studies is provided here.

European Commission (2011)

European Commission (2011), a commissioned study undertaken by Frontier Economics together with Atkins and the Institute of Transport Studies (University of Leeds), conducted ex-post CBAs of selected transport projects financed by Cohesion Fund (established in 1993 to strengthen the economic and social cohesion of the European Union). The three questions that the study sought to answer were:

- What were the impacts of the projects examined?
- How could ex-post CBA contribute to the practice of ex-ante CBA?
- What is the potential and the limit of ex-post CBA as a tool to identify the impact of infrastructure projects?

The methodology used to address the above three questions comprised the following three broad steps:

1. Selecting a sample to review. Out of a list of 40 transport projects, 20 were selected for an initial review. The results of the review for each of the selected projects were presented in a three-page brief that contains a project description, a preliminary assessment of the quality of the ex-ante CBA, information on the degree of completion of the project, and the identification of the data requirements to complete a full ex-post CBA. Using a set of criteria, the list was further shortened to 10 to be subjected to in-depth ex-post CBA.

2. Ex-post project impact analysis. A more detailed review was then undertaken of ex-ante CBAs conducted at the time when funding applications were made. This review provided background material for the in-depth ex-post evaluation that assessed the overall performance of the 10 selected projects. The ex-post evaluations were based on data already available and, where necessary, new data that had to be collected. The results of the ex-post evaluations were then compared with ex-ante evaluations to assess the appropriateness of the CBA methodology being applied and to identify causes of possible discrepancies between CBA predictions and actual outcomes.
3. Assessing ex-post CBA as a methodology for regular use. This step included assessing the potential for ex-post CBA to become an integral part of the infrastructure funding appraisal and evaluation process. They evaluated the extent to which ex-post CBA can strengthen the evidence base underpinning the ex-ante analysis with the aim of improving the methods of ex-ante evaluation.

To measure project performance, the following economic appraisal indicators were used:

- present value of benefits
- present value of costs
- net present value
- benefit–cost ratio, and
- internal rate of return.

CBA does not describe the socio-economic impacts of transport investments such as the impacts on mobility and accessibility, distributional equity, urban amenity and land-use.

The European Commission (2011) made assessments of socio-economic impacts by gathering information through interviews with project stakeholders.

Odeck (2012)

The Norwegian Public Roads Administration (NPRA) and Norwegian University of Science and Technology (NTNU) have conducted ex-post CBAs for 20 trunk road schemes since 2006 (Odeck 2012). These studies were sanctioned by the Norwegian Ministry of Transport. Key questions these studies sought to address were:

- Did the roads achieve their stated road program benefits?
- What was the magnitude of deviations between forecasts and outturns?
- What caused the deviations?

Key features of the NPRA/NTNU framework include:

- Ex-post CBAs are conducted for three to five projects each year.
- Projects are selected for ex-post evaluation if investment costs are higher than NOK200m (AU$34m) and they have been open for traffic in at least five years.
- Ex-ante CBAs are those presented at the time when the decision to proceed with the project is made.
- Ex-post CBAs focus on monetised impacts only.
- Complex (urban) projects are excluded.

The following key steps were adopted in NPRA/NTNU ex-post evaluations:

1. Acquire project overview, project history and project development over time.
2. Locate the ex-ante CBA (the one presented to the decision makers before the decision to proceed with the project).
3. Replicate the ex-ante CBA (likely having to use a newer version of the CBA software).
4. Substitute the outturn data into the replicated CBA in step 3 (for example, actual construction costs, actual and updated forecast traffic, average speed or travel time and crash rates).
5. Compare the before-decision analysis (step 3) and the ex-post assessment (step 4) and explain the differences.

The NPRA/NTNU approach is ongoing (three to five projects a year). The knowledge base increases with time so that valuable lessons can be drawn from the past ex-post evaluations.

BITRE (2007a and b)

The case studies undertaken by BITRE in 2005–2007 had a narrower scope than the European Commission and NPRA/NTNU studies. The objectives of the BITRE's case studies were to:

- check the accuracy of the ex-ante CBAs
- reveal sources of differences (if any) in results between ex-ante and ex-post CBAs
- draw lessons from the case studies to improve future CBAs.

Altogether seven projects were selected for ex-post review, comprising two bypasses around rural towns, one bridge upgrade project, two road duplication projects in rural areas and two road upgrade projects on urban approaches. The selection was made on the basis of size and type of projects, their geographical distribution and data availability (for both ex-ante and ex-post CBAs).

The approach used by BITRE was akin to that adopted by Odeck (2012). The key steps in BITRE's ex-post evaluations were:

1. Provide a description of the project (design, cost, timing and history of the project).
2. Locate and review the ex-ante CBA(s).
3. Identify issues in the ex-post evaluation (mostly emerging from the review of the ex-ante CBAs).
4. Replicate the ex-ante CBA.
5. Collect data for the ex-post CBA (for example, traffic and crash data).
6. Update traffic and crash forecasts.
7. Undertake the ex-post CBA (including adjusting model inputs, updating model parameters and making other project-specific corrections).
8. Compare results between the ex-ante and ex-post CBAs.
9. Explain the differences.
10. Draw lessons.

Appendix G: Selection of case studies in Round 2

The ex-post evaluation in the second round centred on projects implemented under the Nation Building Program over the six-year period from 2008–09 to 2013–14. Altogether, there were approximately 103 projects listed under the program. A multi-stage process was used to decide which projects to select for ex-post review.

Stage 1

The first-stage selection was based on the criteria related to project type, size and location. The focus was on large (over $100 million in costs) non-urban road duplication and bypass projects. This resulted in a list of 19 projects for further shortlisting (table G1).

Table G1 Initial selection of projects

No.	Project name	State	Cost[1] ($m)	BCR[2] (@4.4%)
1	Pacific Highway – Banora Point Upgrade	NSW	359	1.8
2	Pacific Highway – Bulahdelah Bypass	NSW	315	3.1
3	Hume Highway – Tarcutta Bypass	NSW	290	0.4
4	Hume Highway – Woomargama Bypass	NSW	265	0.4
5	Hume Highway – Holbrook Bypass	NSW	247	0.5
6	Great Western Highway – Wentworth Falls East	NSW	115	1.7
7	Pacific Highway – Karuah to Bulahdelah Stages 2 & 3	NSW	253	1.2
8	Pacific Highway – Ballina Bypass	NSW	640	3.7
9	Princes Highway East (Traralgon to Sale)	VIC	175	0.8
10	Geelong Ring Road Stage 4A & 4B	VIC	235	0.2
11	Western Highway – Anthonys Cutting Realignment between Melton and Bacchus Marsh	VIC	200	1.1
12	Western Highway – Duplication from Ballarat to Stawell	VIC	505	0.2
13	Nagambie Bypass (Goulburn Valley Highway)	VIC	222	0.5
14	Bruce Highway – Cardwell Range realignment	QLD	115	1.5
15	Bruce Highway – Cooroy to Curra (Section B)	QLD	613	2.5
16	Northern Expressway (Max Fatchen Expressway) and Port Wakefield Road Upgrade	SA	564	3.9
17	Dampier Highway duplication, Broadhurst Road to Dampier	WA	100	2.0
18	Mandurah Entrance Road	WA	155	3.1
19	Brighton Bypass	TAS	191	1.2
Total			**5,459**	**1.8**

Note: These were selected from a total of 103 road projects under the Nation Building Program. The selection was made on the following basis: non-urban (or outer urban) duplication and bypass projects completed (or partly completed for some sub-sections) in or before 2013 with costs equal to or greater than $100m.

Source: [1] Ex-ante cost estimates.

[2] BITRE estimates based on Project Proposal Reports. BCRs were those at a 4.4% discount rate.

Stage 2

This stage involved an initial screening of the Project Proposal Report for each project (including the ex-ante CBA report if available), which gave a sense of what each project was about and the likely quality of project documentation. The stage 2 selection was based mainly on the following considerations:

- locational spread of the projects
- availability and quality of project documentation
- completion time
- anomalies in the ex-ante CBA.

Through that process, the number of projects was reduced from 19 to 10. A discussion is provided below of these projects by State groupings.

NSW projects

More than half of the NSW projects listed in table G1 were evaluated using the NSW Government's in-house computer model, Rural Evaluation System (REVS), from the former RTA. It appeared that there had been a trend for increased outsourcing of economic evaluation tasks. Of the eight NSW projects, three were evaluated by external consultants (No.1 Banora Point Upgrade, No. 2 Bulahdelah Bypass by RMS Contractor and No. 8 Ballina Bypass by PricewaterhouseCoopers). It would be interesting to review the quality of the outsourced CBA work through ex-post evaluation.

Initial review of ex-ante CBAs found that there were some anomalies in those undertaken by RMS Contractor that are worth further investigation. In view of the above, the following NSW projects were recommended as candidates for case studies (ranked in the order of preference):

- Pacific Highway – Bulahdelah Bypass
- Pacific Highway – Banora Point Upgrade
- Pacific Highway – Ballina Bypass.

VIC projects

The projects selected for Victoria were Anthonys Cutting Realignment between Melton and Bacchus Marsh (No. 11), and Nagambie Bypass (No. 13). Other projects were excluded because they were not fully complete at the time of selection.

The availability of project documentation for the Nagambie Bypass appeared to be better than that for the Anthony's Cutting Realignment project. For this reason, the project was seen to be of higher significance in terms of priority to be reviewed.

- Goulburn Valley Highway – Nagambie Bypass
- Western Highway – Anthonys Cutting Realignment between Melton and Bacchus Marsh.

QLD projects

Of the two Queensland projects listed in table G1, the CBA documentation for the Cooroy to Curra project (No. 15) was found to be more comprehensive than that for the Cardwell Range Realignment (No. 14). Furthermore, it was of interest that the ex-ante CBA for the Cooroy to Curra project included a very unusual treatment of the contribution of Queensland Water Infrastructure to project costs. For these reasons, the Cooroy to Curra project was ranked as a higher priority for review.

- Bruce Highway – Cooroy to Curra (Section B)
- Bruce Highway – Cardwell Range Realignment.

SA projects

The only eligible project for South Australia was the Northern Expressway (now known as Max Fatchen Expressway) and Port Wakefield Road Upgrade (No. 16).

An ex-post evaluation of this project was likely to face special challenges in relation to traffic modelling because a large section of the expressway is located in an urban environment. An urban transport model would be required to model the impact of the project in the study areas.

WA projects

The projects selected for Western Australia were the Dampier Highway Duplication – Broadhurst Road to Dampier (No. 17); and the Mandurah Entrance Road (No. 18).

The Dampier Highway duplication project was chosen as a higher priority project for review mainly because of its unusually high traffic growth forecasts.

- Dampier Highway Duplication – Broadhurst Road to Dampier
- Mandurah Entrance Road.

TAS projects

The Brighton Bypass project was the only candidate for Tasmania. Limited information at the time led to a decision not to include this project in the second round of ex-post evaluations.

Stage 3

The third stage involved recommending projects for case studies based on the project ranking from the stage 2 analysis. Altogether, five projects were recommended as the first set of candidates for case studies based on geographical considerations (the top-ranking project for each of the five mainland States). These were (in no particular order):

- Pacific Highway – Bulahdelah Bypass
- Goulbourn Valley Highway – Nagambie Bypass
- Bruce Highway – Cooroy to Curra (Section B)
- Northern Expressway (Max Fatchen Expressway) and Port Wakefield Road Upgrade
- Dampier Highway Duplication – Broadhurst Road to Dampier.

List of acronyms

AADT	Annual average daily traffic
AADV	Annual average daily vehicles
ABS	Australian Bureau of Statistics
ACA	Adelaide Crafers Highway
ACC	Average crash costs
ACH	Adelaide Crafers Highway
ACT	Australian Capital Territory
ATAP	Australian Transport Assessment and Planning
ATC	Australian Transport Council
BCR	Benefit-cost ratio
BITRE	Bureau of Infrastructure, Transport and Regional Economics
BTE	Bureau of Transport Economics
CBA	Cost-benefit analysis
CNB	Constant net benefit
CPI	Consumer Price Index
DIRD	Department of Infrastructure, Regional Development and Cities
DfT	Department for Transport
DNP	Declining net benefit
DNB	Decreasing net benefits
DPTI	Department of Planning, Transport and Infrastructure
DTEI	Department of Transport, Energy and Infrastructure
DUS	Department of Urban Services, ACT
EC	European Commission
EIS	Environmental Impact Statement
FYRR	First year rate of return

GEH	Great Eastern Highway
GFC	Great Financial Crises
GVH	Goulburn Valley Highway
HC	Human capital
INB	Increasing net benefit
KSIE	Karratha Support Industry Estate
MAC	Media access control
MASTEM	Metropolitan Adelaide Strategic Transport Evaluation Model
MRWA	Main Roads Western Australia
MRS	Model road state
MVKT	Million vehicle kilometres travelled
NAASRA	National Association of Australian State Roads Authorities
NIMPAC	NAASRA Improved Model for Project Analysis and Costing
NMF	Norwegian Ministry of Finance
NOA	Notes on Administration
NPRA	Norwegian Public Roads Administration
NPVNet present value	
NRM	NAASRA Roughness Meter
NSW	New South Wales
NTNU	Norwegian University of Science and Technology
PCE	Post completion evaluation
PCU	Passenger car unit
PPR	Project Proposal Report
QDMR	Queensland Department of Main Roads
QDTMR	Queensland Department of Transport and Main Roads
QWI	Queensland Water Infrastructure
REVS	Rural Evaluation System
RMS	Road and Maritime Services
RTA	Road Traffic Authority
RV	Residual value
SIDRA	Signalised & Unsignalised Intersection Design and Research Aid

SLD	Straight line depreciation
TIC	Transport and Infrastructure Council
TTCT	ravel time cost
TTS	Travel time savings
VCR	Volume/capacity ratio
VHT	Vehicle hours travelled
VKT	Vehicle kilometres travelled
VLC	Veitch Lister Consulting
VOC	Vehicle operating cost
VSL	Value of statistical life
WAPC	Western Australian Planning Commission
WARES	Western Australia's Rural Evaluation System
WEB	Wider economic benefit
WTP	Willingness to pay

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