NSW GOVERNMENT

Transport for NSW


Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives

June 2018





Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives

Transport Economic Appraisal Guidelines

Evaluation and Assurance, Finance and Investment
June 2018

VERSION CONTROL AND DOCUMENT HISTORY	
Version:	1.4
Version Release Date:	March 2013
Status:	Final Draft
Document Name:	Principles and Guidelines for Economic Appraisal of Transport Investments and Initiatives

Version No:	1.5
Version Release Date:	1 Nov. 13
Amendment:	Updated Appendix 4 for 2012/13

Version No:	1.6
Version Release Date:	March 15
Amendment:	1. Updated Appendix 4 • Economic parameter values indexed for 2013/14 prices • Included infrastructure cost benchmarks • Reference to the Willingness to pay (WTP) approach in value of travel time (VTT) –flag NSW Stated Preference Study including for rail, bus, ferry, car drivers and car passengers 2. Incorporated new sections • Clearways CBA methodology and case study • Road safety advertising campaign CBA methodology and case study • ICT Investment benefits 3. Included Program Evaluation section 4. Expanded Benefit Realisation section 5. Expanded Post Completion Evaluation section
Version No.	1.7
Version Release Date:	July 2016
	1. Updated/indexed Appendix 4 economic parameter values for 2015/16 prices 2. Included estimating travel time reliability benefits of transport projects 3. Included Pro-Forma Brief to Economic Appraisal Consultants and CBA Summary Reporting Template (Appendix 5) 4. Included practice guide and worked examples in estimating de-congestion benefits 5. Expanded Technical Appendix 9 on consumer surplus by including a resource cost correction in using the public transport project model (PTPM) 6. More detailed guidance on probabilistic cost benefit analysis including @risk and a worked up example (Appendix 10) 7. More detailed guidance on estimation of wider economic benefits (Appendix 12)
Version No.	1.8
Version Release Date:	June 2018

	1. Appendix 4 updated/indexed economic parameter values for 2017/18 prices for all relevant parameters to reflect the latest ABS data releases (CPI/PPI for March 2018, and to AWE for November 2017)] 2. Modification to discount rate sensitivity 4% to 3% in line with *NSW Government Guide to cost Benefit Analysis, Treasury ref TPP 17-03, March 2017* 3. Appendix 4 – Inclusion of high level commentary on the Austroads approach to calculating vehicle operating costs (as recommended by Infrastructure Australia) 4. Appendix 4 – update, formatting of content and tables to ensure greater consistency throughout the document, and improve readability. 5. Updated references and minor correction to grammar and spelling.

FOREWORD to Version 1.7

Transport for NSW is committed to achieving greater value for money from our significant investment in transport assets and to improving the efficiency and quality of transport services. An important cornerstone in achieving these is ensuring that programs, projects and new initiatives represent the best possible transport solutions. The conduct of economic appraisal provides evidence that aids sound decision making towards making these investments.

The TfNSW *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives* sits within the Transport Investment Policy Framework and aims to help managers across the Transport Cluster to plan and conduct economic appraisal based on a consistent framework. The use and application of the guidelines facilitate evaluation of economic efficiency of investment proposals and contributes in improved resource allocation by ensuring that the strategic alignment and value for money assessment have been consistently determined across the transport cluster.

The *Transport Economic Appraisal Guidelines* set out the principles, concepts, methodology and procedures to be used in the evaluation of proposed investments and initiatives in the transport cluster. Analytical steps, illustrative calculations, practice guides and advice and references to reports and tools are provided. User friendly models and tools have been developed covering prototype transport projects to assist in cost benefit analysis of similar projects. The links to these calculation models are embedded in the document to make it accessible to users.

Economic parameter values are provided for consistent use across the Transport Cluster. These are updated on an annual basis and are disseminated to the whole cluster for continued and consistent application.

Both instructor-based and online training modules are provided including case studies and practice guides on the application of economic appraisal methods and models to particular projects, programs or activities in the work areas.

The *Transport Economic Appraisal Guidelines* is a living document that is continuously being reviewed and updated to enhance its relevance and ensure adherence to best practice. New methodologies are included as they become relevant to ensure that Transport for NSW is at the leading edge of robust, transparent decision making.

You can send any comments or feedback to EconomicAdvisory@transport.nsw.gov.au or Robert.J.Smith@transport.nsw.gov.au

Tim Reardon
Secretary

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PRINCIPLES AND GUIDELINES: ECONOMIC APPRAISAL OF TRANSPORT INVESTMENTS AND INITIATIVES

1. Introduction

Transport for NSW (TfNSW) is responsible for the coordinated planning and delivery of transport services in NSW. Funding decisions by TfNSW operate under a consistent framework for assessing project and program proposals and requirements.

TfNSW's funding decisions take a cluster wide view of the NSW Transport sector including:

- An integrated approach to addressing the expected growth in the freight and passenger transport task
- A focus on the relationship between transport infrastructure and economic productivity and land use
- Appraising new modes and technologies
- Emerging approaches in forecasting transport demand.

1.1 Objective of this document

The objective of this document is to provide underlying principles and guidelines for the economic appraisal of transport projects and initiatives. It is a standard appraisal framework to be applied to proposed projects, programs and initiatives within the NSW Transport cluster. It contains a consistent set of economic parameters and values for use in economic appraisal of transport investments and initiatives.

The document also provides explanations, illustrative calculations, practical advice on data limitations and references to reports and tools that can assist practitioners in estimating the benefits and costs of transport investments and initiatives.

A standard appraisal approach across the NSW Transport sector ensures multi-modal (i.e. cross agency and network) impacts are considered, captured and quantified in the appraisal process. This multi-modal portfolio approach increases the comparability of project appraisals and the efficiency of State-funded capital investment.

Having overarching guidelines for the Transport portfolio improves the resource allocation to projects by ensuring that the strategic alignment, benefits and value for money assessment of projects, programs and initiatives have been consistently determined across the Transport portfolio. This is to say that a dollar of investment in the road network is treated the same as a dollar of investment in the rail network.

This document also discusses emerging and unresolved economic appraisal issues and their relevance to current projects.

1.2 Other economic analysis guidelines

Other guidelines for economic appraisal are reviewed to identify standard and leading edge methods in the costs and benefits of transport projects. (See Appendix 1 for a list and summary features of these guidelines and manuals).

Presently there is a nationally agreed framework for conducting cost benefit analysis of transport projects. This is the Australian Transport Assessment and Planning (ATAP) Guidelines.

The ATAP Guidelines provide a comprehensive framework for planning, assessing and developing transport systems and related initiatives. The Guidelines content has been endorsed by the Transport and Infrastructure Council (the Council). The Council's membership consists of the transport ministers of the Commonwealth, states and territories and New Zealand, and the president of the Australian Local Government Association.

The ATAP Guidelines considers a full range of potential solutions or options moving beyond the narrow focus of infrastructure and single mode solutions. It proposes a 3-level appraisal process with corresponding business case development:

- Strategic Merit Test (Strategic Business Case)
- Rapid appraisal (Outline or Preliminary Business Case)
- Detailed Appraisal (Full Business Case)

It also includes well-developed road user effects (RUE) unit values which are widely used for economic evaluation of both urban and non-urban road investment projects.

Within NSW, the NSW Treasury's *Guide to Cost-Benefit Analysis* (2017) and *Guidelines for Financial Appraisal* (2007) provide a framework for undertaking economic and/or financial appraisals across all public sector agencies. Some agencies have also published their own industry specific appraisal manuals (such as NSW Health Infrastructure's *Guidelines for the Economic Appraisal of Capital Projects*).

The NSW Treasury guidelines provide the overarching framework for investment appraisals in the NSW public sector. They include general descriptions and generic methods of economic appraisal to be applied to transport projects, programs and initiatives. It covers the discounted cash flow techniques of cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) all of which may be used at different times to evaluate projects.

Cost-benefit analysis is the preferred approach when considering the range of costs and benefits attributable to a project. CBA assists decision-makers while recognising that there are always benefits which economics struggles to put a value on. It has value in planning the timing and direction of a project, rather than simply deciding whether or not to implement a project. Different types of CBA can be applied at different stages of a project ranging from scoping studies to highly detailed analyses. The stages are sequential and the results of each stage can be reviewed before deciding if further work is required.

The annexes to the guidelines and the embedded models provide more detailed information and guidance for those actually conducting analyses. To aid consistency, a common database of "standard values" to use in CBA of transport investments and initiatives across the portfolio is needed.

Economic parameter values for quantifying benefits and costs are listed in Chapter 2 and discussed in detail in Appendix 4. Ways of assessing the wider impact of transport (including case studies) are also presented in this document.

1.3 Economic appraisal within the Infrastructure Investor Assurance Framework

The Infrastructure Investor Assurance Framework[1] is a cross-portfolio framework that applies to Transport for NSW and its operating entities. The framework ensures a strategic overview and alignment of the program and project objectives with the State Plans, the Future Transport and the corporate plans. The focus is on capital growth and maintenance.

The Infrastructure Investor Assurance Framework does not make investment decisions – rather, it provides the process, governance and tools as an integrated capability that enables these decisions to be made.

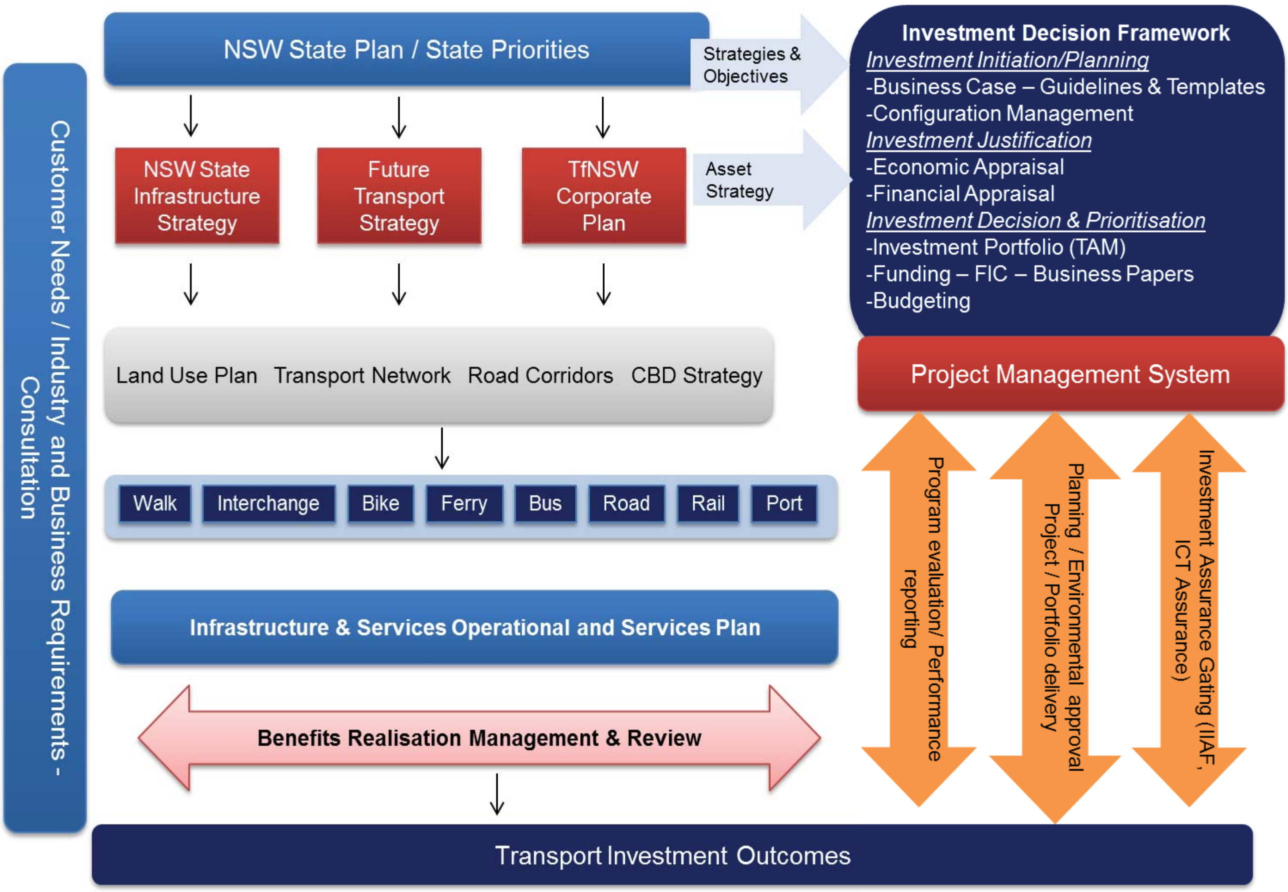
[1] See INSW [http://infrastructure.nsw.gov.au/project-assurance]

Economic appraisal assists investment decision making through the use of robust tools such as CBA which informs decisions on investment proposals.

A mandatory requirement for all business cases submitted to Treasury is the completion of an economic appraisal (supported by financial analysis) to evaluate the costs and benefits of the options and to determine which option offers superior value for money. Refer to the NSW Treasury Circular Submission of Business Cases (TC12/19), Guidelines for Capital Business Case (tpp08-5), the Department of Premier and Cabinet's Business Case Guidelines other than Capital and the TfNSW Business Case Policy Guidelines & Business Case Template.

The figure below shows the causal connections between strategic objectives driven by the goal of providing the greatest social and economic benefit for the whole of NSW and the greatest value for the customers, investments, enablers and transport investment outcomes.

Figure 1.1 Transport Investment Decision Framework



1.4 Process of economic appraisals

An economic evaluation is undertaken in co-ordination with a project's development. The process and sequence of activities are set out in the figure below.

Figure 1.2: Cost-Benefit Analysis Process

Statement of objective/ Problem definition	• To improve transport network efficiency • To provide more services/improve mobility • To improve services and amenity to customers • Improve accessibility
Project definition and project scope	• Description, location, characteristics (e.g. brownfield/greenfield), constraints • Exclusions to physical scope (to avoid scope creep) • In scope and out of scope; aggregation
Specify the base case and alternative options	• Base case - Status Quo or Do Minimum • New infrastructure, modified service • Alter transport task with another option • Technological solution or organisation/process change
Determine the level of evaluation	• Modes, intermodal systems, multimodal • Local sites, corridor, network-wide, regional
Identify and calculate quantifiable costs and benefits for base case and each option	• **Costs:** Capital costs, major periodic and routine maintenance and repairs, operating costs, user costs • **Benefits:** Avoided capital and recurrent costs, residual value, user benefits (savings in VOC, travel time, safety, reliability), WEBs, environmental benefits,
Discount costs and benefits and calculate decision criteria	• Base discount rate of 7%, sensitivities of 3% and 10% • NPV, BCR, FYRR, NPVI, IRR
Risks and sensitivity testing	• Perform realistic sensitivity tests on key assumptions i.e. with respect to demand and usage, capital costs (P50, P90), construction period. Identify "switch points"; test interrelationships as well
Present quantified and non-quantified results	• CBA results (monetised) • Economic Impact Analysis to measure those quantified but non-monetised effects • Appraisal Summary Table (AST) to integrate economic and environmental impacts
Recommend preferred option	• Prepare economic appraisal report and include discussion regarding preferrred option, referring to economic evaluation and other qualitative analysis to support argument

1.5 Funding and assessment framework of Government agencies

Economic appraisals are required for funding submissions to Commonwealth and State government agencies including:

- **Infrastructure Australia** - focuses on projects of national significance costing over $100m. Projects are assessed under the *Assessment Framework (2018)*[2].
- **Commonwealth Department of Infrastructure, Regional Development and Cities -** provides funding to road and transport projects under the Transport Infrastructure Program which includes key National Partnership Agreements.
- **Infrastructure NSW** - evaluates submissions by agencies for projects costing more than $100m, coordinates NSW's infrastructure funding submissions to the Commonwealth and provides a risk-based project assessment through INSW's Infrastructure Investor Assurance Framework (IIAF) (2016).
- **NSW Treasury** - economic appraisals are required to be submitted to NSW Treasury for projects costing more than $5 million as part of Preliminary Business Case or Final Business Case submissions[3].
- **Transport for NSW** - prepares economic evaluations, financial submissions and funding options for projects across all modes; conducts project assurance assessment for projects; assesses business cases, economic and financial appraisals submitted for funding.

The detailed funding and assessment requirements for Commonwealth and State government agencies are summarised in the table below. The links to the guidelines and templates are also included.

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[2] For details, see the Assessment Framework, Infrastructure Australia, 2018

[3] The detailed submission requirements can be found in NSW Treasury Circular, Submission of Business Cases, TC 12/19, 11 October 2012.

Table 1.1 - Funding and Assessment Framework of Commonwealth and State Governments

Attributes	Infrastructure Australia (IA)	Commonwealth Department of Infrastructure, Regional Development and Cities	Infrastructure NSW (INSW) & GSC	NSW Government Departments – Treasury, DPC and DFSI	Transport for NSW (TfNSW)
Projects and proposals it assesses	• Infrastructure Australia reviews and produces a list of priority projects, focusing on projects worth over $100 million or those of national significance	• National Building projects (including rail, road, boom gates and rail crossing) • Building Australia Fund projects • Major Cities projects • Liveable Cities program projects • Nation Building Blackspot Program	• Risk based assurance reviews of High Profile/High Risk (Tier 1) and Tier 2 capital projects • Review of unsolicited private infrastructure proposals • Assess public private partnership proposals by agencies • Coordinate NSW infrastructure funding submissions to the Commonwealth •	• Capital projects • Recurrent projects (Treasury) • Information and Communication Technology (ICT) projects (DFSI)	• Capital projects • Maintenance proposals • ICT proposals • Business cases for all projects, programs or capital purchases in excess of $1m
Reporting / submission requirements	Submissions must follow the IA templates for the stages: • Problem Identification and Prioritisation • Initiative Identification and Options Development • Business Case Development • Business Case Assessment • Post Completion Review	• NSW Blackspot Program (How to Apply for Funding- Funding criteria and assessment processes are detailed in Notes on Administration for Nation Building Black Spot Program)	• Project registration via the Reporting and Assurance Portal (RAP) • Regular project reporting: - Monthly for HPHR - Quarterly for Tier 2 & Tier 3 projects	• Summaries of economic appraisals are required to be submitted for projects costing between $1m and $10m • Full reports on economic appraisals are required to be submitted for projects costing in excess of $10m	• Economic appraisals required for projects costing in excess of $1m
Strategic priorities	The Australian Infrastructure Plan (2016) focusses on: • Productive Cities, Productive Regions • Efficient Infrastructure Markets • Sustainable and Equitable Infrastructure • Better Decisions and Better Delivery	• Nation Building—Economic Stimulus Plan: Many of the programs are being administered by the Commonwealth Department of Infrastructure, Regional Development and Cities • Nation Building – Black Spot Funding	• INSW, Building Momentum State Infrastructure Strategy 2018-2038 (2018) • GREATER SYDNEY REGION PLAN A Metropolis of Three Cities – connecting people (2018)	• NSW State Plan • NSW 2021 • NSW Premier's/State Priorities	• Future Transport 2016 Strategy • Greater Sydney Services and Infrastructure Plan, Future Transport 2056 • Regional NSW Services and Infrastructure Plan, Future Transport 2056 • NSW Draft Freight and Ports Strategy • Corporate Plan • Results and Services Plan • Total Asset Management

Attributes	Infrastructure Australia (IA)	Commonwealth Department of Infrastructure, Regional Development and Cities	Infrastructure NSW (INSW) & GSC	NSW Government Departments – Treasury, DPC and DFSI	Transport for NSW (TfNSW)
Assessment Guidelines	• Assessment Framework (2018) • Better Infrastructure Decision Making Submission Coversheet and Templates Building Australia Fund Evaluation Criteria	• ATAP Guidelines (2016) • National Guidelines for Transport System Management (2005)	• Infrastructure Investor Assurance Framework (2016) • INSW Contingency Management Guidebook (2014)	• NSW Treasury Guide to Cost-Benefit Analysis (2017) • NSW Government Guidelines for Financial Appraisal (2007) • NSW Treasury Guidelines for Capital Business Cases (2007) • Treasury Circular 16-09 Infrastructure Investor Assurance Framework (2016) • DFSI issued Secretary Circular and the ICT Assurance Framework	• Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives (2016) • Business Case Policy • Business Case Template

2. Economic Appraisal Framework, Process and Decision Criteria

This chapter discusses the scope and level of economic appraisal and the conventional approach to cost-benefit and cost-effectiveness analyses.

The analysis of broader based impacts of transport initiatives are also presented with some examples.

Decision criteria and threshold values including sensitivity analysis and risk adjustment are discussed in this part of the Guidelines.

This chapter is scheduled for consultation and review for Version 2.0 of the Guidelines.

2.1 Introduction

2.1.1 Scope and Level of Economic Analysis

Cost-benefit analysis (CBA) are normally undertaken from the point of view of society as a whole or a subset of society such as the state, territory or region.

Economic analysis should demonstrate that the project will generate benefits for the users of the assets and the community at large, and the cost of implementing these is covered by these benefits. In this section we define the projects and programs in the context of public transport projects, roads, and other facilities or systems.

This section also describes the benefits and costs that accrue to users if transport projects are implemented. The methods of how these benefits and costs are measured and valued in monetary terms are demonstrated including the economic viability of projects from a socioeconomic point of view.

2.1.2 Market Prices, Opportunity Costs and Willingness to Pay

Economic evaluations are based on economic costs or resource costs and economic benefits. Where goods and services are freely bought and sold, it is generally presumed that market prices reflect economic costs and benefits. However, if market prices are distorted or if goods and services are not freely traded, or if there is no price charged, then indirect methods for measuring costs and benefits are required. For instance, taxes and subsidies are just transfer payments from one sector (individuals/businesses) to another (government). A major cost item in road evaluations which is subject to distortions via taxes is fuel. The price of fuel net of any taxes should be used to value changes in vehicle operating costs. Thus, the appropriate cost to use is the cost excluding these items, i.e., resource costs.

The indirect methods of measuring costs and benefits include the opportunity costs of resources. These are the values the resources would have in their next best alternative use. Alternatively, it is the foregone return that may accrue to a different firm or from a different activity, but would still accrue to society as a whole. When output is fixed, this would be the gross price inclusive of any indirect tax.

A principle of evaluation is based on user's willingness to pay (WTP) for a good or service. The most common definition of WTP is "the maximum amount that an individual would be willing to pay for a good or service" or the stated price that an individual would be willing to accept to avoid the loss or the diminution of an environmental service.

There are three ways to estimate WTP:

- Observe the prices that people pay for goods in non-distorted competitive markets
- Observe individual expenditures of money, time, labour, etc. to obtain goods or to avoid their loss
- Ask people directly what they are willing to pay for goods or services in the future.

The first two approaches are based on observations of behaviour and are called Revealed Preference techniques while the third technique is based upon Stated Preferences and includes the contingent valuation methodology.

Surveys and questionnaires using stated preference techniques are frequently used to estimate what people would pay for a benefit gained from the resources used. Some benefits can be valued on the basis of savings in resource costs (for example, the imputed value of the reduction in travel time).

Although the value of benefits based on savings in resource costs may be lower than if the benefits were valued according to willingness to pay (WTP), it would be wrong to include the benefits derived from both techniques in an evaluation because that would be double counting the benefits. Where there is no established framework, the benefits must be valued on a case by case basis.

If use of resources is fixed, the savings should be based on WTP principle. If not fixed, they should be based on marginal cost of production. It should be noted that public transport fares, while freely traded, do not reflect the real cost of resources used due to subsidisation of public transport services.

2.1.3 Discount rate

The discount rate is a critical parameter in cost-benefit analysis whenever costs and benefits differ in their distribution over time, especially when they occur over a long time period.

The theory of discounting is to translate future costs and benefits to a common time unit, in order to compare costs and benefits that accrue at different times and express them as an equivalent amount in today's dollars. Government projects are not in general free of risk. Although discount rates embody an appropriate compensation for risk, risk is dealt with separately from discounting in economic evaluation.

For private projects, PPP for instance, the rate should be equal to the rate of return on private projects with similar levels of risk. The market price of risk is what people have to be paid to bear risk and reveals attitudes to risk even where markets are imperfect. The appropriate adjustments for taxes and risk cannot be precisely estimated — one reason why sensitivity testing is important.

The debate on which rate should be used to discount future benefits and costs in CBA has been ongoing for many decades, and may never be resolved owing to the range of estimation methods and varying objectives of different governments and agencies. The principles of discounting can be agreed, however, the exact discount rate given the principles may be hard to decide.

Government projects for which cost-benefit analysis can assist decision making cover a huge range: regulatory changes; infrastructure investments with significant gestation periods and long benefit streams, whose magnitudes are positively related to general economic conditions; and climate change policies with cost and benefit streams extending over centuries, but with high uncertainty. No single discount rate could meet the precise financing and risk characteristics of each project in this wide range of applications. Using an artificially high discount rate for project evaluation can make future generations worse off.

The NSW Treasury Guide to Cost-Benefit Analysis (2017) recommends a central real discount rate of 7 per cent, with sensitivity for 3% and 10%.

There is an absence of overwhelming consensus on the right discount rate to use for economic appraisal. Appendix 2 (Review of Discount Rate for use in Economic Appraisal of Transport Initiatives) provides a summary of existing approaches. Calculated discount rates ranging from 3.7 to 8.5 per cent could be theoretically supported depending on the approach adopted and the range of differing views e.g., based on consumption rate or producer rates. Thus, there are merits in continuing to apply the current 7 per cent rate which was the result of the weighted average cost of capital approach.

Infrastructure Australia (IA)[1] has issued a Discount Rate Methodology Guidance which provides a methodology for the development of the discount rate used to assess the social infrastructure projects. The guidance focuses on the development of the discount rate but did not provide a suggested rate in itself.

2.1.4 Evaluation period

This relates to the appraisal period which is the expected life of the asset created by the initiative in its intended use. The evaluation period takes in the initial period of capital investment and the subsequent period over which the benefits of the project accrue.

The following factors should be considered in the selection of an evaluation period:

- It is important that the period chosen should not have a decisive influence on the economic outcome of the project being evaluated;
- It should be sufficiently long so as to achieve a reasonably full representation of benefits of projects which require large initial outlays; and
- It should not favour one option over another due to differing asset lives.

It is usual to assume a 30-year life for road projects. Economic analysis of maintenance options, however, may use longer than 30 years since the useful life of concrete pavement extend beyond 30 years. A longer evaluation period may be appropriate for projects that have long asset lives, i.e., bridges. A 50-year life is also often used for rail tracks and tunnels. For rail rolling stock, the project period is 35 years while a bus's economic life is 15 years. Computer hardware and intelligent transport system initiatives will have shorter lives. (Table 80 of Appendix 4 provides estimate of economic or useful life of assets). Residual value of the asset can be included as a benefit at the end of evaluation period if the economic life of the asset is longer than the evaluation period.

There may be instances where assets with shorter lifespan may be replaced with assets embodying improved technology. This reflects an extra benefit of assets with shorter life, with the accompanying benefit of a lower level of risk. The greater frequency of replacement enables the benefits of improved technology to be incorporated into the production process more quickly and may facilitate adjustment to changes in the quantity and type of service required.

While benefits of greater flexibility and lower risk associated with shorter asset lives may be difficult to quantify, the costs which are involved in obtaining these benefits can be quantified by comparison with the equivalent annual cost of each option. Such a comparison should be undertaken where the benefits of a shorter asset life are considered likely to be significant.

This is most likely to be the case where the pace of technological change is relatively rapid, demand is volatile or there is a particularly large difference in asset lives.

2.1.5 Inflation

In economic analysis it is important that inflation does not bias the results. Inflation causes costs and benefits that occur later to appear higher in cash terms. This could bias the results towards projects with later benefits. Also inflation does not increase the real value of the benefits or costs, it only increases their money or nominal value. Thus from an economic (real resource costs) point of view, the impact of inflation can be ignored unless differential rates of inflation are expected. Real prices, i.e. prices net of inflation, are thus used for economic evaluation (vis-a-viz nominal prices which include the effect of inflation). All costs and benefits are expressed in terms of the price level for a given year, defined as the price year. The price year selected should be the same as that used for any accompanying financial analysis.

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[1] National PPP Guidelines, Volume 5, Discount Rate Methodology Guidance, December 2008.

If differential rates of relative prices are expected, the difference maybe included if they are likely to be significant. For example, if the cost of road building is expected to increase at a rate lower than the level of general price inflation, the costs of road building should be adjusted downward to reflect the difference between the general price inflation and the inflation in the costs of road building.

Where cost or benefit items are expected to increase at a rate greater than general price inflation, then they should similarly be adjusted upwards prior to use in a CBA. This may occur with values of travel time which are generally related to wage levels. If wage levels show a trend to increase in real terms (i.e. above general price inflation rates) then these values should be adjusted upwards in the CBA.

2.2 Common Approaches

2.2.1 Cost Effectiveness Analysis (CEA)

Cost-effectiveness analysis (CEA) is used when the benefits are similar for all the options being considered. The NSW Government CBA Guidelines propose that CEA should only be used as a supplementary approach to CBA because it does not assess the net impact on social welfare. CEA should be treated as a second-best option and does not substitute for CBA except in rare instances where it is not possible to estimate benefits.

A CEA aims to identify the least cost option with costs defined and discounted in the same manner as in a CBA. The technique for valuing costs will be the same as for CBA. Benefits are not ignored even if they cannot be quantified or valued. Benefits remain a vital part of any appraisal report and their identification and description is one of the components of CEA.

For example, CEA could be used when the objective is to reduce the level of emissions from motor vehicles. The reduction in emissions may be measurable but not subject to valuation in monetary terms. However the benefits arising from vehicle emission reduction need to be identified and assessed in relation to quantified benefits and costs.

2.2.2 Cost Benefit Analysis (CBA)

It should first be recognised that CBA has a long established record of wide use in project appraisal. A CBA is always comparative to a base case which may be the continuation of the status quo. Of interest are the differences between the base case and the defined option(s): those factors that are common between options have no bearing on choosing the most worthwhile option.

2.2.3 CBA and Financial Analysis

Is a financial evaluation also required? Generally, financial analysis is only required if the project is expected to generate any revenue or if there is a private sector funding proposal involved.

The major difference between CBA and financial analysis is that in the former, the costs and benefits accruing to the community as a whole are considered and benefits not directly traded in the market place will be included. In the latter, only financial costs and incomes of a particular organisation are considered. In CBA, ideally all costs and benefits are relevant; no matter to whom they accrue.

A financial appraisal is usually simpler because it is only concerned with those costs and benefits that are already valued in money terms. It is only necessary to determine the values of the expenditure and income arising from the scheme. It will take into account the payment of interest and the prices to be paid for goods and services.

It must be emphasised that although CBA is an important and useful tool for use in decision-making, it is not a substitute for judgement in the particular circumstances of a specific investment.

The results of CBA must be considered within an overall project assessment framework, which addresses the other non-economic or non-quantifiable effects.

If the project is outside the annual budgetary allocation process private sector funding should be considered. For large or significant projects, full or partial private sector funding may be a possibility.

2.3 Major Steps in Cost Benefit Analysis

Statement of objective of the study and the problem being addressed by the project

Understand and describe the initiative. Any evaluation of a proposed project should begin by considering the project's scope and objectives.

Identify the objectives the project is designed to achieve including any problems it will solve is usually the first step in a CBA. This is critical because it enables the analyst to consider and document upfront what quantifiable and non-quantifiable benefits may result. Projects will generally be initiated to address problems or deficiencies facing existing or potential users of transport infrastructure including expanding service levels or standards. Unquantifiable benefits can be identified and discussed in the introduction to a project's evaluation.

The setting of objectives helps to provide reasons for why a project is proposed. The general reasons usually are:

- To improve transport network efficiency. Network efficiency is achieved when the performance of the transport network is optimised.
- Measures to increase road capacity and passenger capacity of public transport of the existing transport network.
- To provide more services.
- To improve services and amenity to customers.
- Improve mobility / facilitate more trips. Examples include providing public transport in outer urban low density areas and measures to improve accessibility of the public transport system for individuals with a disability.
- Improve accessibility by reducing travel time and increasing mode choice options.

Project identification and specification should be related to the strategic objectives and development programs of the government. Defining measurable operational performance goals against benchmarks also assists in providing the basis for the post completion review.

Project specification and determination of the scope of the project

Begin with a description of the project including its location and physical characteristics (a map may be included).The specification should describe how it is consistent with the corporate and regional plans and how the project will assist in achieving the objectives. It should also define the type of the project:

- New capital project
- Contraction or amplification of existing facilities
- Replacement of existing facilities
- Upgrading or improving existing facilities.

For example, the following questions should be answered in the specification:

- Is it a new project?
- Has it been evaluated previously?
- Is it part of a larger program or strategy?

Describing the project's main characteristics may also assist in defining the scope of the project.

It is important to set an appropriate level of effort for conducting a CBA. This will depend on the project phase and the size of project. Ideally a CBA should be involved from the start of a project. However there may be some situations where irreversible decisions to pursue certain projects or project options have already been taken. It may be advisable in some cases where decisions are not irreversible to conduct a CBA even though money has been committed and work begun. If the project is found to be viable as a result of the “better late than never” CBA, then it can proceed as planned, but with an added degree of confidence. If the project is not found to be viable then it can be restructured.

The level of detail of the CBA needed partly depends on the cost of the project and to the sensitivity required for the results.

There are different levels of detail, corresponding to the first three stages in the project life cycle:

- **Assessment of need or opportunity.** This corresponds to the stage of identification of requirement for the project and consists of a broad based analysis of the do-nothing option.
- **Scoping CBA.** This corresponds to the development and investigation of project options.
- **Full CBA.** This corresponds to business case preparation and presentation and consists of a detailed investigation of a small number of project options.

Note that following the assessment of need or opportunity, it may be decided that further analysis is not required for projects which cost less than a specified lower limit. This may be because the cost of any additional study would not be justified in relation to the relatively low cost of the project.

In general, full CBAs should be undertaken for all individual projects with a total cost in excess of $1 million. Summary sheets are required to be submitted to Treasury for projects between $1 million and $10 million. Full appraisals are required to be submitted for projects over $10 million.

Aggregation and Disaggregation

It is important that the project is not so broad that it is actually a program of discrete projects. Conversely, the project should not be a component of a discrete project. It must constitute a stand-alone investment.

Consider the upgrading of a stretch of rail track which involves two sets of works. Suppose Works A has benefits of $25m and costs of $5m and Works B has benefits of $5m and costs of $10m. If the track works are evaluated as one project the NPV is $15m. But if Works A and Works B have distinct objectives and can proceed independently these two should be evaluated as individual projects – Works A having NPV of $20m and Works B having an NPV of -$5m.

Overall, several principles should be adopted:

- Proposed projects should be specified at the minimum level of aggregation consistent with independent alternative options of directly achieving the objectives.
- The specification of a project option to be evaluated should include all works necessary for the objective to be achieved and should not include components which are not necessary for achieving the objectives.
- The evaluation of subsidiary components should be considered if this will assist in developing a more effective option at the aggregate level.
- Even though component evaluation may be undertaken, the total project still needs to be evaluated.

- Consider whether the project can be undertaken in stages. This may assist funding by spreading the project over time and reducing project risk by giving flexibility to cancel a project if the assessed benefits are not being derived.

Specify the Base Case and alternative options

A cost-benefit analysis focuses on how a project will change the base case. Hence the correct specification of the Base Case is important. The Base Case is usually defined as business as usual or a no policy change case. When evaluating a new link in a network, the future network without the link needs to be carefully specified in order to avoid project bias. The Base Case is not necessarily a do-nothing or no change situation. It should include any significant assumptions about actions that need to be undertaken and one off future events that affect benefits or costs.

A common error in defining the Base Case is a failure to fully specify its costs. An example is the possibility of road maintenance costs increasing in the future, if a major improvement is not undertaken now.

The high level transport options are:

- Base Case – this could be Status Quo (do nothing or no action required) or Do Minimum interventions. It could also be the use of the existing transport system in a different way or more efficiently.
- Modify or add to existing transport system with new infrastructure, modified service or regulations.
- Alter proposed transport task in conjunction with another option.
- Technological solution.
- Organisation or process change.
- Education and information provision.

Prudence in transportation investment planning counsels that major new projects should be approved only if they can be justified after accounting for efforts designed to make the most efficient and productive use of existing facilities, called the Base Case. The Base Case can include certain transportation system innovations, small scale spot infrastructure capacity improvements, expanded bus service and so on. If relatively low cost steps can be found to diminish or delay existing transport problems without recourse to high cost investment, scarce capital resources can be employed more efficiently in meeting other urban and regional needs.

Identify and Analyse Options

The analysis of solutions is equally critical. After having defined the Base Case, it is necessary to identify all promising technical alternatives on the basis of physical circumstances and available technologies. The main risk of distorting the evaluation is the risk of neglecting relevant alternatives, in particular, low cost solutions such as managing and pricing solutions.

The costs and benefits of various options to address the objectives need to be identified and quantified against the Base Case particularly in the initial Project Scoping Proposal analysis. The best course of action may not be obvious at the outset. A variety of solutions providing different emphasis on benefits at different costs are likely to be applicable. Cost-benefit analysis provides a tool to compare and evaluate the benefits and costs of different options to achieve predetermined objectives.

The range of viable options will vary with the nature of the project and the problem. Tasks set at the strategic level may generate a wide range of options, for example, consideration of alternative modes of transport may be appropriate or solutions that do not involve large capital investments. Often, consultation with stakeholders will assist in identifying options or enable options to be excluded. It is important to look at the cross-modal effect of each viable option.

Identification of options need not be limited to the most obvious mode. Australia's National Guidelines on transport system appraisal recommend that governments undertake an options analysis including an 'options list' that *"encourages consideration of a full range of policy instruments"*. This will involve an objective analysis of the benefits that might be offered by different modes across an individual corridor and across an integrated, multimodal transport network.

It is essential that a thorough initial search of possible options is conducted. This will include revisiting the status quo and solutions offered by the development of new assets, new technologies or non-acquisition or non-build options including demand management.

This can be achieved by a combination of the following:

- Value engineering
- Learning from other states, jurisdictions, countries
- Past experience
- Canvas experts
- Conference papers
- University research
- Group brainstorming
- Internet search
- Literature search

The following elements are essential to the successful identification of options:

- Identifying the options and the criteria for the option evaluation
- Providing impartial scoring for the options and applying weighting criteria
- Viewing and analysing the results; sensitivity and robustness analyses
- Ensuring stakeholder participation to achieve buy-in to the decision

The principles of achieving integration of transport and land uses should be considered in the generation of project options.

It is more than assessing the project in one mode. In identifying the solution, the approach to be taken should be looking at a range of practical solutions which may include multi-modal projects rather than a project in obvious single mode. The approach is to undertake an options analysis including an 'options list' that *"encourages consideration of a full range of policy instruments"*. This may also include non-build solutions together or separate from build options.

This will involve undertaking an objective analysis of the benefits that might be offered by different modes across an individual corridor and across an integrated transport network. The generalised trip cost under each relevant modes / options should be calculated. It may be that the most cost effective option is where a corridor is serviced by several modes, e.g., walking or cycling for part way <1 kms, bus or light rail for distance up to 30 kms and rail for >30 kms (as heavy rail is most cost effective at long distances). The identification of all relevant options usually bring to the fore the best value for money option, best practical environmental option, best engineering solution or the best practicable means option.

A project's relationship to other projects proposed by the transport agencies should be explored and described. A proposed project may be complementary to other projects, in that it serves to enhance the impact of other projects, or may possibly reduce their effectiveness. The relationship to other projects is likely to be more significant in urban areas where many parts of the transport network may be affected by a change to one road link or changes within an area.

By identifying technical, environmental or public acceptability issues etc up front, some project options can be quickly and easily deleted because they fail to satisfy constraints, e.g., legislative and practicability constraints.

Where a wide range of options are generated, it is not usually necessary to perform a CBA on all of them. Options can be grouped on the basis of similar characteristics and analysis only undertaken on a representative option from each group. Alternatively an iterative process can be used with coarse and fine evaluations being undertaken.

The First Year Rate of Return (FYRR), which helps to identify the most economically efficient time to construct the project, can also be applied to reduce the number of options under consideration.

Determine the level of the evaluation to be undertaken

The selection of the appropriate level of evaluation is important. There can be individual projects, linked projects or programs of projects as part of a series of related expenditures to meet particular objectives or route upgrades.

The following categories provide guidance on choosing the appropriate level of analysis. Note that the term "job" refers to an individual item of capital or maintenance investment such as those normally represented by a single entry on a program of works. Jobs are often defined at a relatively segmented level for project management or budgeting reasons. The term "project" is used to refer to a single job or a group of jobs that stand alone to meet a particular network objective.

Where jobs are interdependent, i.e., where they depend upon implementation of other jobs for the realisation of their benefits, they should be assessed as one project. An example would be a new bridge with an associated deviation.

Where jobs (projects) are linked, i.e., where they are part of a program of works to upgrade a road corridor or the upgrading includes projects that have a common objective or objectives, it is recommended that they be assessed as one project. The substantial upgrading of a whole road (or link) over a period of time would be the most common example of this. Once the evaluation of a program has been completed, the projects within the program can be separately evaluated. The evaluations of these individual projects may be used to identify projects within the program that return the most benefits or enable individual projects within the program to be scheduled for funding and completion. Note that benefits from a program may be greater than the sum of benefits from the individual jobs comprising the project.

Where jobs are not interdependent, they may be assessed on an individual basis.

Identify and calculate quantifiable costs and benefits under the Base Case and each option

Transparent assessment of all options is paramount. As discussed above, the selection of a particular mode, such as rail, light rail or a busway, should be accompanied by a transparent assessment of the reasons for the selection. This assessment should include a full analysis of the benefits and costs of alternative modes.

All relevant, quantifiable costs and benefits are to be incorporated in the cost-benefit analysis. The taxonomy in relation to economic costs covers four cost categories:

Project Costs

Project costs should be itemised in a structured manner. This is necessary for a variety of reasons. Firstly, different assets will have different lives and therefore different residual values at the end of the appraisal period. Secondly, the operational and maintenance costs associated with different elements of project infrastructure are likely to vary.

Project costs include:

- Capital - includes land, construction, infrastructure, IT & system costs & environmental impact amelioration / mitigation costs (base case costs and asset renewal)
- Planning & design, surveying and preparation

- Set up or establishment costs
- Annual operating & maintenance costs
- Contingency

Finally, a detailed breakdown allows the make-up of infrastructure costs to be better understood. In particular, it:

- Minimizes the risk that costs are overlooked;
- Focuses attention on areas of greatest significance to the total project cost; and
- Permits closer attention to areas where there are uncertainties and risks in estimating the costs of a project.

Some rules in estimating costs for cost-benefit analysis are:

- Value all costs in a CBA at their 'social opportunity costs'. For most investment costs, the social opportunity cost will be the same as the market price.
- Value land at its market price at the time of commencement of the project, even if it has been acquired in the past at a lower or higher price, because this represents its opportunity cost. If the land has already been acquired, use market price net of selling costs. If the land is yet to be purchased, include all acquisition costs. Land that is required for access purposes, having no alternative use, has a zero opportunity cost. Do not value it at the price per square metre of surrounding land.
- Whole of Life Cost - Rather than focus just on construction cost, the economic analysis that should be adopted should focus on whole-of-life cost that represents the present value of all future expenditure for a project option over the analysis period.
- Buildings or houses that have to be demolished to make way for the project should be valued at market prices (net of selling costs), plus demolition costs minus scrap or residual value. Labour costs should generally reflect market rates with an allowance for labour on-costs (generally around 30 per cent).
- Construction externalities refer to costs imposed on others by the construction process, for example disruption to traffic, severance, noise and dust. Refer to Appendices 4 and 7 for Valuation of environmental externalities.
- For vehicles used in construction, a rental cost should be included to cover wear and tear and usage of capital tied up in the equipment. Use social cost to value the fuel they consume, that is, exclude fuel excise.
- Estimate the amount of time required for each phase of project implementation and total the costs for each year.
- Be transparent about how the investment costs have been estimated by showing them item by item, including listing physical quantities of inputs and unit costs.

Capital Costs

Capital costs include items such as concept development, planning and design, engineering and environmental investigations, property (land) purchase and adjustment, utility adjustments, community relations, project management and project construction etc. Any project management costs that have been incurred in the past should be identified but not included and are considered as sunk costs.

Capital costs consist largely of once-and-for-all outlays. The numerous components of capital cost should be estimated as accurately as possible for each year in which they occur, i.e., if the project takes longer than twelve months to construct, an expenditure profile should be developed allocating the total cost across the years of expected expenses shown in base/price year constant dollars.

Capital costs components include

- Land costs: all land should be valued at opportunity costs; and
- Any additional costs for demolition, land clearance, site preparation should also be included.

Land acquired for a project should be included as part of the capital cost in the economic analysis and valued at current market prices. Land which has already been acquired, at a lower (or higher) price in previous years and is used in the project should also be included in the capital cost and again valued at current market prices i.e. at the base /price year. The market price is effectively its value or "opportunity cost" at the time of construction. Land should not be treated as a "sunk cost" as an alternative use option is nearly always possible for land. The value of land available for sale due to obsolescence of an existing road should be included as a cost saving.

However, where land is purchased for a specific project and only a portion of it is required for the project, the proceeds of the sale of the surplus land with the project case will reduce the incremental cost of the project, or alternatively, allocate only the value of that proportion of land in the project case which is physically necessary for the project.

Small, isolated or irregularly shaped lots of residual land are often difficult to develop. If amalgamation with adjacent property is impracticable, the resource cost of the land is its amenity value only. If amalgamation is possible, the market value of the main property with and without the addition of the small lot should be assessed.

When property does not have a market value, the two most practical valuation approaches are:

- The use of replacement cost or
- The use of proxy market value i.e. the market value of the land with its highest foregone alternative use.

The value of land and buildings should reflect the market price or the opportunity cost of the asset. Present capital values allow for expected increases in property rents. In the case of land already owned, its opportunity cost is its highest value in alternative use. If land is to be sold as part of the project, the proceeds from the sale represents the opportunity cost of land and this is treated as a benefit of the project.

Other key cost categories include:

- Construction cost, including project management costs – the administrative cost of producing a fixed tangible capital asset.
- Capital replacement costs including locomotives, wagons, cars, equipment, including installation, communication systems, tracks, sleepers, overhead wing. These costs will vary with the state of technology, train consists and engineering standards.
- Refurbishment and upgrading costs including trains, offices, railway stations, amenities, interchanges. These costs will vary with floor space and design.
- Labour training associated with the new capital project.
- Inventories – initial stock of spare components supporting the new projects
- Decommissioning costs – the costs of removing and demolishing buildings and equipment at the end of the project’s life, and restoring the site to acceptable environmental standards.

- Contingency costs – the allocation of funds to cover unforeseen circumstances and uncertainties in producing the fixed capital asset.
- Sunk Costs – these are the costs that are already incurred and hence, are irrelevant to the investment decision. However, where sunk project expenditures have a market value that can be realised (e.g. land), the potential market value is still included in the evaluation. For comparison of alternative options, sunk costs are not relevant but, while they are not included in the projects capital costs for completeness of reporting a reference to any sunk costs applicable to the project should be identified.

It is important that the estimate of mean capital costs be as accurate as possible. In this regard, care should be made to determine if the available costs are “strategic” or “conceptual”.

A ***strategic estimate*** is a first-order estimate of the cost of the proposed project based on broad requirements and general type of terrain, classification of the roadway, identification of possible interchanges etc. Strategic estimates can be used to obtain general approval-in-principle and for discussion purposes prior to undertaking further studies and incorporated in Project Scoping Proposals. Occasionally it may be appropriate to evaluate options using a "strategic estimate" with the "concept estimate" only being used for the preferred option. The strategic estimate covers the same categories as concept estimates, but at less detail.

A ***concept estimate*** is prepared during the project’s concept and development stages, and finalised following the determination of the Environmental Impact Assessment and the finalisation of the project development.

The RTA (now RMS) Project Estimating Manual presents and discusses concepts estimates and provides appropriate estimate method to use for cost-benefit analysis of road projects. It is based on the project schedule and assumed funding allocations as required by the project schedule. Refer to Project estimating.

See also RMS Global Strategic Rates which provide broad strategic information on historic costs that might be useful in preparing the first strategic estimate of cost for a new proposal based on historical data. See RMS Global Strategic Rate .

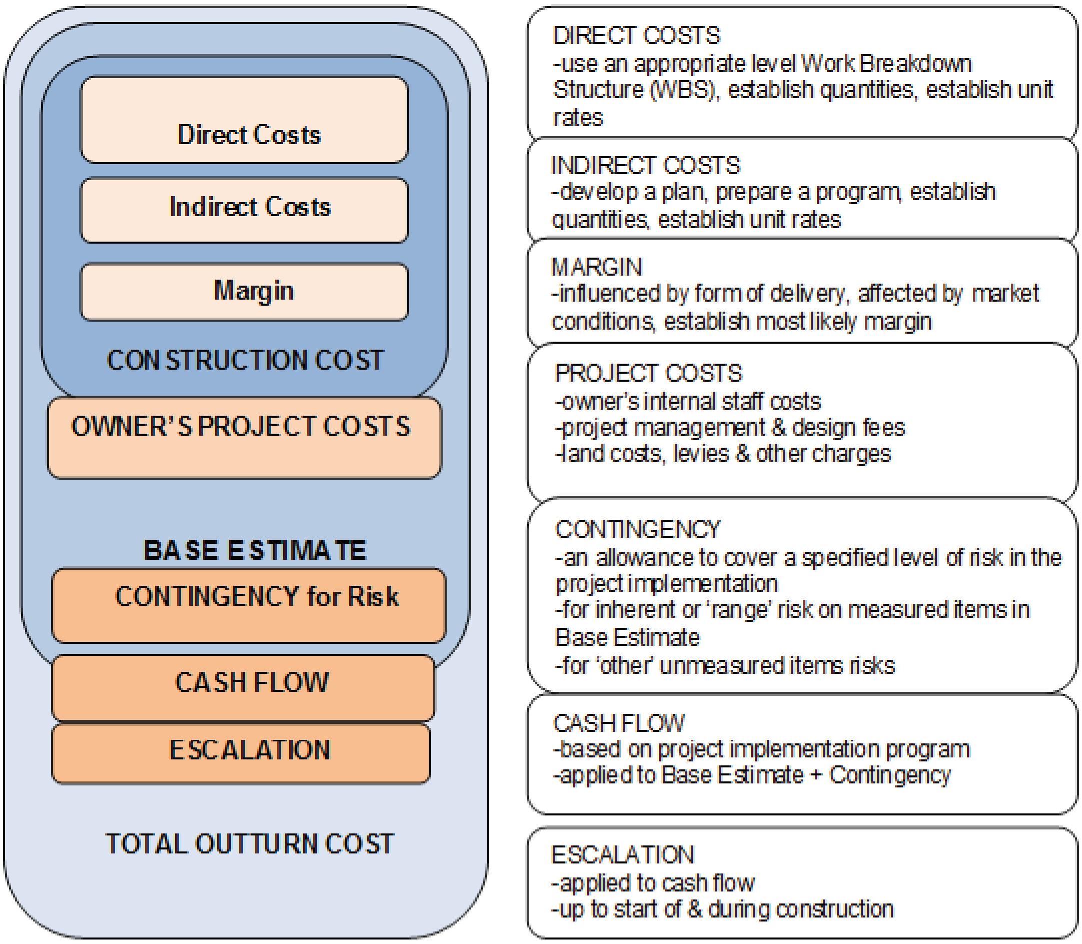
For rail projects, RailCorp has followed the ***Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction*** published by the Commonwealth Department of Infrastructure and Transport. The Best Practice Cost Estimation Standard outlines the project cost estimate which includes the following components: (see also Figure 2.1) Refer to Cost Estimation for more details. The Standard sets out the following cost categories:

- A base estimate comprising the sum of construction costs and client’s costs
- Direct cost: for road projects, direct costs may include costs for environmental works, temporary works, traffic management, public utility adjustments, earthworks, retaining walls, drainage, bridges, tunnels, noise barriers, pavements, road lighting, road making, signage, furniture, traffic signals and control systems, landscaping, etc.
- For rail projects, direct costs may include costs for environmental works, temporary works, public utility adjustments, earthworks, retaining walls, drainage, bridges, tunnels, noise barriers, roadwork and landscaping, car parking, stations, buildings, facilities, track works, overhead wiring, signalling, rail communications, power supply and distribution, trackside protection, etc.
- Indirect costs: contractors’ site establishment, management and supervision. Depending on the form of procurement, design cost may be included if the design is undertaken by the contractor.

- Margin: contractors' normal profit margin.
- A contingency allowance that is applied to the base estimate to reflect the required levels of confidence with the estimate to cover additional costs for inherent risk and contingent risk. Inherent risk can be thought as the variability in the estimate for direct and indirect cost items. Contingent risk is for those items that are not listed in direct and indirect cost items to cover events such as abnormal weather, contaminated grounds, etc.
- Cash flow applied to the base estimate plus contingency based on the project program.
- The Best Practice Cost Estimation Standard notes that a key element of the cost estimate is the inclusion of a realistic contingency allowance. A realistic contingency is estimated based on the cost variation of similar projects and similar project work items. There are two basic questions that need to be answered in order to establish the contingency allowance:
- What is the risk profile of the project; and
- What level or probability of risk occurring should be allowed for in the contingency.

The risk profile is based on an assessment of 'inherent' and 'contingent' risks, i.e., those items not listed in the base estimate because they are unknown or loosely identified and may not occur.

Figure 2.1 Components of a cost estimate



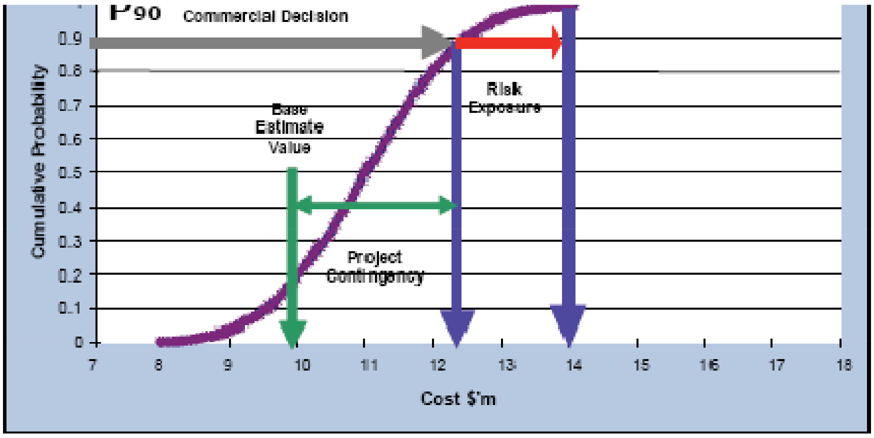
Source: Evans and Peck, Best Practice Cost Estimation Standard, p 28

Typically contingent risks include weather impact, industrial issues, geo-technical investigations and potential claims from contractors. The contingency allowance should be estimated by one of the following two methods:

- A probabilistic method – identifying the cost components, determining the likely range of each component and undertaking a computer simulation process (e.g. a Monte Carlo or similar analysis) to generate a probability distribution of project costs; or
- A deterministic method – this is achieved by manually applying a percentage to either individual cost elements or to the aggregate cost estimate.

While road and rail agencies in Australia use both methods, the Standard recommends the use of the probabilistic method wherever possible. When contingency is calculated using the probabilistic method, the risk is represented graphically by an 'S' curve, as shown in the figure below.

Figure 2.2: Probabilistic cost curve



Source: Evans and Peck, Best Practice Cost Estimation Standard, p 16.

The contingency allowance is expressed as a 'P' or probability value. Funding agencies typically require P50 or P90 values, and sometimes mean values. These terms are defined as follows:

- P50 represents the project cost such that there is a 50 per cent likelihood that the project cost will not be exceeded.
- P90 represents the project cost with sufficient risk provisions such that there is a 90 per cent likelihood that the project cost will not be exceeded. P90 represents a conservative position, one that has only a 10 per cent chance of being exceeded.
- The mean expected costs are the weighted average costs.
- Concept estimates should be based on project concept design, and based on work to be undertaken as detailed in the project schedule.

Cost-benefit analysis is conducted at various stages of project delivery. A CBA should generally adopt (at each stage) the most accurate costing available at the stage plus appropriate contingency. Other cost estimates may be included as sensitivity tests or for budgeting purposes.

The relevant transport agencies and TfNSW Project Management Office can provide best practice cost estimates for specific projects. There are also some benchmark and reference costs estimated for some works which could be used for strategic cost estimates. See Table 51 of Appendix 4 for some of these works such as a new arterial road, road widening, on-road cycleway, pavement resurfacing, pedestrian crossing or over or underpass and traffic calming.

Recurrent Costs - Operating and Maintenance Costs

Recurrent and user costs are ongoing costs when the project is operational.

The operating parameters of recurrent costs include:

- Current and projected prescribed levels of service;
- Projected rate of growth in business;
- Levels of service expected for peak and off-peak periods;
- Current and projected numbers of passengers / motorists;
- Current and projected levels of freight; and
- Current and projected rail / road statistics — for example:
    - Vehicle km
    - Train km
    - Locomotive km
    - Distances
    - Gross tonne kilometres (gtk)
    - Net tonne kilometres (ntk)
    - Track occupation time.

Recurrent costs include a number of operating costs, such as:

- Labour costs
- Maintenance costs
- Energy costs (for example, fuel, electricity, gas)
- Utility services (for example, telephone, water and wastewater services), and
- Overheads.

Routine and periodic maintenance costs including refurbishment and (capital) replacement costs that occur during the analysis period and are included as part of the project costs. Routine maintenance includes surface patching, repairing and replacing road side furniture, graffiti control, maintaining drains and culverts, cleaning and replacing lights in tunnels and controlling vegetation etc. Periodic maintenance or capital replacement includes roadway re-sheeting or resealing, roughening concrete pavements, major restoration of tunnels and asphalt overlays etc.

Estimates of maintenance costs in the Base Case and project cases are usually derived from historical expenditure figures and calculated for the desired level of service. Inspection of maintenance cost records can be used to estimate the appropriate costs. Regions may wish to use standard unit rates for maintenance activities by road type. The periodic maintenance requirements should also be included and ideally separately identified to avoid confusion and any errors. It is appropriate to show periodic maintenance separately on the cost side in an analysis under a heading periodic maintenance costs or capital replacement costs.

The difference between the maintenance costs of the base case and those of the options can be determined by subtraction. Occasionally, the new option(s) may produce cost savings; at other times cost increases (for example, due to a wider road) may be produced. Maintenance cost savings or increases must be determined for each year of the evaluation period and considered in the calculation of the CBA as addition to capital costs in case of increases or deduction from the capital costs in the case of cost savings.

Changes in maintenance costs are traditionally considered on the benefit side of the analysis, so that increases in maintenance costs in the project case are treated as negative benefits. However, to align with the whole of life cost concept and to consider the increasing constraint placed on the maintenance budget, changes in maintenance costs are included in the calculation of total project costs on the cost side of the analysis. For example, if the project is expecting maintenance cost savings, it reduces the whole of life costs, whereas if there is an increase in maintenance costs, it increases the whole of life costs.

Depreciation is not to be included and all costs are to be shown in constant base/price year dollars so no allowance needs to be made for inflation in the projections.

User Costs

These may include:

- Waiting time penalties
- Travel time penalties
- Modal shift penalties
- Accident recovery time penalties
- Accessibility costs. Accessibility is broadly defined as the variety of opportunities provided to people through efficient arrangement of land use and various modes of transport. It measures the ease with which people are able to find and reach the best suited opportunity either for work, study or others. Accessibility costs are commonly defined in a deference function which captures the value of travel time, parking costs, toll, fare and different deterrence parameters for trip purposes and transport modes.

In quantifying user costs, the appraisal must determine the category of users and the numbers in each category. For example, in passenger rail projects or programs, user costs may accrue to many passenger groups, including:

- Full fare paying adults
- Children / students
- Pensioners
- People with various social security allowances.

In estimating the value of time in passenger rail appraisals, the average time involved in waiting, travelling and changing modes must be specified. The value of time used in evaluation is specified in Appendix 4 which is based on average weekly earnings adjusted to reflect differences in travel characteristics – for example differences between business and private trips.

The average distance between nodes, for example distance between residence and railway stations is required to quantify accessibility costs if these differ between options.

Construction Dis-benefits and Secondary Costs

It should be noted that the market prices of construction may not reflect the externalities that occur in construction, such as traffic disruptions and neighbourhood disturbances. These effects are sometimes significant and should not be overlooked. For example, where disruption to adjacent landowners or to traffic as a result of road construction is likely to be significant, an appropriate cost should be included in the analysis when it occurs.

It is also important to include secondary costs that may be imposed on the community. The secondary costs may include, but not limited to, the, increased noise or severance, traffic delays due to construction activity, impacts on access to services industry productivity etc. Attempts should be made to identify and where possible value these costs.

For instance, the cost of delay due to traffic as a result of a road construction can be estimated using the following formula:

$$Cost\ of\ Travel\ Time\ Penalty = \frac{TTV\ x\ ADV\ x\ VPH\ X\ H}{60} \qquad Equation\ 2.1$$

where:
TTV is the weighted average travel time value, per vehicle hour;
ADV is the average delay per vehicle, in minutes;
VPH is vehicles per hour
H is the duration of traffic, in hours

For example, given the following traffic parameters, the cost penalty is estimated as follows:

	Example (1):	Example (2):
Traffic Parameters:		
TTV	$23.39	$23.39
VPH	200	400
ADV	1	5
H	2	2
Cost penalty for travel time:	$155.94	$1,559.47

Some assumptions and adjustments will have to be made on whether the traffic delays occur only during peak periods and on the percentage of traffic flow during the peak periods.

Identify Benefits

The effects of capital projects can arise in many different forms and many of the effects represent different economic manifestations of a single result. For instance, travellers will often value faster journey times but improved travel times lead others to change their choice of residential location. This can alter the supply and demand for housing, leading to higher or lower housing prices and rents. While increased rents reflect an increase in the economic value of housing it would be double counting to add this measure to the value of travel time savings since such rents stem from an economic chain reaction namely the capitalisation of improved travel times.

Health benefits represent another example. Population health can improve when the use of public transport results in higher air quality. It would be double counting however to add the value of improved health (reduced incidence of disease) to the estimated value of improved air quality if the estimation method employed in valuing air quality accounts implicitly for health gains. In this example double counting arises not from a failure to recognise an economic chain reaction but rather failure to recognise overlapping measuring methods.

Principles in identification and measurement of benefits

- Ensure that important effects of the program, project or policy have not been omitted as this will lead to significant underestimates of total benefits;
- Comprehensive identification of costs and benefits are reflected;
- Avoid double counting benefits;
- Use time and resources effectively, weighing the cost of conducting additional analysis against the usefulness of additional information on benefits.
- Some categories of benefits may not be assessed either because they are expected to be small or because the costs or time needed to quantify them far exceed the time or resource levels appropriate for analysis of a particular project / policy.

Applying this approach to benefit assessment involves first conducting scoping analysis to collect available information on the potential benefits of the project and using this information to develop preliminary estimates.

Benefits of transport projects in a cost-benefit analysis:

The following are the most common benefits in transport.

User benefits and non-user benefits

- Travel Time Cost Savings
- Vehicle Operating Cost (VOC) Savings
- Accident (Crash) Cost Savings
- Induced and generated trips
- Improvement in Environment
- Improvements in Network / Service Reliability
- Passenger comfort due to improvements in amenities

Agency and other benefits

- Avoidable capital and recurrent costs
- Asset sale proceeds
- Incremental revenue

The direct user and non-user benefits are discussed in more detail below:

Travel Time Savings

Travel time costs are the cost of time spent in travelling. They vary with the amount of time spent in travelling as well as with the disutility (the discomfort and lack of amenity) of the travel mode.

The value of travel time in leisure is subjective, and many studies have produced varying estimates.

The value of travel time estimates for urban and rural travel and different travel modes are set out in Appendix 4 of these Guidelines which provides unit values for vehicle composition during major periods of the day, assumed vehicle occupancy, time values per person and average hourly value for travel time.

The road travel times are estimated using Austroad's Updates for Road User Cost (RUC) Unit Values[2] which is combined with average vehicle occupancies and flow periods to calculate the weighted average hourly value for travel time.

Accurate valuation of travel time savings depends on accurate estimates of travel times, traffic composition, vehicle occupancy and the proportions of private and business travel. If there is any reason to believe that the average values from Appendix 4 are not applicable to a particular project, project-specific data should be collected and evidence of project specific value of travel time savings should be presented in economic appraisal report.

The travel times for the Base Case and each option should be estimated for each traffic flow period, for several future years. The times should be split between light and heavy vehicles.

It is not necessary to calculate travel times for each future year as this would result in extensive calculations. It should be sufficient to calculate travel times every 5 or 10 years, using either speed-flow curves or modelled output and interpolate intervening years and extrapolate final years.

However, attention should be paid to the effects of traffic growth on capacity and thus speeds, particularly where traffic demand is approaching capacity, so that the onset of deteriorating speeds and queuing is properly assessed. The year(s) for which detailed land-use projections and traffic estimates are available should also be individually assessed. The selection of future years for assessment can accommodate this.

The travel times for each period can be simply calculated from the average vehicle speed and the road length. Where a road length varies in character, it will be necessary to calculate average speeds and travel times for separate stretches of road. Urban models will compute this automatically. Modelled speeds may also include some allowances for delays at intersection.

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[2] Austroads Report "Guide to Project Evaluation – Part 4: Project Evaluation Data Updated Road User Effects Unit Values", March 2012.

Travel modelling usually produces two travel or patronage forecasts for two outward periods, usually after 10 years and then 20 years from the base period. The traffic or trip forecast for the intervening years are interpolated. For years after the 20 year period, the convention is to leave the traffic or patronage constant unless there is a very strong reason to assume that there will be a continuing growth and saturation will not ensue.

Once the travel times for the Base Case and the options for each flow group and vehicle category have been determined, the travel time savings can be calculated by subtracting the base travel times from each option. The value of travel time savings can then be calculated for each vehicle category, using the appropriate value of time per vehicle hour. These calculations must be repeated for each year under study and interpolated or extrapolated for the whole evaluation period.

Vehicle Operating Costs Savings (VOCS)

Vehicle operating costs (VOCs) are the cost to the owner of operating a motor vehicle. In determining VOC cost savings, the costs for each class of vehicle are a function of the price of running cost inputs, length of the road section, traffic volume and composition on the section and can vary by road roughness condition, gradient and vehicle speed. On this basis, VOC is made up of the following components:

- Basic running costs (fixed & operating costs) of vehicles such as depreciation, fuel, repairs and maintenance
- Additional running costs due to road surface
- Additional running costs due to any significant speed fluctuations from cruise speed
- Additional fuel costs due to stopping such as queuing at traffic signals

Note that in CBA, commensurate with other values, fuel is valued as a resource cost i.e. excluding excise and GST.

Methods for calculating VOCs vary depending on the type of traffic model and its outputs. Macroscopic models usually report the traffic volume and average speed on each road link. VOCs can be calculated using the speed-based VOC models presented in Tables 11 to 14 in Appendix 4 based on Urban Stop Start and Freeway models.

Microscopic models generally report vehicle kilometres travelled and numbers of stops. (Refer to Table 15 of Appendix 4).

For rural projects, Appendix 4, Tables 26 to 42 provides detailed tabulations of VOC per vehicle kilometre for different vehicle types, speed, road types and road conditions (gradient, curvature and terrain and roughness).

Safety Benefits and Accident Cost Savings

Road Safety Strategy targets reductions in road fatalities.

The objective is to reduce the trauma and costs to the community of road deaths and injuries. The cost of a crash to society is the value of the trauma and property damage caused by the crash.

Safety benefits are estimated by calculating the Base Case crash costs minus the project case crash costs for each year of the evaluation period. The costs can be evaluated either by:

- Utilising historical accident records for the roads making up the project and estimating the future the crash rates, type and severity and then multiplying them by the estimated cost of crashes.
- Using standard crash rates per category of road multiplied by the estimated costs of crashes. The crash rates per road category are based on observed relationships between crash numbers, vehicle flows and road category.

The estimated cost of crashes (crash cost values) can be found in Appendix 4. The costs are expressed using human capital or willingness to pay values. NSW Treasury recommends that analysis be undertaken using both methods for a period to gauge the degree of significance of the change in appraisal results due to two approaches.

Where a serious accident record is evident it may be appropriate to assume a "do-minimum" in the base case in which some remedial safety measures will be carried out, resulting in fewer crash numbers in the base case. This may reduce the relative benefits of other options under evaluation, but uncaptured benefits are captured in the investment for “do minimum” measures.

The benefits for each option can be determined by estimating the likely number of accidents prevented (fatalities or injuries) multiplied by the relevant accident cost.

The value of statistical life (VSL) is the parameter used in evaluation of safety benefits in economic appraisals of infrastructure or related projects. A literature review (Appendix 4 Table 53) indicates that VSL ranges from $2m to $11m covering various countries. A study conducted for the then Roads and Traffic Authority (now Roads and Maritime Services) estimated the value that the NSW community is willing to pay or forego in exchange for a reduction in the probability of crash related injuries and death using a stated choice (SC) methodology. This value was estimated to be $6.41million in Dec 11 prices, which had been officially endorsed by the then Roads and Traffic Authority and acknowledged by TfNSW and NSW Treasury.

The cost of accidents classified according to accident outcome, road type and accident type is provided in Appendix 4.

The cost of each alternative treatment can be estimated by reference to standard costs of standard treatments, or estimates can be made from first principles.

Appendix 4 presents the types of accidents and treatment types and standard treatments used in Road Safety Cost Benefit Model.

With regards to rail projects, new projects are ranked according to their category and funded accordingly. One of the categories is safety and the safety projects usually have first call on resources because of their nature, but they still require economic and financial evaluations.

In a road – rail level crossings for grade separation project example[3], accident savings was calculated using incident history data, which include reported:

- Near misses;
- Gate or boom strikes;
- Incidents involving actual train/vehicle or train/pedestrian accidents.

In the example, a near miss is assumed to be equivalent to 50% of an actual incident since these near misses are an indicator of risk and also a source of trauma, especially to train drivers. A boom strike is equivalent to 25% (of the economic cost of an accident). Boom strikes result in significant costs as, in addition to the damage, they cause the crossing to be closed causing delays to train travellers and road users. In addition if trains queue up they can cause adjacent level crossings to remain closed, compounding the impact on road users. A total weighted incident rating for the road-rail crossing site is calculated by taking 100% of actual incidents, 50% of near misses and 25% of boom strikes.

These assumptions were applied to the accident data to give an estimated annual accident saving, which is then adjusted for future years in proportion to forecast traffic growth.

From the data, the rate of all accidents at the crossing that would be saved was estimated under the grade separated option

[3] Example from Public Transport Victoria, VicRoad, Prioritising Road-Rail Level Crossings for Grade Separation using an MCA approach, Jonathan Taylor, SKM & Russel Crawford, VicRoads

The number of adjacent accidents saved through grade separation will vary considerably from site to site, depending on the details of road layout changes surrounding the rail crossing. Furthermore, with a road underpass or overpass solution (in which the rail track vertical alignment is unchanged) it is possible that pedestrian crossings of the rail track would still occur, with the attendant risk of continued incidents.

There are attendant delays to train services too due to these incidents and these are avoided if appropriate treatment of the level crossing area is implemented. The valuation of these avoided delays should be included in the benefit valuation of the project.

Improvements in Travel Time Reliability

Travel time reliability refers to reaching the destination in a consistent journey time. Value of travel time reliability is estimated from the reduced travel time variability and associated buffer time that drivers have allowed for before making trips. Chapter 7 provides more detailed guidance on measuring and valuing reliability benefits.

Avoidable capital and recurrent costs

Avoidable costs are costs incurred in the Base Case that can be avoided if an alternative is implemented. In the with/without project comparison they are capital and recurrent costs that are incurred between the present day and the end of the evaluation period.

Asset sale proceeds

Where there is a market for an asset, the proceeds or revenues from the sale of an asset can be estimated based on the asset's market value. This would be the case if, for instance, a piece of surplus real property along rail corridor or rolling stocks were sold. However, given the specific function of rail assets, there are, in some instances, few alternative uses for the asset outside the rail industry and hence there are very few secondary markets for rail assets. Under this scenario the asset is deemed to have no value and may be considered a sunk cost.

Incremental net revenue

Incremental net revenue can be estimated using the following information:

- The projected number of passengers and tonnages of freight;
- The composition of passenger and freight type;
- The types of passenger fares and freight rates; and
- The costs involved in earning the additional revenue.

It may be necessary to calculate an average fare and apply it to the total number of passengers. The costs involved in earning the additional revenue are subtracted from the gross revenue to obtain incremental net revenue.

The inclusion of incremental net revenue as an economic benefit is appropriate when a project is expected to lead to lower costs for a given route and increased traffic or patronage levels or a new passenger rolling stock is expected to lead to higher passenger numbers than would otherwise be the case. Where evaluations are mainly concerned with improved efficiencies and lower costs, and there is little prospect of changes in traffic or patronage levels, the inclusion of incremental net revenue is inappropriate. Also, where any changes in traffic and patronage levels lead to additional train running costs, the resource benefits of the options will be picked up by comparing these costs. Any additional revenue included would constitute double counting.

Benefits to the Broader Community

Induced and Generated Trips

Any increase in total travel over the entire transport system that results from a change in transport system capacity is considered as the induced trips. Some induced trips may results from short-term responses to transport system capacity changes, while other induced trips may result from longer term location decisions by households, employment and other facilities. With a new or improved transport facility, people tend to use the new or improved facility in place of existing facility. These trips are commonly referred to as diverted trips. Trips that people change from one mode to another are referred to as mode shift trips.

The benefits derived from induced trips contribute to the consumer surplus and can be calculated using the "Rule of Half" (ROH). (Refer to Chapter 6 and Appendix 9 for a more detailed discussion of ROH and alternative measurement approach).

Improvement in Pedestrian safety and amenities

Benefits should also include effects on pedestrian and other road users' safety.

Pedestrian accident costs are estimated from the number of pedestrian accidents and the unit cost per accident.

Pedestrian safety benefits should be evaluated when a project is expected to reduce pedestrian crash occurrence (see Appendix 4 Section 4 for discussions and values for accident costs by type of accidents, average crash cost by road type, and by vehicle type).

For example, a project that will improve the connectivity and amenity of pedestrian link between Wynyard and Barangaroo is expected to generate significant de-crowding effects, removal of queuing on footpaths and pedestrian crossings. Similar to passengers, the benefit to consider is a reduction in travel time expressed in term of in-vehicle factor (IVT). There are also changes in the level of safety from reduced potential pedestrian – vehicle conflicts.

Transportation projects often involve construction and improvements to amenities, which are considered as perceived benefits to public transport users. The amenity improvements may include improvements to vehicles in terms of cleanliness, seating characteristics, comfort as well as improvements to surrounding infrastructure facilities such as shelter, CCTV and lighting, especially at interchanges of bus and rail stops.

Valuation of amenities is conducted using an equivalent IVT factor. The IVT factor is determined mostly by stated preference valuation surveys which represent passenger's willingness to pay under different scenarios and is an incremental value (difference between improvement and base case).

The Australian Transport Council (ATC) National Guidelines for Transport System Management in Australia provides indicative IVT parameter values used in the valuation of amenity improvements for both vehicle and infrastructure (Volume 4). For example, the parameter value of 0.3 IVT of a train station that has good platform lighting is equivalent to 18 seconds reduction in commuter's travel time. In addition, improved comfort and ventilation in buses such as having air conditioning is valued at 1.0 IVT which is the same as a reduction of 1 minute in travel time.[4]

The methodology to value amenities is similar to that of estimating travel time savings. The value of travel time savings parameter is multiplied to the reduction in total IVT associated with the amenity improvement. A total package of improvements which includes improvements such as shelter, CCTV and lighting, is expected to be valued lower than the sum of the individual components (assume 50% of the total to adjust for overestimation).

A measure of the change in public realm quality brought about by a proposed project or intervention is also available through the use of an approach called Pedestrian Environment Review System (PERS), a tool which allows quantification of the quality of the existing and proposed public areas.

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[4] While most sections of the National Guidelines has currently been refreshed during Stage 1 and Stage 2 review, the section relating to public transport will be dealt in Stage 3. Thus, new values may replace these values and these will be included in the future update of the Transport Principles and Guidelines.

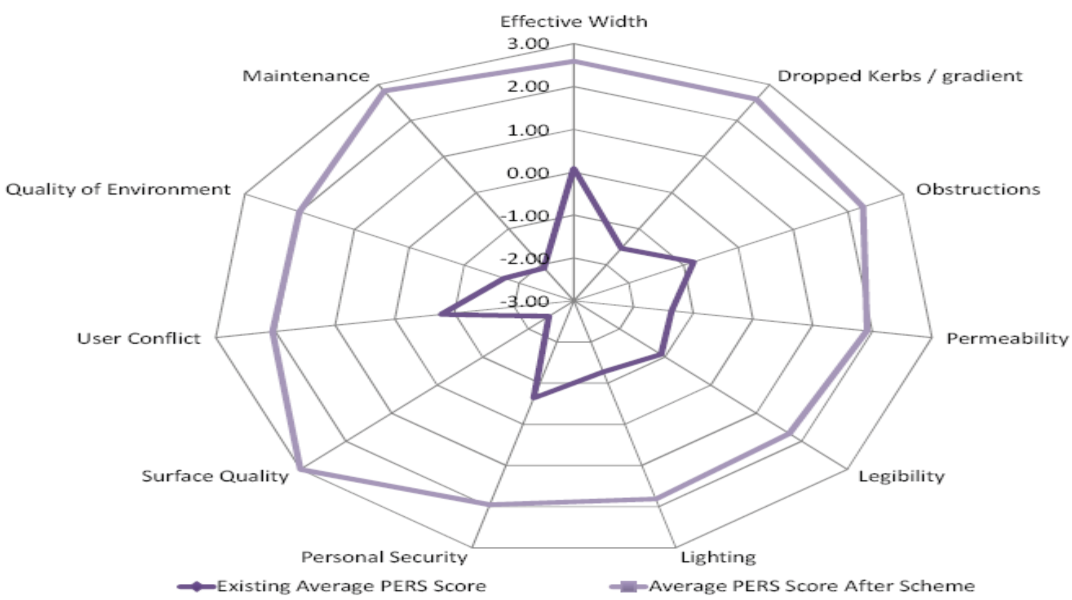
PERS can assess infrastructure provision of links and public spaces by placing scores (e.g. lowest score -3 (very poor) highest score +3 (very good) on a scale on a number of established characteristics such as:

- Lighting
- Quality of surface
- Effective width
- Obstructions
- Permeability
- Security
- User conflict
- Overall quality of environment

Pedestrian facilities and public spaces can be linked (footway, street, or highway) where the public can informally rest and enjoy. Such a space may or may not be a definable area and can range in scale from a small plaza to a city park and pedestrians may use all or part of the space as a route. It can be a space for social activities with things for people to see and do.

The diagram below shows the improvement to the public realm generated by a proposed interchange or network hub improvement project. For link characteristics, the scheme proposals improve the PERS scores for surface quality and maintenance as well as the quality of environment within the study area. For public spaces, there is a dramatic improvement in all PERS characteristics, e.g., ‘moving in the space’ and ‘feeling comfortable’ attributable to the pedestrianisation of these areas and reduced dominance of road traffic, making the spaces accessible to all types of users.

Figure 2.3: Change in PERS Scores for link characteristics



Reduced Environmental Externalities

Mode shifts and congestion relief generate related environmental benefits and social cost savings associated with associated with reduced emissions and greenhouse gases. They accrue in various degrees to public transport users, road / highway users and to the community as a whole.

The inclusion of 'externalities' and in particular environmental impacts is an important part of an economic assessment as well as being a formal part of project evaluation within the Transport portfolio and must be seen as an integral part of the broader economic appraisal process. The objective is to internalise environmental externalities into the decision-making process on the basis that the environment is not a free good.

The external and environmental effects to be considered are:

- Noise
- Vibration
- Severance
- Visual intrusion (scenic quality)
- Other environmental issues from the Environmental Impact Assessment, e.g. air quality, water quality, heritage, ecological
- Local disturbance due to construction
- Upstream and downstream effects.

The effects of a road project or project options on the above should be quantified as far as possible. The assessment and quantification of environmental effects should be considered in the project evaluation as early as option selection phase. The scale of these effects needs to be assessed for any proposed project and project options, together with the project costs, relative to the benefits of the proposed scheme.

The assessment undertaken during the Environmental Impact Assessment can be used as the basis for environmental assessment within the economic evaluation.

The benefits and costs due to the project’s impact on the environment are not readily traded in market. For these non-marketed effects, several different valuation approaches can be used.

The different valuation principles currently in use for evaluation of road infrastructure projects can be classified as follows:

- **Effects for which prices exist**

  Market-based values are available and provide useful information for project evaluation. Consistent treatment of taxes and subsidies are required throughout the evaluation. Where market prices are distorted through monopoly, regulation or failure to internalise external effects in the analysis (externalities), it may be necessary to take these distortions into account, to maintain consistency in the evaluation. The prices obtained in this way, such as the social values of project effects are sometimes referred to as "shadow prices"
- **Effects for which prices can be imputed from quasi-market observations -** No direct market exists, but values can be inferred from observed or stated human behaviour. The principal method is the use of "revealed preferences" or "stated preferences"
- **Effects for which surrogate prices can be used -** Indicators such as the cost of replacing a lost asset or amenity are used as a surrogate for foregone benefits. The methods used here may provide helpful indications of minimum and maximum values.
- **Effects indicated only by use of quantitative physical measures -** This category comprises effects inappropriate for use with one of the methods above, e.g., noise unit.

Effects indicated only by use of qualitative description

A general trend has been a methodological increase in the estimation of unit prices in the above method categories. For example, noise effects range, from initially qualitative statements associated with point scores, through quantitative annoyance assessments based on defined annoyance units to economic noise cost estimates made using prices inputted from quasi-market observations or surrogate prices.

The amount of work done on measuring, predicting and assessing intangible effects depends on both the severity of the effect and the amount of difference there is between the existing situation and the various improvement options. For minor works, it is possible that there will be no significant differences in the various intangible factors between the options. In these cases, a note to that effect is all that is required.

Even if the intangible effects are quite major, there may be little difference between the existing situation and any of the options. In this case, the existence of the effect and the similarity between the options should both be noted. More detailed investigation will usually not be warranted.

If there is a significant difference between options, either in total effects, or if there is a change in the distribution of effect so that there are clear gainers and losers, more detailed examination will be necessary.

Table 61 to Table 63 of Appendix 4 present the environmental parameters for passenger cars, buses, freight vehicles and trains. Section 3.3 of Chapter 3 provides the explanations on how these parameters can be used in transport project evaluation.

Consumer surplus from induced trips

Consumer Surplus is a measure of benefits defined as the difference between what the customer is willing to pay and the actual amount paid. The consumer surplus can be calculated using the fare elasticity, which is readily available. RailCorp (now Sydney Trains) has derived a methodology for estimating the consumer surplus by integrating the demand function which is in the form of a negative exponential and a function of the fare.

The provision of new transport infrastructure or a new transport mode can result in induced trips. The benefits derived from induced trips contribute to the consumer surplus and can be calculated using the “Rule of Half” (ROH).

Theoretically, the logsum approach is more accurate because it is based on actual demand curves, while the ROH approach assumes the linearity of the demand curve as shown in Figure 1 of Appendix 9. However, the logsum approach has not been used often in actual economic appraisals. This is because the logsum is essentially the sum of utilities which has no unit, while in conventional economic appraisal, benefits are directly estimated in dollar term. To convert the utility into dollar term, analyst must know the marginal utility of income, which varies from the project specific surveys and there is no formal guide on how it should be derived. In addition, logsum is estimated as the total of utilities.

Although it is possible to separate the utilities for different attributes (e.g., fare, travel time or comfort), it is not easy to estimate conventional transport benefits in terms of value of travel time savings, vehicle operating cost savings, accident cost savings and transport externality benefits. Finally, in some projects, transport demands are not estimated from utility models in which logsum can be calculated.

TfNSW recommends that consumer surplus benefits continued to be estimated using the ROH approach. For certain projects where the logsum from the utility models can be readily estimated and the marginal utility with respect of income is available, the logsum approach can be used in economic appraisal with appropriate cross-check with benefits estimated from ROH approach. (Refer to Appendix 9 for more discussions on Rule of Half and LogSum approaches in measuring consumer surplus.)

Cross modal and network effects

In identifying and valuing costs and benefits, it is important that the cross modal (or multi-modal) and network effects are taken into account. Cross modal and network effects are likely to occur when the project changes the demand for use of other transport infrastructure, in addition to the infrastructure being upgraded, regardless of mode. As a result of an improvement to infrastructure, there could be diverted demand in the form of passengers switching from an alternate mode or route e.g. an urban road improvement that reduces traffic on other routes. In addition there may be increased demand for use of the project infrastructure may increase demand for use of other infrastructure e.g. an upgrade to part of a highway or a rail service could increase demand for complementary parts of the same highway or a railway.

Typical situations of multi-modal effects are:

- An investment on passenger rail would reduce car use, alleviate road congestion and mitigate negative environmental impacts.
- A road project aiming to eliminate bottlenecks might improve traffic flow and travel speed for a large area of road network. The project might improve bus on-time running thus boost bus patronage.
- Network effects may also refer to corridor impacts. When a major transport corridor (e.g., Pacific Highway) is upgraded in stages or by sections, the total benefits delivered by entire corridor might be more than the sum of benefits of individual sections. The additional benefits are mainly generated from freight transport, in that higher productive trucks can be used for inter-state transporting.
- The construction of a new high speed rail route between capital cities has an impact on air travel as the lower generalised cost of high speed rail, compared to the cost of air travel decreases the mode share of air travel.

The CBA for the improvement should incorporate the effects of the improved project on other roads or facilities in the corridor.

The amount of diverted traffic can be estimated using the cross elasticity of demand. See Table 69 in Appendix 4 for direct and cross elasticities of demand with respect to price. A change in generalised costs resulting from the improvement and elasticity of demand can be used to estimate the induced traffic.

The additional network benefits can be calculated (recommended by ATC) using the volume of diverted and generated traffic multiplied by the difference in the marginal social cost and the marginal perceived price paid. The marginal social generalised cost includes externalities, safety and infrastructure operating costs. There are no additional network benefits or costs if the diverted transport users pay the full social cost of the service from which they have been diverted.

If the perceived price paid is below the marginal social cost then there is a benefit.

The improvement could reduce or increase congestion costs on other parts of the network which should be incorporated as a network effect.

Community Economic Development Benefits

Transport development can increase the value of commercial and residential properties. Increases in property value that enter the CBA framework are those arising over and above the effects of travel time savings on rents. Transport investment improves the accessibility for new and existing transport users in catchment areas, which is often translated into enhanced land values or commonly referred to as land value lift.[5] Such increases represent non-user benefits, namely

5 See Lari, A Levinson, D. Zhao, Z., et al (2009) value capture for transportation finance: technical research report, Centre for Transportation Studies, University of Minnesota & Densmore, K. and Mulley, C., (2012). Accessibility and residual and value lift: Identifying spatial variations in the accessibility impacts of a bus transitway, Institute of Transport and Logistic Studies, University of Sydney.

consumers' willingness to pay for locational attributes associated with urbanisation that extend beyond the use of rail bus or transitway as a travel mode.

Low-income mobility benefits

Low income mobility benefits may arise in two ways:

- The availability of affordable transportation to low income people
- Budgetary savings arising from reduced social service outlays on home based health and welfare services such as home health care and unemployment benefits.

Wider Economic Benefits

The Wider Economic Benefits (WEBs) refer to the following welfare benefit (Refer to Chapter 3 for details).

- Agglomeration economies
- Increased competition as a result of better transport
- Increased output in imperfectly-competitive markets
- Economic welfare benefits arising from improved labour supply

Residual value of the project's capital investment

Some components of the investment in a project may not be made until later in the project life or there may be a significant life remaining in the asset at the end of the analysis period that may still have the capacity to accrue benefits. A simple way of accounting for this is to use residual values. Residual value is a measure of the capacity of the asset to continue earning benefits. It represents a negative capital cost or an offset to capital costs.

In economic appraisal, residual value can be estimated as the present value of future benefit stream from the end of evaluation period to the end of asset economic life.

In financial appraisal, to calculate residual value, the remaining life of the asset or project at the end of the analysis period should be expressed as a proportion of the total life of the asset. The capital cost of the project multiplied by that proportion will equal the residual value that should then be discounted in the same way as other costs and benefits.

Using the accounting approach, the residual value is estimated by determining the selling price or the prevailing market value of the asset at the end of the project life, or the remaining income stream.

Thus,

$$Residual\ Value\ = Book\ Value\ - DEPR\ (t0\ \ldots\ldots tn) \qquad Equation\ 2.2$$

where: t_0 and t_n refer to the beginning and terminal years of the project, respectively

DEPR is depreciation which could be computed using the function R'(T), i.e., getting the first differential of the residual function R=R(T), or using the conventional straight line depreciation (SLD) formula.

$$Equation\ 2.3$$

$$Residual\ Value\ (SLD) - \frac{Capital\ Cost\ x\ Asset\ life\ remaining\ after\ appraisal\ period}{Asset\ life}$$

The prevailing market price of the asset may be provided by property values or projected independently.

Another approach in residual value estimation is to equate the residual value to the interest return or earnings that the scrap value of the asset could earn if placed in the bond market. A situation where this approach could be used is when it is more efficient to retire an economic project or asset, i.e. if the marginal revenue from the project less depreciation flow is equal to the interest returns of investing the scrap or salvage value (S) of the asset in the bond market.

Equation 2.4

$$Residual\ Value\ =\ Initial\ Investment\ Outlays - Revenues$$

where revenue is equal to quantity of demand multiplied by unit price (e.g. toll or shadow toll) less operating and maintenance costs

A further method of calculating a residual value is to base it on the depreciation rates for "infrastructure systems". These values are published annually in the operating entities' annual reports in the section "Notes to and forming part of the Financial Statements…." for the particular year.

The taxonomy below represents a rigorous way of identifying and classifying benefits from transport projects:

Table 2.1: List of Benefits and Costs

Quantifiable	Unquantifiable	Secondary impacts
Investment costs	Integration	**Employment (construction & operation phases)**
Planning and design costs	Amenity value	**Tourism**
Land	Barrier effects on humans and on biodiversity	**Land values**
Site surveying and preparation	Biodiversity and ecosystems	**Industry development**
Construction costs	Heritage	**Community spirit/pride**
Negative externalities during construction	Aesthetic value	**Communication**
Legal costs	Culture	**Connectivity**
Benefits during operation	Increased comfort, cleanliness and security for passengers	**Information sharing**
Savings in vehicle/train operating costs (rent, power, fees, communications, etc.)	Reduced damage to freight and reduced pilferage	**Social cohesion**
Improved productivity / efficiency (increased service – same staff; timeliness; new service – same staff; increased capacity – same costs)	Safer workplaces; faster service, wider range of services, greater access to services, equity of access, better systems support	**Social well-being & equity**
Capacity benefits	Better asset utilisation	**Increased incomes**
Reduction in downtime; Reduced delays	Amenity value	**Access to services**
Savings in infrastructure operating costs including maintenance &	Comfort & convenience	**Production levels**

Quantifiable	Unquantifiable	Secondary impacts
administration (less staff, less overtime, less costly skills, reduced turnover)		
Savings (dis-savings) in user costs	Health	**Productivity for industries**
Savings in time costs for commuters, passengers and/or freight	Increased information accuracy	
Safety - Savings in crash costs	Faster decision making	
Reduced environmental externalities (noise, pollution)		
Service quality improvements, reliability		
Accessibility *		
Benefits associated with diverted and generated traffic		
Scrap or residual values of assets		

* Accessibility is defined as the ease with which the land use and transport system allow activities or destinations to be reached by individuals.

Calculate Incremental Costs and Benefits

The cost-benefit analysis should be based on costs and benefits of the "with project" options incremental to the base case. The most effective way of evaluating a project is to include all the absolute costs and benefits associated with the options, and then compare the options to calculate the costs and benefits of the project options(s) incremental to the base case. This method facilitates data checking, interpretation of results and any subsequent modifications.

Another method is to exclude the common amounts between the base case and the option(s) for each cost and benefit item and include only the amounts above the base case for the option(s). This method however does not provide a clear perspective on the scale of costs and benefit associated with the project. Although these two methods will produce identical results, the first method is recommended for comprehensiveness and clarity.

Discount costs and benefits

Discounting enables future benefits and costs to be evaluated at a common base year. The base year is the year that costs and benefits are discounted to arrive at a present value. The base year is usually the year in which the evaluation is undertaken and the decision to proceed with the project is made.

NSW Treasury's Guide to Cost-Benefit Analysis (2017) requires projects to be evaluated at a real discount rate of 7% with sensitivity tests using the discount rates of 3% and 10%.

Discounting is performed for two reasons:

- **Social time preference** – Income or benefits now are preferable to income or benefits in the future.
- **Opportunity cost of capital** – The capital can earn a rate of return in other sectors of the economy if it is not used in the proposed project.

Calculate the decision criteria

The decision criteria used in project evaluations are:

- Net present value (NPV)
- Benefit cost ratio (BCR)
- Internal rate of return (IRR)
- Net present value per dollar of capital investment (NPVI)
- First Year Rate of Return

Net present value (NPV)

NPV is the difference between the present value of benefits and the present value of costs. A positive net present value indicates that the project has economic merit.

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+r)^t} \quad \text{Equation 2.5}$$

where:

- t is time in years
- n is number of years during which benefits and costs occur
- r is the discount rate
- B_t is benefits in year t
- C_t is infrastructure capital and operating costs in year t

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

The use of NPV as the main reporting criterion of a project's economic worth is recommended because this enables economic benefits to be maximised. The NPV is used to compare mutually exclusive options for the same initiative, alternative combinations of related initiatives (where implementation of one affects the benefits and/or costs of another), and alternative implementation timings for the same initiative.

Benefit cost ratio (BCR)

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

$$BCR1 = \frac{PV\ of\ Benefits}{PV\ of\ Capital\ Cost \pm PV\ of\ change\ in\ Recurrent\ Costs} \quad \text{Equation 2.6}$$

$$BCR2 = \frac{PV(Benefits \pm PV\ of\ change\ in\ Recurrent\ Costs)}{PV(Capital\ Cost)} \quad \text{Equation 2.7}$$

BCR1 configuration is applied when the budget constraint applies to both upfront investment and ongoing operating and maintenance costs.

BCR2 configuration applies if the project is being paid for out of the capital fund (budget constraint applies only to the capital cost and the recurrent costs are paid out of project revenues). All agency cost incurred during the construction period is treated as investment costs and this forms the denominator of the BCR. The recurrent costs during the operating period is treated as infrastructure operating costs and included in the numerator of the BCR. As long as operating and maintenance costs are small in relation to benefits and investment costs, BCR1 and BCR2 will be close.

Benefits refer to user and non-user benefits. For transport projects, benefits usually include value of travel time savings (travel time, waiting time, access time and egress time), vehicle operating cost savings (VOCs), transport safety benefits, environmental benefits such as from reduced air pollution and noise, road decongestion, benefits derived by reduced public transport crowding and enhanced public transport amenities (e.g., station and train presentations). If Wider Economic Benefits (WEBs) are estimated, calculate BCR including and excluding WEBs.

A BCR greater than 1 indicates that the project is economically worthwhile and has economic merit. This means that the present value of benefits exceed the present value of costs. The BCR is the most commonly used evaluation criterion and used as a convenient way to express the economic worth of an initiative, and to rank initiatives from an economic efficiency perspective where there is a budget constraint.

If projects are mutually exclusive, the use of the BCR removes the effects of different scales of the alternative initiatives thus is not preferable to use.

The Incremental Benefit Cost Ratio (IBCR) is suggested to seek an optimal solution for analysis of mutually exclusive options under funding constraints. This approach determines if the additional or incremental costs of higher cost options are justified by the additional benefits gained. See Section 2.6.9-Choosing the best option-Project level analysis.

Internal Rate of Return (IRR)

IRR is the discount rate at which the present value of benefits equals the present value of costs. It provides an indication of the economic worth of an initiative without requiring specification of a discount rate.

An internal rate of return greater than 7% (or the specified discount rate) indicates an economically worthwhile project. The IRR can however yield ambiguous results if the streams of costs and benefits are not continuous over time.

NPV and IRR are usually equivalent and they offer the same insight into expected project performance provided that the discount rate used to compute the NPV is the same as the required rate of return used to say whether the IRR is “high” or “low”.

Never use the IRR to rank initiatives or to choose between mutually exclusive options as this amounts to comparing initiatives using different discount rates. It is recommended that the IRR be used only in financial analysis.

Net present value per dollar of capital investment (NPVI)

NPVI is defined as the NPV divided by present value of the investment costs, where the capital costs are those incurred to initially complete the project (NPV/PVI). NPVI is calculated as follows:

$$NPVI = \sum_{n=0}^{N} \frac{(B-C)n}{(1+r)^n} \Big/ \sum_{n=0}^{N} \frac{I_n}{(1+r)^n} \qquad \textit{Equation 2.8}$$

where:

B_n = benefit in year n

I_n = capital investment in the project in year n

$C_n = I_n$ + operating costs in year n

n = number of years (project period)

r = interest rate or the discount rate

In most circumstances there is a constraint on the availability of capital funds. In such cases the Treasury Guidelines suggest the use of NPV per $ of capital investment, i.e. NPVI. This measures the overall economic return of a project in relation to its requirement for initial capital expenditure (which is the constrained input).

The NPVI is capital efficiency ratio and is used as a capital constraint measure. The project with the highest NPVI is chosen first when there is a constraint on capital.

This investment decision criterion is recommended for use in economic analysis in a resource-constrained situation. Using this measure, projects with the highest NPV per dollar of total capital are selected until the budget is exhausted. NPVI seeks to *maximise aggregate NPV from the available funds*, since there are circumstances where the return on the incremental expenditure may be relatively low (i.e., the option with the highest NPV requires very high expenditure).

First Year Rate of Return FYRR)

The first year rate of return (expressed as a percentage) is a measure of the benefits achieved in the first full year of a scheme's operation divided by the capital costs incurred to achieve this. It is expressed as a percentage and discounted values are used.

$$FYRR = \frac{PVB\ (Yr1)}{PVI}\ x\ \frac{100}{1} \qquad \textit{Equation 2.9}$$

The first year rate of return is typically used to determine the best start date for a scheme. If a scheme has a FYRR below the discount rate (e.g. 7%) then the implementation of the scheme should be deferred until the FYRR either equals or exceeds the discount rate.

As an aid to selecting projects for further analysis where there are many competing projects, it is advisable to first estimate the FYRR using current traffic volumes. Then select only those projects with a high FYRR (i.e., above 7%) for further analysis, unless other overriding criteria suggest otherwise.

This is because if projects use similar assumptions for traffic growth and/or growth in annual cost and benefits then future benefits will usually be related to the benefits earned in the first year. Those schemes earning more benefits in one year will continue to earn more benefits throughout the evaluation period. Thus the FYRR can be taken as a proxy for the full 30-year cost-benefit analysis. A 'simple' mathematical calculation can provide an estimate of the 30-year NPV if the growth rate of benefits and the discount rate are known. Only those schemes with an FYRR of 7% or above should be selected.

Only when future growth rates and the expected value of future benefits vary over time does it make sense to calculate benefits over a 30-year time horizon (N.B. CBA is a technique to compare differing streams of costs and benefits over time; if these are not different, then CBA is not necessarily required).

Many of the forecasting procedures used rely on averaging, interpolation and extrapolation of trends or future scenarios. Thus the opportunity for options to exhibit benefits which vary over time is reduced. This is particularly so if vehicle operating costs (VOC) and travel time costs are not regularly reassessed to reflect the effect of traffic growth. Thus the FYRR can be used more extensively to choose between schemes with similar future effects.

Appendix 3 presents an example of the discounted cash flow analysis to demonstrate the use of discounting and the derivation of the decision criteria.

Assess risks and uncertainty – Undertake sensitivity analysis

Risk assessment in economic evaluations involves identifying risk factors, estimating the likelihood of risk occurrence and determining the consequence of risk occurrence. Risks typically in association of transport project evaluations include:

- Demand and usage forecasting
- Capital cost increase
- Prolonged construction period

Sensitivity analysis should be undertaken to test the robustness of the evaluation results under the identified risk factors, uncertainties, key assumptions and parameters.

Identify Preferred Option

The preferred option is identified by:

- Ranking of options by NPV, BCR, FYRR, IRR and NPVI
- Results of sensitivity analysis
- Intangibles and unquantified costs and benefits
- Other factors including broad social, environmental and policy objectives

The preferred option should have the potential to improve the social welfare in that the gainers could compensate the losers in the social accounting framework. In CBA the benefits of the project should at least equal or be greater than the cost of the project.

In so far as some impacts are qualitative and not quantified in monetary units, they should also be included in the overall project or program assessment. (See Chapter 3 for various methods to integrate CBA results with unquantified factors.

Prepare Economic Appraisal Report

The economic appraisal must balance the goals of accuracy and completeness against the cost of data acquisition, detailed modelling and valuation of consequences hence the results of applied economic appraisal must contain uncertainties in particular areas, assumptions in the place of data that are not available and effects that cannot be quantified or monetised. These limitations must be highlighted when presenting the inputs, modelling and results.

The CBA results are presented in a summary table such as the table below:

Table 2.2: CBA Summary Results

Discount Rate	3%	7%	10%
PV Cost ($m)	1.30	1.30	1.30
PV Benefit ($m)	5.94	5.13	4.47
NPV ($m)	4.64	3.83	3.17
BCR	**4.55**	**3.94**	**3.44**

Additional information on top of the CBA summary results should be provided by completing the table below.

This template assists in checking the sanity of benefit estimates and demand forecasts. From this benefit table, it can also be seen whether the percentage split of benefits is consistent with the project's stated objectives. The split of benefits between passengers and freight/business provides information on whether a project supports passenger or productivity-related objectives.

Table 2.3: CBA Benefit Components

<table>
<tr><th colspan="2">Benefit Component</th><th>PV of Benefits ($m)</th><th>Year 10 Benefits ($m)</th><th>Year 10 Benefits as a % of Total Benefits</th></tr>
<tr><td rowspan="3">Travel time savings</td><td>Passenger</td><td></td><td></td><td></td></tr>
<tr><td>Freight and business</td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Reduced vehicle operating costs</td><td>Passenger</td><td></td><td></td><td></td></tr>
<tr><td>Freight and business</td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Generated travel benefits</td><td>Passenger</td><td></td><td></td><td></td></tr>
<tr><td>Freight and business</td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td></td></tr>
<tr><td>Accident reductions</td><td>Total safety benefits</td><td></td><td></td><td></td></tr>
</table>

Benefit Component		PV of Benefits ($m)	Year 10 Benefits ($m)	Year 10 Benefits as a % of Total Benefits
Environmental benefits	Reduced GHE			
	Reduced local pollution			
	Reduced noise			
	Total environmental benefits			
Reduced maintenance costs	Total reduced maintenance costs			
Wider economic benefits	Agglomeration benefits			
	Other WEBs			
	Total WEBs			
Other benefits	Total other benefits			
TOTAL BENEFITS				

Source: Commonwealth Department of Infrastructure and Regional Development

2.4 Sensitivity and risk analysis

Where uncertainty is associated with estimates of some (or all) benefit and cost items, then sensitivity analysis should be performed. Sensitivity analysis is used to assess the possible impact of uncertainty. It illustrates what would happen if the assumptions made about some or all of the key variables proved to be incorrect and shows how changes in the values of various factors affect the overall cost or benefit of a given investment project. It is a necessary part of any investment appraisal.

It is also a useful means of indicating the critical elements on which the positive outcome of the project depends and the robustness of the assumptions. This allows attention to be focussed on those areas during project implementation or to divert further resources to the improvement of cost and benefit estimates and the reduction of uncertainty.

The steps in undertaking sensitivity tests are:

- Determine plausible ranges of values of risk factors and uncertainties. The typical variation of cost estimation in concept and pre-tender phase is provided in the table below. The cost variations should be reflected in the sensitivity analysis.

Table 2.4: Cost Variations in Estimates

Phase	Type of estimate	Sensitivity Analysis ranges
Project scoping	Concept, business case	25% to 40% (P50 level of confidence)
Project development	Pre-tender	5% to 15% (P90 level of confidence)
Project delivery	Construction	Actual cost

- Calculate the effects on the decision criteria (NPV, NPVI, BCR and IRR). In many cases, it would be useful to report the decision criteria of optimistic, most likely and pessimistic scenarios. It may be useful to identify the 'switch points' or threshold values for conditions at which the recommended option changes, i.e. when the estimation of net benefits changes sign. While switch points are not tests of confidence in the statistical sense, they can help provide decision makers with an understanding of how robust the analysis is.

- Test interrelationships – varying a single parameter, leaving other parameters at base values and varying two parameters simultaneously can provide a richer picture of the implications of base values and the robustness of the analysis.

If sensitivity analysis is to be useful to decision-makers it needs to be undertaken systematically and presented clearly. There is no value in examining a large number of sensitivities chosen in an arbitrary way. The choice of sensitivities should be made carefully having regard to the uncertainty of specific factors, particularly those that are more uncertain than others or where uncertainty is not symmetrical. Account should also be taken of any important relationships between factors.

Risk and Uncertainty

Risk can be distinguished from uncertainty. Risk is defined as referring to situations where probabilities can be known. That is, the number and size of each possible outcome is known and the chance of each outcome occurring can be objectively determined. For example, in the case of throwing unbiased dice, the number of possible outcomes and their probabilities are known prior to the event.

Uncertainty, on the other hand, refers to situations with unknown probabilities. That is, the number and size of each outcome may or may not be known, but the chance of any single outcome occurring cannot be objectively determined. For example, the demand for few services is dependent on many factors and the relative influence of these factors may vary over time in an unpredictable manner. Another example is research and development projects where the outcome is unknown.

In practice, the distinction between risk and uncertainty is not likely to be completely clear. A degree of uncertainty will be associated with almost any significant capital project. The problem is particularly acute in regard to public sector investments that are often comparatively long-lived and of a substantial size, with little recoverable value.

Uncertainty is inherent in economic analyses, particularly those associated with benefits for which there are no existing markets, e.g., environmental benefits. The issue for the analysis is not how to avoid uncertainty, but how to account for it and present useful conclusions to those making decisions.

Transparency and clarity of presentation are the guiding principles for assessing and describing uncertainty in economic analysis. In assessing and presenting uncertainty the analyst should if feasible:

- Present outcomes or conclusions based on expected or most plausible values;
- Provide description of all known key assumptions, biases and omissions;
- Perform sensitivity analysis on key assumptions; and
- Justify the assumptions used in the sensitivity analysis.

The outcome of the initial assessment of uncertainty may be sufficient to support project or policy decision. If however the implications of uncertainty are not adequately captured in the initial assessment then a more sophisticated analysis should be undertaken. The need for additional analysis should be clearly stated, along with a description of other methods used for assessing uncertainty such as decision trees, Delphi type methods, meta-analysis or probabilistic methods including Monte Carlo analysis which explicitly characterise analytical uncertainty and variability.

The concept of risk is often interpreted narrowly as being measured by variability or range of possible outcomes of a project. Greater variation implies more risk according to this view. However, risk and uncertainty should be conceptualised more broadly, i.e., rather than being taken in isolation the risk of a project is measured by its effect on the variability in outcomes of the entire portfolio of assets. In general the degree of risk associated with an asset is measured in terms of the covariance of its relation with those of the portfolio of assets to which it is added.

All NSW Government agencies are required to apply risk analysis when assessing the feasibility of capital projects expected to cost over $5 million. A strategy for identifying and analysing potential project risks and for responding appropriately to those risks is required.

A summary of risks should be presented in the risk register as below.

Table 2.5: Risk Register Template

Risk (Description)	Responsible Officer/ Agency	Assessment	Risk Mitigation/ Avoidance Strategy
Administrative risks			
Contractual risks			
Operating risks			
Demand risk			
Commercial risks			
Land / property acquisition risk			
Market risks			

The **Transport Enterprise Risk Management (TERM)** template is suggested to be used in incorporating risk management into the preparation of the business case. The risk exposure, i.e., whether it is **Very High, High, Moderate, or Low** is determined by scoring the likelihood and consequences of identified risks as indicated in the table below: (Please refer to [TfNSW Enterprise Risk Management] for the TfNSW enterprise risk management policy, procedure and reference guide).

Table 2.6 Risk Evaluation Table

RISK RATINGS: A=Very High B=High C =Medium D=Low			Consequence					
			Insignificant	Minor	Moderate	Major	Severe	Catastrophic
			C6	C5	C4	C3	C2	C1
Likelihood	Almost Certain	L1	C	B	B	A	A	A
	Very Likely/ Probable	L2	C	C	B	B	A	A
	Likely	L3	D	C	C	B	B	A
	Unlikely	L4	D	D	C	C	B	B
	Very Unlikely/ Improbable	L5	D	D	D	C	C	B
	Almost Unprecedented	L6	D	D	D	D	C	C
			D	D	D	D		C

Source: Transport Enterprise Risk Management (TERM) Standard

The above risk framework presents the relationship denoted by the equation:

$$Risk = Event * Likelihood * Consequence \qquad \text{Equation 2.10}$$

Where:

- **Event** denotes some kind of initiating detrimental factor such as delay
- **Likelihood** denotes the probability of the Event occurrence, and
- **Consequence** indicates the resulting consequences caused by the Event (including monetary, resource or other loss)

A more refined quantified assessment of risks can be undertaken based on at least two approaches:

- Monte Carlo simulation approach
- Cause and Effect approach

Both consider the probabilistic influence from the project development through to implementation and operation.

These approaches use the framework presented above but are expanded to include the probability of propagation which is the probability that an event leads to a specific failure. This failure is one of the possible failures that may result from a specific event.

Equation 2.11

$$Risk = Event * Probability\ of\ Occurrence * \sum (Probability\ of\ Propagation * Loss)$$

- **Loss** is the loss associated with each failure that the Event can lead to and
- **Sum** is the sum taken over all possible failures related to one specific Event with their related losses.

Risk Analysis Using Monte Carlo Simulation

It is important to understand and quantify the range of potential outcomes in situations where there is significant *uncertainty* outside of one's own control that can impact on project / program results. It should also be useful to note that the uncertainties involved can have many dimensions. The standard Monte Carlo process includes:

1. Identify the *uncertain variables* (inputs) that affect your results.
2. For each uncertain variable, choose a *distribution* that estimates the range of values it can take. It is important to note that the choice of most relevant probability distribution is important to achieving a reliable result. Adopting this approach allows flexibility to use the appropriate distribution rather than just using the normal distribution which often used in standard analysis, thus avoiding the trap of law of averages.
3. Identify the *uncertain functions* (calculated results) that are considered to be the most important.

There are software programs such as @Risk, Crystal Ball, and even Excel Risk Solver Pro which can be used to conduct Monte Carlo simulations to assist in the risk quantification. Using this approach a full range of outcomes that draw random samples from probability distributions can be revealed that makes the quantification of the likelihood of acceptable or unacceptable results.

A simulation engine or Solver runs thousands of "what-if" scenarios, each time sampling possible values for uncertain variables and computing results, and then summarizes the results in charts, graphs and statistics.

See Appendix 10 for more detailed guidance in the use of @risk including a worked example. Contact Evaluation and Assurance Branch, Finance and Investment for assistance in conducting Monte Carlo Simulation analysis for your specific project risk analysis. High impact factors can be identified in your model using sensitivity analysis across thousands of Monte Carlo trials rather than just an ordinary 'what if' analysis.

2.5 Economic versus Financial Analysis and Sustainability Analysis

Economic and Financial analysis represent complementary yet distinct ways to estimate the net benefits of an investment project. Both are based on the difference between the "With Project" and the "Without Project" situations.

The concept of financial benefit is however different from net economic benefit - whereas financial analysis estimates the financial impact of the project on the project-operating entity, economic analysis estimates the economic impact of the project on the country's / state's economy.

They are complementary because for a project to benefit the economy it must be financially sustainable. If a project is not financially sustainable, there will be inadequate funds to properly operate, maintain and replace assets, and the quality of the output and or service will deteriorate, eventually affecting demand and the realisation of financial revenues and economic benefits. Some public projects are financially sustainable with the government subsidies.

Financial analysis of the project involves estimating the financial internal rate of return (FIRR) in constant prices. The FIRR is the rate of return at which the present value of the stream of financial net flows in financial prices is zero.

If the FIRR is equal to or greater than the financial opportunity cost of capital, the project is considered financially viable. The financial analysis covers the profitability aspect of the project at the enterprise level.

The basic difference between the two is that the financial analysis compares the benefit and cost to the enterprise in constant financial prices while cost-benefit analysis compares the benefits and costs to the whole economy measured in constant economic prices. Financial prices are market prices of goods and services that include the effects of government intervention and distortions in the market structure. Economic prices reflect the true costs and value to the economy of goods and services after adjusting for the effects of government intervention and distortions in the market structure through shadow pricing of the financial prices. In these analysis, depreciation charges, sunk cost and expected changes in general price level are not included, depreciation being treated as cost (investment cash flow already includes this), sunk cost constitute expenditure for fixed assets in place prior to the investment decision, and in the profitability analysis the benefits and costs are valued in constant prices (of the base or appraisal year). However, expected changes in relative prices, as distinct from the general price level, should be incorporated.

Taxes and subsidies included in the price of goods and services are integral parts of financial prices, but they are treated differently in economic prices. If the supply of a project input is incremental and there is a production tax on its price, the supply price is the net of tax price and is the basis of the economic cost per unit of project input.

On the demand side, if the demand for project output is incremental, it total output demand with project exceeds total demand without the project and there is a sales tax on its price, the gross of tax price represent the amount buyers are willing to pay. This price, the demand price, will form the basis of the gross economic benefit of incremental output.

Financial and cost-benefit analysis also differs in relation to the external effects of a project. There are many externalities which are not accounted for in market transactions and that are therefore not directly reflected in the financial cash flow of a project. The environmental impact of a project is a typical example of such an externality. Economic analysis attempts to value such externalities and internalise them into project benefits and costs to improve efficiency of the use of the limited resource and to contribute to the enhancement of environmental sustainability.

For a project to be sustainable, it must be both financially and economically viable. A financially viable project will continue to produce benefits that are sustained throughout its life. Assessing sustainability includes:

- Evaluating the project's fiscal impact, i.e., whether the government can afford to pay the level of financial subsidies that may be necessary for the project to survive or making an assessment of the government's capacity to finance subsidies
- Examining the role of cost recovery through pricing
- Estimating the direct effect on public finances of the project's cash flows

To demonstrate financial sustainability of the project, financial analysis should be undertaken at the enterprise and project levels.

Be clear about whether analysis is in real or nominal terms. It is usual to undertake both CBAs and financial analyses in real terms. In project proposals that include both a CBA and a financial analysis, show (via links within the spreadsheet) how the two analyses relate to each other. There should be inflation adjustments that convert between the CBA in real terms and the financial analysis in nominal terms.

2.6 Optimisation of Road Maintenance

Road maintenance can be categorised as routine, which is small task undertaken frequently, and periodic, which are larger tasks undertaken at intervals of several years or more. Without maintenance, roads can quickly fall into disrepair leading to increased costs of road users in vehicle operation, time, reliability and safety.

The maintenance optimisation problem is, in essence, to find the optimum balance between the costs and benefits of maintenance, while taking into account various constraints including budget. Optimisation models usually deal with periodic maintenance and components of routine maintenance that affect roughness or the rate of pavement deterioration, in particular patching, crack sealing and pothole repair. Other routine maintenance, including vegetation control, repairing signs and other roadside furniture, clearing drains and culverts and repainting line markings, needs not being optimised as a constant amount per kilometre of road or per square metre of pavement is normally assumed. For a given road segment, choices have to be made between alternative treatment types and the timings to implement those treatments. Where maintenance budgets are limited, there is an additional problem of balancing the competing needs of the different segments.

Maintenance requirements of gravel, sealed and concrete roads and bridges differ. Gravel roads need to be regraded at intervals of around 6 months or a year to reduce roughness and re-sheeted at intervals of some 8 to 10 years. Concrete roads require roughening for safety reasons as usage reduces skid resistance, maintenance and repairs to joint between slabs, crack sealing, and slab replacement. Sealed roads with flexible pavements, which carry most vehicle kilometres of traffic and command the greater part of maintenance expenditure, require resealing, resurfacing, overlay, reconstruction in several year intervals.

2.6.1 Maintenance optimisation process

The road maintenance optimisation problem from the point of view of society as a whole involves trading off road agency or maintenance costs against road user costs over time.

Three essential components of a road maintenance optimisation model are:

- Prediction of future pavement condition
- Prediction of the effects of maintenance treatments on road condition
- Estimation of road user costs as a function of road condition

Deterioration models have been used for predicting the future pavement conditions in terms of roughness, rutting, cracking, potholing and pavement strength with and without maintenance treatments. Two approaches used in deterioration models are deterministic approaches and probabilistic approaches.

- **Deterministic approaches** can be mechanistic, empirical or a combination of both. The mechanistic approach uses fundamental theories of pavement behaviour to deterioration trends. This approach produces models that are more easily transferable to different pavements and conditions, but it is usually very data-intensive. Empirical models are less structured, relying mostly on statistical analysis of locally observed deterioration trends. Empirical models may not be transferable to other locations where conditions are different.
- **Probabilistic approaches** cater for the large stochastic elements in pavement deterioration caused by unpredictable and unmeasurable factors. Examples are

the quality of the materials and workmanship in constructing and maintaining the pavement and drains, the characteristics of the sub-grade, and the combination with heavy vehicle loadings. Transition Probability Matrixes (TPMs) are used to indicate the probability that a pavement in each state will change to another state. Transition probabilities are obtained from past data or expert judgement. In the absence of any treatment, a pavement can only remain in the same state for deteriorating to a lower state, never rising to a higher state.

A maintenance treatment, by resealing, rehabilitation or reconstruction, improves the roughness as illustrated in Figure 2.5 below. Each treatment has a cost per square metre that needs to be traded off with user costs.

Figure 2.4: Illustrative pavement life cycles with rehabilitations and reconstructions

Source: ATC (2006) Guidelines for transport system management in Australia, Volume 5

Road roughness affects the road user costs in several ways: vehicle free speed, travel time and fuel consumptions. Agency's road maintenance cost and road user cost can be added for different roughness values. Cost minimisation approach is used for finding out the optimal timing of road maintenance treatment. The cost is expressed as life cycle cost (LCC), which includes discounted economic cost streams over an evaluation period with the residual value at the end of the evaluation period.

2.6.2 Dealing with budget and other constraints

Maintenance budgets are usually expressed as the amounts that can be spent for each year over a number of years (usually 5 years). The optimisation model usually assumes no constraints thereafter. The optimisation model expresses the constraints as a present value, which assumes that the funds can be shifted through time by borrowing or lending at an interest rate equal to the discount rate. While not necessarily realistic, it serves as a benchmark because it ensures optimal allocation of limited funds over time and the allocation is associated with the marginal benefit cost ratio (MBCR). While the budget constraint applies to a group of road segments taken together or a network, the optimal allocation of maintenance funds would be found where the MBCR is the same for all segments. Several model runs may be required to achieve optimal allocation by shifting fund and timing of different road segments. This process can potentially be used to compare investment and maintenance decisions. The optimal split of funds is that which equates the MBCRs of investment and maintenance spending.

Budgets are not the only constraints imposed in road maintenance optimisation model. For example, a 5-year minimum overlay interval in the simulations can be imposed to 'avoid two consecutive condition-responsive overlays from being applied in an impractically short period of time' for heavily trafficked roads. At the other extreme, on very low trafficked roads, the model may find it optimal to rehabilitate only at a roughness level that is so high that, in practice, the pavement would be falling apart. It may be then necessary to impose upper limits on the roughness levels at which treatments are undertaken. Governments may also require upper limits to be imposed on roughness levels on some roads to meet community expectations. Availability of physical resources to undertaken certain treatments (manpower, equipment and materials) may impose further constraints.

With multiple treatment types to choose between, the optimisation problem becomes much more complex. Instead of a smooth, continuous cost surface with a single minimum point, there are multiple local minimums and discrete choices. One way to reduce the number of feasible solutions is to schedule maintenance actions over selected years (for example, in years 1, 2-3, 4-5, instead of year 1, 2, 3, 4 and 5). Another way is to specify condition-responsive treatment rules instead of years of occurrence, for example, "rehabilitate as soon as roughness reaches a certain point". A further way to reduce the size of the problem for optimisation modelling is to aggregate segments into bins with similar characteristics in terms of pavement condition, traffic level and vehicle mix.

Minimising the present value of LCC without budget constraints yields the most economically efficient solution. The most common alternative approach is to minimise the present value of road agency costs subject to minimum standard constraints. The minimum standards may be determined through community consultation to determine the roughness levels that road users consider acceptable. If community wants cannot be accommodated within available funds, the optimisation problem then becomes maximising standards subject to budget constraints.

Other factors to be considered in maintenance optimisation modelling include costs of delays to road users while maintenance activities are carried out. These costs can readily be included with treatment costs. In urban areas with high traffic levels, the need to minimise traffic delay costs affects the type of pavement laid and the times at which the works can be carried out, which adds to treatment costs. Rehabilitation may be combined with widening or shoulder sealing, which constitute investment rather than maintenance as they raise the standard of the existing road above its initial standard. The effects of investment and maintenance can be considered separately in the optimisation model.

2.6.3 Approaches to road maintenance optimisation

The traditional methods of maintenance optimisation were largely based on subjective ranking and prioritisation rules. The prioritisation rules can be based on either economic criteria (e.g., Incremental Benefit Cost Ratio) or engineering criteria (e.g., road class, traffic volume). The weakness of traditional prioritisation methods is that they do not ensure the best possible maintenance strategies when considering long planning time spans. Therefore, techniques have been employed to solve pavement optimisation problems including[6]:

- Linear programming
- Non-linear programming
- Integer programming
- Dynamic programming
- Generic algorithms

[6] See Harvey, M.O. (2012) Optimising road maintenance, paper prepared for OECD/ITF Roundtable on sustainable road funding, Paris, October 2012, for discussions of these techniques and the applications of these techniques in road maintenance optimisations.

2.6.4 Maintenance deferral

As maintenance treatments are deferred, components of the pavement are left vulnerable to damage and to deteriorate more rapidly. The future treatment required to undo the damage can be more considerably expensive than the treatment deferred. If rehabilitation is deferred, damage may occur to lower layers of the pavement and so the next rehabilitation may have to replace pavement layers to a greater depth or involve a thicker overlay, or a reconstruction may be needed. In present value terms the cost savings from deferring maintenance treatments in the short term can be outweighed by the additional cost of more expensive treatments in the future.

The cost of maintenance deferral is treated as a form of borrowing – funds are saved in the short-term at the expense of higher outlays in the future. The 'equivalent interest rate for deferred maintenance' is used to quantify the cost of maintenance deferral in maintenance optimisation.

Steps in calculating the equivalent interest rate of deferred maintenance are:

- Determine minimum acceptable standards at which the roads are just adequate to meet their economic and social purposes.
- Use an optimisation model to find the lowest possible present value of road agency costs consistent with providing these minimum standards in the absence of any budget constraints.
- Use the optimisation model again to find the minimum present value of road agency subject to annual budget constraints for the years during which they are imposed.
- Take the difference of the maintenance cost amounts for each year, and find the internal rate of return for the stream of differences, which is the estimated equivalent interest rate for deferred maintenance.

2.6.5 Optimising the investment – maintenance trade-off

Incurring higher investment costs to construct a stronger pavement at the outset saves future maintenance and user costs. A concrete pavement costs much more than a flexible pavement to construct but requires far less future maintenance spending to provide a given level of service to users.

The benefits from a stronger pavement could be realised either in the form of lower user costs for the same amount spent on maintenance, or lower amount of user costs, or a combination of both. In the maintenance optimisation, the investment-maintenance trade-off is defined as the Marginal Benefit Cost Ratio (MBCR) of maintenance cost savings and user cost savings with respect to cost of additional pavement strength.

2.6.6 Estimating the maintenance backlog

An estimate of the maintenance backlog can highlight the extent of a shortfall in maintenance funding. The concept necessarily involves comparison between the existing and desired road conditions.

The maintenance backlog is the cost of maintenance works that are economically justified at the beginning of the optimisation period. It indicates the funds required to restore network condition to the economically optimal level. In the maintenance optimisation model, the economic optimal level is specified as MBCR for investment being the same for maintenance.

The MBCR approach can be a useful measure of the maintenance deficit indicating the value to users of additional maintenance spending and enabling comparisons to be made with the value of additional investment spending.

2.6.7 Maintenance Optimisation Model

Evaluation & Assurance in TfNSW will develop a prototype maintenance optimisation model to assist road agencies in assessing maintenance priorities as well as to plan and budget for maintenance activities. It can promote best use of available funds by helping determine the types and timings of treatments to be carried out. At a higher level, it can help determine appropriate levels of maintenance funding.

At this stage, it is considered that non-linear programming is feasible as many optimisation problems cannot be satisfactorily represented by linear relationships. The generic algorithms represent the state-of-the-art optimisation method and its applicability to road maintenance optimisation would be explored. The maintenance optimisation model, when developed, audited and tested, will be reported in this Guideline and provided to agencies for practical use.

2.6.8 Analytical framework for Maintenance Project Economic Analysis

Economic analysis at the project level is used to decide between competing treatment options or maintenance strategies at individual locations that have been selected based on a network strategy.

The first step in economic analysis of maintenance is to identify all the technically feasible options that are to be analysed. There will rarely be only one technical option for achieving maintenance objectives. The individual options aim to bring the condition of the road or part of the road to desired standards and deliver a certain level of service to a certain road (sub)-network.

Once all the technically feasible options have been identified, the whole-of-life costs of each option need to be assessed. If the predicted roughness profile over the life of the pavement is the same for all options, the project level analysis considers only the Authority costs in a life cycle analysis. User costs need to be considered if the alternative treatments result in different predicted roughness profile over the life of the pavement.

Standards are set for roughness, rutting and cracking, as part of the Infrastructure Maintenance Program development process. The expenditure for each year over the analysis period that will be associated with each option should be clearly set out. This should include the cyclical resealing and reconstruction activities, as well as routine maintenance for each year and any up front expenditure. To do this requires prediction of the life and deterioration of the pavement, taking into consideration the various treatments that are proposed. Once all technically feasible options are identified, an optimisation approach can be used to determine the best option. This involves choosing that option that maximises community benefits with the least agency and road user costs.

The optimisation approach should use mutually exclusive options. If interdependencies exist so that realisation of benefits depends on a number of components, then these should be considered as a single option, i.e., a 'package' of options which is analogous to a 'project' in the development or construction program. This package of options should be wholly subject to economic evaluation.

Maintenance options are usually the following:

- Rehabilitate now – complete restoration of the pavement structure early in the program period;
- Holding action – minor or moderate form of maintenance designed to protect the pavement against rapid deterioration and maintain serviceability with a view to rehabilitation in the future or the following program period;
- “Do minimum” during the program period – the pavement is allowed to deteriorate with no maintenance *other than routine.* Specific works such as

heavy patching, resealing and/or rehabilitation may be included if “doing nothing” is clearly not feasible, i.e., if it is known with some certainty that the road would deteriorate to an unserviceable level without intervention. This is the traditional base case option in economic analysis of maintenance.

Each option to be analysed is to have two values attached to it:

- the whole-*of-life* cost (or life cycle cost (LCC)) of the agency; and
- other costs associated with road users and the community over the analysis period.

The whole-of-life agency cost for each option has to be determined. Whole-of-life cost is defined as the present value of all future expenditure for an option, over the analysis period. Present values are calculated using the standard discount rate of 7% with sensitivity testing at 3% and 10%. The appropriate base case is the option with the lowest whole-of-life agency cost.

The fundamental concepts of economic analysis are not changed. However, the focus changes from choosing the option with the maximum NPV or higher BCR, to choosing the best option taking into account funding restrictions for capital and maintenance and condition targets for the road assets.

2.6.9 Choosing the best option – project level analysis

There are usually a number of projects in a strategic plan for an area or corridor. To determine the most cost effective package of projects for an area or corridor, it is necessary to evaluate alternative combinations, staging and sequences of projects.

When faced with mutually exclusive project options[7], analysis by Incremental Benefit Cost Ratio (IBCR) can determine which option will provide the optimal economic outcome (This procedure has been documented previously by PIARC[8] and Transit New Zealand[9]). The IBCR approach determines whether the additional costs of higher cost options are justified by additional benefits gained. Australian Transport Assessment and Planning Guidelines (ATAP) Cost Benefit Analysis provides the formula for IBCR as follows:

$$ICBR = \frac{(PV(B_2 - OC_2) - PV(B_1 - OC_1)}{(PV(IC_2) - PV(IC_1)} \qquad \text{Equation 2.12}$$

where OC is infrastructure operating cost and IC is investment cost at year t.

The whole of life cost analysis can be incorporated in the evaluation of packages of projects, by undertaking the analysis over the full life of the projects.

Analysis of the project options by IBCR can be used with cut-off values, given that constraints over available funds exist.

Incremental BCR is then calculated. The highest cost option with an IBCR equal to or greater than the cut-off value should be chosen.

The iterative process is:

1. list the options in order of whole-of-life agency cost;
2. starting with the lowest agency cost alternative, calculate the IBCR of the next higher cost option (the IBCR is the ratio of the present value of incremental

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7 Mutually exclusive project options arise when the acceptance of one precludes the rest.
8 "Methods for Selecting Road Investment", Economic and Finance Committee of PIARC (Permanent International Association of Road Congresses), Paris 1991.
9 "Project Evaluation Manual: Full Procedures", Transit New Zealand, Wellington 1991

benefit to the present value of incremental cost. Incremental benefit is the saving in user costs compared to the lower agency cost alternative. Incremental cost is the additional agency cost);

3. if the IBCR is greater than or equal to the cut-off value, the higher cost alternative passes the test and it becomes the basis for comparison with the next higher cost option;
4. if the IBCR is less than the cut-off value, the higher cost alternative fails the test and the lower cost alternative remains as the basis for the next comparison;
5. repeat this procedure for the next higher cost option, until all options have been analysed;
6. the option with the highest agency cost and which passes the test is the best option.

The value of the cut-off ratio is dependent on the available budget. Different incremental cut-off values will lead to different options being selected as the optimal economic outcome. It is suggested that the cut-off IBCR should be from 1.5 to 2 for rural areas, 2 to 3 for towns and 3 to 4 for the Sydney-Newcastle-Wollongong area[10]

An example of IBCR calculation is demonstrated in the discussions below. The results of whole of life cost analysis or LCC costing and the estimated road user costs over the project period (30 years) are summarised in the table below.

Table 2.7 – Incremental Benefit Cost Ratio Calculation

	Agency Cost (in $m) (over 30 years)	Road User Costs (in $m) (over 30 years)
Option 1 (Do Nothing)	2.081	1.599
Option 6-Replacement – 150 m long	2.860	1.199
Option 5-Replacement – existing level	2.904	1.333
Option 8-Current Preferred Option	2.904	0.400
Option 2	3.294	0.933
Option 3	3.855	0.400
Option 4	5.820	0.267
Option 7- Replacement – flood free	12.398	0.133

The process of the Incremental BCR calculation is as follows:

a) Select the cheapest (agency cost) option (Option 1).

b) The next highest cost option (Option 6) is some $0.778m more expensive, and yields a road user benefit (i.e., reduction in road user cost) of $0.400m. The IBCR is thus 0.51. ***Reject Option 6.*** **(Fail)**

[10] Rural areas are traditionally favoured so as to promote the export of materials and primary industry goods as well as other equity considerations.

c) The next highest cost option (Option 5) is some $0.823m more expensive than Option 1, and yields a road user benefit (i.e., reduction in road user cost) of $0.267m. The IBCR is 0.32. ***Reject Option 5*. (Fail)**

d) The next highest cost option (Option 8) is some $0.823m more expensive than Option 1, and yields a road user benefit (i.e. reduction in road user cost) of $1.199m. The IBCR is thus 1.46. ***Accept Option 8 if BCR cut off is 1*. *Reject if cut off is 2.0***

e) The next highest cost option (Option 2) is some $0.390m more expensive than Option 8, and yields an increase in road user cost. ***Reject Option 2*.**

f) The next highest cost option (Option 3) is some $0.950m more expensive than Option 8, and yields an increase in road user cost. ***Reject Option 3*.**

g) The next highest cost option (Option 4) is some $2.915m more expensive than Option 8, and yields a road user benefit (i.e. reduction in road user cost) of $0.133m. The IBCR is thus, 0.05. ***Reject Option 4*.**

h) The next highest cost option (Option 7) is some $9.493m more expensive than Option 8, and yields a road user benefit (i.e. reduction in road user cost) of $0.267m. The IBCR is thus 0.03. ***Reject Option 7*.**

i) The last remaining option is thus Option 8, which is economically justified on the basis of the assumptions listed above.

Conclusions

At the cut-off value of 2.0, retention of the existing bridge would be the optimal economic option.

However, if the cut-off value is 1.0, Option 8 is the best option from an economic point of view because it offers good road user benefits for a cost not appreciably greater than the cost of maintaining and periodically repairing the existing timber bridge.

It was noted that this analysis gives no weighting to any environmental or social factors, which may outweigh the economic arguments presented here.

2.7 Economic Parameters – Measurement and Updated Values

Appendix 4 present the conventional economic parameters for standard economic appraisal, the underlying economic rationale and measurement principles and the most updated values or range of values based on meta-analysis on specific parameters. Also included in this appendix are the data sources.

The economic parameters outlined below are provided in **Appendix 4**. The values of these parameters will be updated annually to be used for economic evaluation of transport projects, policies, services and programs.

1. **Value of Travel Time (VTT)**
    a. In-vehicle, waiting / queuing time / transfer
    b. Commuter, business, freight
    c. Driver, passenger, pedestrian
    d. Urban-rural
2. **Road Vehicle operating costs (VOCs)**
    a. Urban: Cars and Commercial Vehicles
    b. Rural: Cars and Commercial Vehicles
    c. Urban road congestion cost
    d. Resource cost / Perceived cost / Financial cost
3. **Public transport vehicle operating cost**
    a. Heavy rail-passenger
    b. Heavy rail-freight
    c. Light rail
    d. Transitway and metro bus
    e. Bus depot
    f. Ferry service
4. **Benchmark costs for local infrastructure projects**
5. **Public transport average fare**
6. **Crash cost**
    a. Willingness to Pay (WTP) approach and Human Capital approach
    b. Person cost – fatal, serious, moderate, minor injury
    c. Incident cost, property damage cost
    d. Crash cost – freeway, arterial, local
    e. Crash cost – car, bus, train
7. **Environmental Externalities**
    a. Air pollution
    b. Greenhouse Gas Emission
    c. Noise
    d. Water pollution
    e. Urban separation

f. Nature and landscape

g. Upstream / downstream

8. Active transport

9. Road Damage Cost

10. Transport Elasticity

11. Expansion Factors

12. Public transport attributes

a. Crowding

b. Quality attributes

c. Reliability

13. Asset life

14. Contingency

15. Option Value

3. Socio, economic and environmental assessments

Questions:

- What approaches and tools can be used for assessment of broader or wider socio economic and environmental impacts of transport projects?
- What are the things to watch out for when undertaking wider economic impact studies?

This chapter includes broader concepts and methods which have attained national and international recognition for contribution to economic methodology. These approaches allow for a more comprehensive analysis of transport initiatives.

This chapter is scheduled for consultation and review for Version 2.0 of the Guidelines.

3.1 Broader Assessment Approaches and Tools

a. Multi-Criteria Analysis (MCA)
b. Goal Achievement Matrix (GAM)
c. Strategic Merit Test (SMT)
d. Objective Impact Assessment (OIA)
e. Appraisal Summary Technique (AST)
f. Wider Economic Impacts (WEI)
g. Wider Economic Benefit (WEB)

3.1.1 Multi-Criteria Analysis (MCA)

Multi Criteria Analysis (MCA) is a tool used to aid choices between a range of projects or options where some impacts are qualitative in nature. MCA can be used to determine the relative ranking of projects based on their score. A higher score indicates the project is ranked higher in comparison with the other options. The MCA framework takes into account all impacts of a project, including those that are not quantifiable in monetary terms such as social or health effects.

A MCA model consists of an evaluation criteria or objectives, and weights which indicate the importance of the criteria in the project selection process. The main steps in a MCA evaluation include:

1. Identify and define the options
2. Identify the criteria/objectives or sub criteria that reflect the value associated with the consequences of each option
3. Score the performance of each option against the set criteria/objectives using a scale
4. Assign weights for each criteria to reflect the relative importance to the decision
5. Derive an overall value/score by combining the weights and scores for each option
6. Examine the result and rank the options
7. Conduct sensitivity analysis by changing relative weights and scores

The criteria and weights which the project is to be judged against are usually determined by a decision making group consisting of subject matter experts and stakeholders. The criteria and weights should reflect a consensus amongst the group and should also be justified. Differences in goals and objectives of the project can be changed by varying the criteria weights. The criteria may include areas such as economic, social and environmental impact. The criteria/objectives of each project option are scored on a scale. A weighted average score can then be determined for each option.

The main strength of MCA is that benefits which are unable to be readily quantified in monetary terms and are of major importance are included in the evaluation. Also, MCA provides transparency as the criteria and objectives are stated and considered explicitly. On the other hand, the limitations of MCA are that the criteria and weights may lack an agreed theoretical framework, the weighting framework can be subjective and it is harder to take into account impacts occurring at different times.

An example of the use of MCA can be seen in prioritising road-rail level crossings for grade separation, conducted by the Victorian Department of Transport and Sinclair Knight Merz. MCA was used to identify a prioritised short list of level crossings sites for grade separation in Melbourne. Economic, social, environmental and strategic fit formed part of the criteria as well as sub objectives which included project implementation cost, reduced risk of death or injury, reduced greenhouse gas emissions and alignment with road network operating objectives. Workshop participants were divided into three groups and assigned weights to each criteria. The final weightings represent an average of the weightings of the three groups. As a result of the scoring and weighting of each level crossing site, a ranking of level crossing sites was obtained.

3.1.2 Goal Achievement Matrix (GAM)

The Goal Achievement Matrix (GAM) is another tool which can be used in the analysis of impacts that do not lend themselves to quantification in monetary terms (such as social objectives). GAM is based on estimating which option best achieves a set of predetermined objectives. Weights are assigned to the goals, so that each option can be evaluated in terms of the goals achieved. The following illustrates the use of GAM:

- **Formulate a set of goals.** Each goal should have an associated metric so that achievement of the goal can be measured. These metrics represent the cost and benefits. If a quantitative measure cannot be associated with each goal, then a qualitative description of the impact should be used. The impacts of each quantifiable goal should be measured in the same units to allow for an objective comparison between options. An example of goals and their associated metrics include:

    1. Accident reduction measured by number of fatalities; injury and property damage costs.
    2. Increased accessibility measured by average travel time.
    3. Reduction of air pollution measured by the amount of pollutants.

- **Score or rank the options in term of their effectiveness in achieving each goal.** Typically the value assigned is +1, 0 or -1 to show whether the impact has contributed (identified benefit), left unchanged or detracted (identified costs) from goal achievement.
- **Assign weightings for each goal**. Weightings can be derived from studies or can be agreed upon by stakeholders, highlighting the flexibility of GAM to capture equity effects through the weightings.
- **Combine scores and weights** to obtain relative measures of goal achievement for each option. The highest scoring option represents the option that is most aligned to the goals and is most preferred.

The advantages of GAM are that it:

- explicitly considers a wide range of goals, allowing social, environmental and economic outcomes to appropriately influence decision making.

- is a simple tool that can be used by stakeholders as a means to promote community wide consultation, allowing differing impacts to be considered, and
- is also able to include equity effects and impacts that are not easily monetised in traditional cost benefit analysis.

A disadvantage of the tool is that there is no common framework or system of measurement that can be applied to estimate the level of achievement of all goals. The success of the tool is determined by the weights applied to the goals, which tend to be subjective determined. Furthermore, any interaction and interdependence of objectives are not taken into account.

3.1.3 Strategic Merit Test (SMT)

Strategic merit testing is a technique used to check if a proposed project aligns with the economic, environmental and social objectives, policies and strategies of the government. This qualitative project appraisal tool is used during the strategic planning phase and includes a series of questions that try to identify the contribution of the proposed project to the government's objectives, policies and strategies. This tool also checks if all the alternative options have been properly considered and assesses if the proposed project contains any hurdles. Strategically fit proposals move forward for further assessment.

Questions to examine strategic fitness could include:

1. What are the objectives and goals of this project?
2. How do the objectives and goals of this project align with that of the government?
3. What are the risks of the project?
4. Have all the alternative options been given sufficient consideration?
5. Is the project success dependent on successful completion of any other project/s?

Apart from examining the strategic fitness of the project, this tool requires the users to clearly describe the project and alternatives, including resource requirements, time, stage, and challenges and planning process thus giving a complete picture and better understanding of the project. The Australian Transport Council provides a Strategic Merit Testing template in its national guidelines for transport system management.

3.1.4 Objective Impact Assessment (OIA)

Strategic merit testing may pass a number of projects, but it does not reveal the scale of alignment. Objective impact assessment is a process aimed at testing the degree to which projects are likely to deliver on the objectives of government. This process generally involves the following steps:

1. Identify the problems that needs to be resolved
2. Confirm the project objectives
3. Identify the main options
4. Identify the degree of impact of each option on the government's objective

The degree of impact includes any pros, cons, synergies and trade-offs. This process is a comprehensive technique for the examination of strategic fitness. While strategic merit testing focuses only on the strategic alignment of a particular option, objective impact assessment helps view the range of options identified. The Australian Transport Council's Strategic Merit Testing template includes an objective impact table. The template requires the user to list the government's objectives, sub-objectives, project's qualitative and quantitative impacts for each sub-objective and an individual rating for each impact.

Completion of the strategic merit testing template and objective impact table requires the proponent of the project and the government or any jurisdiction to work in consultation with each other to establish a common understanding of the relevant objectives, impacts and scale.

3.1.5 Appraisal Summary Technique (AST)

The Appraisal Summary Technique can be used in the assessment of the economic, environmental and social impacts of a project. An example of an appraisal summary table is that of Department for Transport UK, published in its transport appraisal guidance document.

As in objective impact assessment, an appraisal summary table is created which include the description of objectives, sub-objectives, impacts and ratings or scores. Objectives are broadly classified into economic, social and environment. Sub-objectives are detailed breakdowns of objectives that assist in revealing an extensive range of impacts.

The project proponent is required to enter the objectives and an assessment staff or team determines the impact through ratings or scores. Impacts are described qualitatively and quantitatively. For each impact a score is provided. The scoring could be a grade, a monetary value or general points on a scale.

While it is similar to an objective impact table, an appraisal summary table is a more comprehensive description of all the economic, environmental and social impacts of a project. An objective impact table covers only the impacts on specific governmental or the relevant jurisdictional objectives. The final scores of the appraisal summary table support consistent and systematic decision making across all the projects. (See Chapter 7, Section 7.3.2 for an AST example for assessment and ranking of interchange projects.)

3.1.6 Economic Impacts Assessment (EIA)

Economic impact assessment focuses on the changes in the economy in terms of productivity gains such as increases in gross domestic / state product or business output and employment or job creation. (See also Section 5.3.3 for tools to use for economic impact assessment). Business travel time savings which are recognised in cost benefit analysis are also covered in EIA as business travel time savings can result in firms increasing output and reducing prices with commensurate benefits to consumers.

3.1.7 Wider Economic Benefits

Wider Economic Benefits (WEBs) commonly refers to the impacts of transport investments on agglomeration economies, increased competition as a result of better transport system, increased output in imperfectly-competitive markets and economic welfare benefits arising from an improved labour supply. The following describes the main classes of WEBs:

1. Agglomeration economies

As a city grows and becomes denser, its firms often become more productive. The productivity benefits arise from proximity and clustering explained by economies of scope and scale, access to more customers, access to more suppliers, knowledge spill overs and access to workforce enabling better job matching.

Agglomeration economies of transport projects are estimated based on the following logic:

- Transport projects reduce the generalised travel costs for its affected areas
- Lower costs encourage increased effective employment density

- As the effective employment density increases, the productivity and welfare benefits increase. The benefits of agglomeration and clustering, if any, have not been captured in conventional economic appraisals which mainly deal with value of travel time savings, vehicle operating cost savings, and accident reduction.

The degree of agglomeration or clustering is measured by employment density, defined as the number of employees per square kilometre. A better measure of agglomeration is effective employment density defined as total employment in the locality plus employment in surrounding areas weighted by their proximity. The proximity is a function of the generalised travel cost. The effective employment density increases if a transport project reduces the generalised travel cost even if the total employment in different zones remains unchanged.

The calculation of agglomeration economies requires calculation of productivity elasticity with respect to effective employment density by industry sectors by spatial travel zones. Agglomeration elasticity measures the percentage changes in output productivity as a result of a percentage change in effective employment density. Hensher et al (2012)[1] estimated the agglomeration elasticity for Sydney in their studies of the wider economic impacts of transport infrastructure investment. The elasticities were estimated for different industries and in different travel zones as presented in Table 3.1 below.

Compared with elasticities in Sydney as estimated by Hensher et al, productivity elasticities in the UK are relatively 'inelastic', but elasticities in New Zealand are higher. In a study of the wider economic benefits of Sydney's North West Rail Link project[2], it was demonstrated that agglomeration benefits are 7.3% lower if UK elasticities are used and 80% higher if New Zealand elasticities were used. This is probably because New Zealand has a lower employment density, thus the marginal effect of increases on productivity is higher.

Table 3.1 Elasticity of productivity with respect to effective employment density, by industry

Industry by ANZSIC divisions	Australia ITLS (A)	UK (B)	New Zealand (C)
A - Agriculture, Forestry and Fishing	0.047	0	0.032
B - Mining	0.163	0	0.035
C - Manufacturing	0.035	0.047	0.061
D - Electricity, Gas and Water Supply	0.108	0	0.035
E - Construction	0.051	0.072	0.056
F - Wholesale Trade	0.034	0.042	0.086
G - Retail Trade	0.003 (D)	0.042	0.086
H - Accommodation, Cafes and Restaurants	-0.011	0.042	0.056
I - Transport and Storage	0.044	0.168	0.057
J - Communication Services	0.051	0.168	0.068
K - Finance and Insurance	0.058	0.116	0.087
L - Property and Business Services	0.057	0.02	0.087
M - Government Administration and Defence	0.049 (E)	0.004	0.087
N - Education	0.047	0.004	0.076
O - Health and Community Services	0.029	0.004	0.083
P - Cultural and Recreational Services	0.032	0.004	0.053
Q - Personal and Other Services	0.007 (D)	0.004	0.065 (F)

[1] Hensher, DA, Truong, TP, Mulley, C and Ellison, R (2012) Assessing the Wider Economy Impacts of transport infrastructure investment with an illustrative application to the North-West rail Link project in Sydney, Australia, Institute of Transport and Logistics Studies, the University of Sydney, Draft paper, February 2012

[2] Legaspi, J. et al., Estimating the wider economic benefit of transport investments: The case of the Sydney North West Rail Link project, Case Stud. Transp. Policy (2015), http://dx.doi.org/10.1016/j.cstp.2015.02.002

Not stated	0.021	0.043	0.065

(A) Hensher et al (2012) Assessing the wider economy impacts of transport infrastructure investments with an illustrative application to the North-West Rail Link project in Sydney Australia
(B) Graham (2006) Wider Economic Benefits of Transport Improvement: Link between agglomeration and productivity, stage 2 report prepared for UK Department for Transport.
(C) Kernohan and Rognlien (2011) Wider economic impacts of transport investments in New Zealand September 2011, NZ Transport Agency research report 448
(D) Statistically insignificant at 10% level
(E) The average of public administration and safety (0.062), administrative and support services (0.030) and professional, science and technology services (0.055)
(F) The elasticity of "personal and other services" is not provided in NZ Transport Agency (2011) report. The overall elasticity for all industries is used.

2. Increased competition as a result of better transport

Competition is imperfect in most sectors because products exist in many different varieties and qualities, buyers do not possess all necessary information, and some firms can exert market power to affect supply and prices. These factors can lead to higher prices, lower production and a sub-optimal mix of outputs.

Transport costs can be a barrier to competition. Lower transport costs will increase the firms' market coverage enabling them to compete in new markets. On the other hand, they will face stronger competition from firms in other markets. Increased competition can lead to efficiency gains which are not captured in conventional economic appraisal.

However, there is little evidence to suggest that a transport project can significantly improve the competition in a densely populated area where an extensive transport system already exists.

3. Increased output in imperfectly-competitive markets

In conventional economic appraisals, values of travel time savings (VTTS) are measured for both commuting trips and business trips. For commuting trips, the VTTS represents the value that people put on their time, and for business trips, it is the value that firms put on their worker's time, represented as the gross wage rate.

When a transport project reduces business travel time, firms can respond to cost savings by increasing output. For example, if a delivery driver, previously making 8 deliveries in an hour, now could make 10 deliveries with a transport improvement, the delivery company may lower its price, in which consumer would benefit, or retain the improved profit margin. A combination of the two may occur.

4. Economic welfare benefits arising from improved labour supply

Transport investments reduce the generalised travel cost that leads to the following labour market impacts:

- More people choose to work as a result of commuting travel time savings
- Some people choose to work longer hours because they spend less time commuting
- Some people change to a higher paid and more productive job, as better transport improves the accessibility of firms and workers

As people's decision on whether to work, how many hours to work and types of job is based on after-tax income, the tax component for additional labour supply is not captured in conventional economic evaluation. The Wider Economic Benefits captures these additional welfare benefits.

Refer to Appendix 12 for the framework for assessing wider economic benefits of transport projects and discussions on the TfNSW in-house WEB model.

TfNSW has developed an in-house wider economic benefit model. The model uses the following output from the Sydney Strategic Travel Model (STM):

Estimating Wider Economic Impacts and Benefits

1. TRESIS-SGEM Model

The Institute of Transport and Logistics Studies (ITLS) has developed an integrated model system known as TRESIS-SGEM. The Transport Environmental Strategy Impact Simulator (TRESIS) has a detailed behavioural system at the transport sectoral level that accounts for the interrelationship between transport and location choices of individuals and households. Sydney General Economic Model (SGEM), a spatial computable general equilibrium model for the Sydney metropolitan area, can identify a number of economy wide impacts of specific transport polices and strategies.

The model has been applied to the assessment of WEI (Wider Economic Impact) for the NWRL project (a 23 km rail link in North West of Sydney). The model estimated additional WEIs associated with redistribution of employment activities, as well as gains in labour productivity linked to agglomeration effects arising from these redistributions. The WEIs were estimated to add about 17.6% to the traditional user benefits calculated for transport project (Hensher et al 2012).

Another application of the TRESIS-SGEM is for assessing the wider economy and social impacts of high speed rail between Sydney and Melbourne[3]. The model considers the agglomeration benefits and its magnitude with the introduction of high-speed rail investment. It focuses on two types of agglomerations: (1) production agglomeration economies, which derives from proximity between firms and other sources of agglomeration from workers, other firms and other facilities; (2) household agglomeration, which derives from proximity between households and sources of utility deriving activities (social, personal, business, and other non-work related activities). Three scenarios were analysed for the average speeds of high speed rail at 150km/h, 200km/h and 250km/h. The model results (table below) indicate that the project increases the effective employment density by between 1.85% and 3.57% dependent on the average speed, and produces wider social and economic benefits in the range of $2.1 billion to $4.1 billion, equivalent to between 0.67% and 1.3% of total household income.

Table 3.2 - Wider economic impacts-Sydney Melbourne High Speed Rail

Average speed of the High Speed Rail	150 km/h	200 km/h	250 km/h
Changes in effective density (% increase)	1.85%	2.94%	3.57%
Wider economic impact: work related travel			
Magnitude ($ millions)	$5.80	$9.03	$11.06
Equivalent to GDP	0.0011%	0.0017%	0.0021%
Wider economic impact: non work related travel			
Magnitude ($ millions)	$2,131.6	$3,407.6	$4,128.2
Equivalent to total household income (THI)	0.67%	1.08%	1.30%

Source: Hensher, D.A., Ellison, R. and Mulley, C. (2012) Assessing the wider economy and social impacts of high speed rail in Australia, report prepared for the Australasian Railway Association (ARA), June 2012.

[3] Hensher, D.A., Ellison, R. and Mulley, C. (2012) Assessing the wider economy and social impacts of high speed rail in Australia, report prepared for the Australasian Railway Association (ARA), June 2012.

2. TfNSW WEBs Model

WEBs is an in-house wider economic benefit model which uses the following output from the Sydney Strategic Travel Model (STM):

- Travel demand between origin-destination travel zones by transport modes (rail, bus and car) in 2021 and 2031.
- In-vehicle travel time between origin-destination travel zones by transport mode.
- Auxiliary (access and egress) time between origin-destination travel zones by mode.
- Waiting time between origin-destination travel zones by transport mode.
- Boarding numbers of rail and bus between origin-destination travel zones, for calculating number of transfers.
- Public transport fare between origin-destination travel zones by transport mode.
- Road toll amount between origin-destination travel zones for car driving.
- Distance travelled between origin-destination travel zones by transport mode.

These outputs are loaded into a macroeconomic model to estimate the impacts of transport investments on welfare and gross domestic products. The welfare impacts refer to agglomeration economies, benefits from the increased competition caused by the increased market catchment due to better transport infrastructure, and increased output and welfare benefits arising from improved labour supply. The GDP impacts stem from the output of an increased workforce, people choosing to work longer hours, people moving to higher paid and more productive jobs and business travel time savings.

The macroeconomic model consists of an economic database and the algorithms for estimating employment density, effective employment density, agglomeration benefits and other wider economic benefits. The economic database provides SLA level employment, average productivity, values of travel time, vehicle occupancy and spatial information of SLA land areas, resident density and employment density. The productivity elasticities are treated as exogenous variables in TfNSW WEBs model. This means that elasticities have to be estimated or sourced from other studies. In the TfNSW WEBs model, the elasticities for Sydney estimated by the Institute of Transport and Logistics Studies have been built in. The elasticities of UK and New Zealand have also been included for testing sensitivities.

Wider Economic Benefits can be presented by industry and by location. The model has been used to assess the wider economic benefits of the North West Rail Link. In this case, the WEBs represent a 14.8% mark-up over conventional economic benefits as shown in the table below.

Table 3.3 Wider Economic Benefits Summary

Cost / Benefit Item	Welfare Benefits ($M)	GDP Impacts ($M)
Project costs (A)	**$4,018**	
Project benefits (A)		
Conventional economic appraisal		
Net user benefits	$3,125	
Fare and other revenue	$322	
Road decongestion benefit	$559	
Externality benefits	$155	
Sub-total conventional benefits	**$4,161**	
Other benefits	$999	
Total Benefits	**$5,160**	

Wider Economic Benefits [B]		
Cost / Benefit Item	**Welfare Benefits ($M)**	**GDP Impacts ($M)**
Welfare Impacts		
WB1: Agglomeration economies	$503 (81.7%)	
WB2: Increased competition	$0	
WB3: Increased output in imperfectly competitive markets	$65 (10.6%)	
WB4: Benefits arising from improved labour supply	$47 (7.6%)	
GDP Impacts		
GB1: More people choose to work		$100
GB2: Some people choose to work longer hours		$0
GB3: Move to higher productive jobs		$88
GB4: Agglomeration economies		$503
GB5: Imperfect competition		$65
GB6: Business time savings and reliability		$650
Total Wider Economic Benefits	**$615**	**$1,407**
WEBs as % of conventional economic benefits	**14.8%**	
Benefit Cost Ratio (Excluding WEBs)	**1.28**	
Benefit Cost Ratio (Including WEBs)	**1.44**	

(A) Economic Appraisal of North West Rail Link, 2010 update by Douglas Economics and reported in Business Case of North West Rail Link, NSW's 2010 Submission to Infrastructure Australia. Values were indexed from 2010 dollars to 2011 dollars using Sydney CPI.

(B) Estimate using in-house WEBs model.

3.2 Safety

3.2.1 Procedures for Road-based Countermeasures

RTA's Accident Investigation and Prevention (AIP) Procedures for Road-Based Countermeasures was issued in May 1995 to guide the process of selecting, evaluating, developing, and implementing AIP programs. The procedures include studying accident problems and feasible countermeasures to address these problems. Each countermeasure has its respective cost and level of effectiveness. Countermeasures include projects which aim to change road users' behaviour to improve their safety. These projects may range from simple signs (warning, regulatory) to large scale deterrent programs (coordinated enforcement and publicity) to changes in driver training and education and testing. These projects aim to reduce the number and\or severity of crashes and casualties through different means, e.g. facilitating appropriate behaviour for traffic conditions, ensuring use of occupant restraints, deterring drink-driving and improving knowledge, understanding and skill.

Treatments are implemented through a program of remedial works such as a 'blackspot program' or a 'safer roads program'. The selection of countermeasures (treatments) or a package of treatments from a number of possible alternatives requires economic assessment of those alternatives.

3.2.2 Major Steps in the process

Selection of treatments from alternatives follows the following steps:

a) Accident database analysis

b) Detailed accident investigation
c) Developing and selecting countermeasures
d) Implementing countermeasures
e) Monitoring and evaluating countermeasures

Following the Accident Database Analysis (where the accident situations on roads are systematically reviewed) and accident investigation, a pool of treatment from the recommendations of the accident investigation studies is formed. The chosen treatment or package of treatments is called a 'project'.

For the economic assessment of road safety countermeasures, accident savings are used in determining the benefits. Other types of benefits can be included as supporting evidence. When calculating the safety BCR of a project, the cost used in the calculation must be the full cost of the project. Part project costs cannot be used to claim the full safety benefits of a project.

The benefits for each alternative can be determined by estimating the likely number of accidents prevented or the targeted reduction in the number of accidents multiplied by the accident cost.

The cost of accidents classified according to accident outcome, road type and accident type are provided in Appendix 4. The cost of each alternative treatment can be estimated by reference to standard costs of standard treatments, or estimates can be made from first principles.

Care must be taken in estimating the 'accident' savings. Accident reduction savings are a function of the change in accidents, if any. For example, with road based countermeasures, if a wide variety of accident-types are present at an intersection, only those accidents directly affected by the proposed treatment can be used in determining the accident 'savings'. It is wrong to estimate the accident savings based on all the accidents at the intersection. (Refer to Procedures for Road-Based Countermeasures, Accident Data Analysis).

The cost and benefit streams for each treatment package are calculated and discounted using a 7% discount rate. The appropriate economic criterion for choosing between alternative treatments is NPV.

The costs and benefits of these proposed projects are evaluated using a prescribed cost benefit approach. However, there are projects which are expected to generate both safety results (reduced accidents) as well as traffic benefits (eliminate traffic delays). In these cases, it is necessary to calculate potential benefits and economic viability of the project as a whole.

Specifically, the following are provided as guidelines:

- Calculation of benefits - When calculating the BCR for a project that is to be funded under the AIP program the BCR should be calculated using accident savings only.

- Consideration of other impacts of measures - Where the measure proposed will have a marked effect on traffic flow, the viability of the measure should be taken into consideration. The relevant sections of the RMS or Council should be consulted to confirm whether the proposed measures will result in undue delays to road users.

- Route and Area Studies - Where a route or area wide AIP study is undertaken, the route or area should be divided into individual components, (usually by individual devices) and the benefits and costs calculated separately. The costs and benefits can then be aggregated over the entire scheme to arrive at a BCR. In some instances, separate BCRs can be calculated for individual components of the scheme, where it is considered that these components could be installed as stand-alone treatments.

- Mass Action Studies - For a mass action scheme, the BCR should be calculated for the scheme as a whole. In particular, it is not correct to calculate the BCR separately for each site, or for those sites having greater numbers of accidents.

- Multiple Measures Proposed - It might be that for some of the sites investigated, a lower and a higher cost solution is recommended. In this case two or more separate BCRs can be calculated. However, the same accident savings should not be used for both of the remedial measures unless only one of the measures will ever be implemented. That is, care should be taken to ensure that the accident reductions assumed for the measure having the lower benefit cost ratio do not include those accident savings already assumed for the measure with the higher BCR, which should be implemented first.

The choice between undertaking either cost-benefit analysis (CBA) or a cost-effectiveness analysis (CEA) will depend on how easily the benefits of the project can be valued. If schemes have quantifiable effects, for example accident reduction targets, then it will be possible to carry out cost-benefit analysis.

If the proposed scheme has benefits that are difficult to quantify or value, then a CEA will be appropriate. The costs are calculated in the same way as for a CBA. The benefits must also be identified and described qualitatively (and quantified where possible)

Each project should be ranked using BCRs. Projects are prioritised on the basis of safety/benefit cost ratios and those projects falling below the budget cut-off are excluded from the program.

For the program to achieve 'maximum' value for money, more projects need to be developed than will be implemented so that the best projects for the budget can be identified.

A road safety project assessment tool which is a spreadsheet model (Road Projects Safety Benefits and Impacts Calculation Model) is currently being used in the RMS and TfNSW for conducting economic analysis of road safety projects including submissions to the Commonwealth Department of Infrastructure, Regional Development and Cities for blackspot funding. This can be accessed online from the RMS website Best Practice Cost Estimation – Publicly funded road and rail construction.

The spreadsheet model requires the following information for each treatment/package of treatments:

- Location of the project;
- Speed limit of main road;
- Expected annual traffic growth;
- Assumed project life;
- Years of accident data and start of data;
- Initial cost of treatment/measure;
- Annual maintenance cost of treatment/measure;
- Measure code;
- Description of accidents according to RUM code; and
- Target number of accident reduction by DCA code.

The model requires input entry on the number of accidents that occurred during the study period and the target reduction in the accident occurrence.

The current safety project evaluation model is based on accident costing disaggregated by crash type (DCA) in the calculation of BCR and NPV.

There are projects, however, where the benefits are expressed in reduction of severity of accidents (e.g., less injurious crashes) rather than reduced number of crashes.

A case study on economic assessment of road safety campaigns is also presented in Section 8.3 Economic Assessment of Non-infrastructure solutions and service procurement projects.

3.3 Environmental assessment

3.3.1 Introduction

The inclusion of 'externalities' and in particular environmental impacts is an important part of an economic assessment as well as being a formal part of project evaluation. The effect of a transport mode on people other than its users must be considered. Economic appraisal of environmental impacts should be seen as an integral part of the broader economic appraisal process. The intention is to internalise environmental externalities into the evaluation process on the basis that the environment is not a free good, and costs and benefits imposed on third parties count toward assessing the community wide impact of a proposal.

Examples of externalities are inconvenience caused to pedestrians by traffic, effects of noise and air pollution on nearby properties, and health and productivity gains that result from eliminating dust by sealing roads.

External and environmental effects to be considered are:

- Noise;
- Vibration;
- Disruptions to pedestrians/cyclists and other travellers (via wait times, etc.);
- Severance;
- Air quality (e.g. particulates, noxious gases, odour, etc.);
- Greenhouse gas emissions;
- Visual intrusion (scenic quality);
- Other environmental issues from the Environmental Impact Assessment, e.g. water quality, heritage, ecological impacts, etc.; and
- Local disturbance due to construction.

The effects of a transport project or project options on the above should be quantified as far as possible. The assessment and quantification of environmental effects should be considered in the project evaluation as early as option selection phase. The scale of these effects needs to be assessed for any proposed project and project options, together with the project costs, relative to the benefits of the proposed scheme.

Valuation Principles

An important stage in project evaluation is the valuation of the different types of benefits or effects accruing from the project. In many cases, the benefits concern project consequences which are not traded in any market. For these non-marketed effects, several different valuation approaches are used.

A general trend has been a methodological increase in the estimation of unit prices in the above method categories. For example, noise effects range, from initially qualitative statements associated with point scores, through quantitative annoyance assessments based on defined annoyance units to economic noise cost estimates made using prices inputted from quasi-market observations or surrogate prices.

The amount of work done on measuring, predicting and assessing intangible effects depends on both the severity of the effect and the amount of difference there is between the existing situation and the various improvement options. For minor works, it is possible that there will be no significant differences in the various intangible factors between the options. In these cases, a note to that effect is all that is required.

Even if the intangible effects are significant, there may be little difference between the existing situation and any of the options. In this case, the existence of the effect and the similarity between the options should both be noted. More detailed investigation will usually not be warranted.

If there is a significant difference between options, either in total effects, or if there is a change in the distribution of effect so that there are clear gainers and losers, more detailed examination will be necessary.

3.3.2 Environmental Impact Assessment

An Environmental Impact Assessment (EIA) is required for all proposed road, bridge and ancillary works. An EIA is started at the time of initiating a scheme and thus the results should be available for inclusion in the economic cost-benefit appraisal. Environmental impacts highlighted by the EIA should be included where possible as external effects of the cost-benefit analysis. Economic analysis results are also included as part of the EIA reports. The EIA and the cost benefit analysis need to be done together.

Special attention should be paid to the following items, in addition to those mentioned above, which should be often included in the assessment framework even if the impact is minor:

- Heritage (indigenous and non-indigenous)
- Biodiversity
- Water quality (hydrology)
- Air quality (in built-up areas)
- Noise and Vibration
- Pedestrian delay
- Severance
- Visual intrusion
- Waste creation
- Land contamination
- Land form stability and erosion
- Community effects
- Business effects: how the project affects local business and the economy
- Effects on other modes of transport

Guidance on the assessment of these matters is given in Appendix A of the RTA's Environmental Impact Assessment Guidelines.

Once the external and environmental effects of a scheme have been assessed they can be presented in a tabular framework to allow easy comprehension of their scale of impact.

3.3.3 Measurement

Aspects of some intangibles, e.g., noise, can be easily measured but are difficult to quantify or monetise. Other intangibles do not lend themselves to physical measurement, and in such cases more subjective assessment will be required, e.g. visual impacts. Subjective assessment should involve professionals competent in assessing the intangible factor concerned and, for human impacts, consultation with the population experiencing the effect.

Where the people experiencing the impact have had no prior exposure, comparison with similar situations elsewhere may assist in obtaining an assessment of likely impacts.

The following section outlines various techniques available for use by projects managers and analysts in the valuation of environmental effects of economic and social development projects, such as roads, bridges, dams, and national parks.

3.3.4 Valuation Methodologies

The relevant concept when measuring the benefit of an environmental improvement through a project is **total economic value (TEV)** defined as the benefits of the project minus the cost of the project and environmental damage caused by the project. In the same way, the damage done to the environment is measured by calculating the TEV that is lost due to the construction of the project.

The relevant comparison when looking at a decision on a project is between the cost of the project, the benefit of the project and the TEV that is gained or lost by the development.

The decision rule on a development project affecting the environment is as follows:

a) Proceed with the project if **$(B_D - C_D - B_P) > 0$**

b) Do not proceed with the project if **$(B_D - C_D - B_P) < 0$**
where
B_D = benefits of the project
C_D = cost of the project
B_P = benefits of preserving the environment by not developing the area.

TEV is in fact a measure of B_P, the total value of the asset left in its natural state. TEV is not generally easy to measure because environmental amenity is not a traded good or service and does not have an observable market price.

There are several approaches to the economic measurement of environmental impacts.

Reference can be made with the NSW Office of Environment and Heritage ENVALUE Database. http://www.environment.nsw.gov.au/envalueapp/

Interested users are also referred to Environmental Valuation Reference Inventory (EVRI), a Canadian-run resource of over 7,000 international studies providing values, techniques and theories on environmental valuation. This provides a range of estimated economic values for particular environmental goods summarising the work undertaken in various countries/States in attempting to value environmental issues. These values are indicative only. These were derived from various economic techniques such as contingent valuation or hedonic pricing (see following sections for discussion of these methodologies).

The EVRI is intended primarily as a tool to assist policy analysts using the benefits transfer approach to estimate economic values for changes in environmental goods and services or human health. In the benefits transfer approach, the results of the previous studies held within the EVRI can be used (transferred) to estimate the economic value of changes stemming from current programs or policies. The main challenge faced in conducting an economic valuation with a benefits transfer is in finding the most appropriate studies to use in the transfer exercise. Choosing an appropriate set of studies involves matching the context of the previous economic studies, termed study sites, with the context of the current program or policy, termed the policy site. Please see https://www.evri.ca/Other/AboutEVRI.aspx for more details on EVRI.

1. Stated Preference Methods

This considers environmental gains such as an improved scenic view and better levels of air quality or water quality, and seeks directly to measure the monetary value of those gains. This may be done by looking for a surrogate market or by stated preference surveys.

The surrogate market approach looks for a market in which goods or factors of production (especially labour services) are bought and sold, and observes that environmental benefits or costs are frequently attributes of those goods or factors. Thus a fine view or the level of air quality is an attribute or feature of a house, risky environments may be features of certain jobs and so on.

The experimental approach simulates a market by placing hypothetical valuations of real improvements in specific environments. The aim is to make the hypothetical valuation as real as possible.

2. Contingent Valuation Method (CVM)

Contingent valuation method uses a direct approach, i.e., basically asking people what they are willing to pay for a benefit and/or what they are willing to receive by way of compensation to tolerate a cost or a loss. The process of asking may either be through a direct questionnaire/survey, or by experimental techniques in which subjects respond to various stimuli in laboratory' conditions. The technique is so named because the value it estimates is contingent upon the hypothetical situation described to the respondent. One of the main advantages of this approach is that it permits estimation of both use and non-use benefits. Use benefits are those that accrue from the physical use of environmental resources such as the benefits to productive activities (e.g., agriculture, forestry, fishery) of preserving or improving the environmental amenities and the benefits derived from activities such as visiting a park, recreational fishing or appreciating a view at a look out.

Non-use benefits are generally classified into five types[4]:

- Existence value - value obtained from the knowledge that an environmental asset exists;
- Vicarious value - value obtained from indirect consumption of an environmental asset through print or media;
- Option value - value obtained by retaining the opportunity to enjoy an environmental asset at some future date;
- Quasi-option value - the value of the opportunity of obtaining better information by delaying a decision that may result in irreversible environmental loss;
- Bequest value - value the current generation obtains from preserving the environment for future generations.

The design and implementation of contingent valuation surveys requires consideration of the following:

a) **Presentation** - the more familiar the respondent is with the intangible effect being valued, the more likely are the results to be accurate (e.g., represent visual impacts through design drawings and artist impressions.
b) **Sample size** - the required sample size is highly dependent on the size of population, the type of question(s) being asked, the standard deviation of the responses and statistical model specification requirements. For small population with diverse opinions, as much as 50% of the population may need to be surveyed, whereas for large populations only 0.1% may need to be surveyed.

[4] See Economic Analysis Manual, RTA, 1999.

The number to be surveyed increases considerably if the question is to be stratified (e.g., one third are to be asked whether they would be prepared to pay $10, one third $20 and one third $30).

c) **Sample selection** - the sample must be randomly drawn from the affected population. These may not only include residents from adjacent properties but also users of the road and, in some cases, residents of wider communities.

d) **"Willingness to pay" versus "willingness to accept compensation"** - some respondents may not provide reliable estimates of willingness to pay for an environmental attribute they consider theirs by right. For this reason, willingness to accept compensation for an environmental "good" foregone may be appropriate in some cases, but tends to result in values two or three times greater than "willingness to pay" values. If a "willingness to accept" compensation method is used the resulting value should be noted. be Dividing it by 2 to 3 is widely accepted as way of deriving a more robust value for use in project evaluation.

e) **Bias minimisation** - the effect of bias in sample selection, survey design and implementation should be minimised. Such factors as "no bid" responses, starting point bias and instrument of payment affect the distribution of responses. Advice should be sought from competent survey practitioners, one or more rounds of pre testing are usually necessary and all assumptions made in undertaking the survey should be reported.

3. Conjoint Analysis (Choice Modelling)

As with contingent valuation, conjoint analysis seeks willingness to pay values by asking people directly, rather than inferring values from observations of people's behaviour. Conjoint analysis reveals how people make complex judgments. The techniques assume that complex decisions, including route choice decisions, are based not on a single factor or criterion, but on several factors 'considered jointly'. This method reveals people's preferences in a realistic manner and enables assessment of the weight or value people give to various factors that underlie their decisions.

The advantage of conjoint analysis over contingent valuation is that it provides an emphasis on trade - offs between different factors and provides a comparison between tangible and intangible costs.

4. Revealed Preference Methods

Dose-response is an example of revealed preference methods of valuation. Examples of a 'dose-response' relationship include the effect of pollution on health, the effect of pollution on physical depreciation of material assets such as metals and buildings, the effect of pollution on aquatic ecosystem and the effect of pollution on vegetation.

This approach treats environmental amenities as factors of production. Environmental values are indirectly estimated by attempting to establish a relationship between the physical effects of some environmental change on human health, productivity, or earnings. An example is the effect of water pollution on the profitability of commercial fishing activities. The objective is to measure the change in net benefits as revealed in market prices caused by environmental damage. Alternatively, benefits can be measured as the increased productivity attributable to improved environmental quality.

Indirect procedures do not constitute a method of finding the willingness to pay (WTP) for the environmental benefit or willingness to accept (WTA) compensation for environmental damage suffered. They estimate the relationship between the 'dose' (e.g., pollution) and the non-monetary effect (e.g., health impairment).

5. Hedonic Price Approach

The hedonic price technique is built on the notion that it is often possible to choose the level of consumption of environmental goods, such as noise and air pollution, through the choice of residential location or selection of market goods. The technique uses statistical analysis to isolate the environmental values that contribute to differences in product prices, typically price differences observed in real estate markets.

Property values are determined by various factors such as output derived from property, shelter usefulness, access to workplace, to commercial amenities and to environmental facilities such as parks, and the environmental quality of the neighbourhood in which the property is located. Given that different locations have varied environmental attributes, such variations will result in differences in property values. These valuations might be used as an input to benefit cost analysis or considered in isolation where the valuation of the environmental attribute is of primary interest.

Sources of property price differential include:

- Property factors:
    - Amount and quality of accommodation available
    - Accessibility of the central business district
    - Level and quality of local public facilities
    - Level of taxes that have to be paid on property

- Environmental characteristics of the neighbourhood:
    - Level of air pollution
    - Traffic and aircraft noise
    - Access to parks and water facilities

The 'hedonic' approach attempts to:

- Identify how much of a property price differential is due to a particular environmental difference between properties;
- Infer how much people are willing to pay for an improvement in the environmental quality that they face and what the social value of improvement is.

The hedonic pricing approach calculates a function describing the relationship between the price of the property (PP) and the above characteristics, e.g.

$$PP = f\{ PROP, NHOOD, ACCESS, ENV\} \qquad \textit{Equation 3.1}$$

Where:

PP = Property price;
Prop = property;
NHood = neighbourhood;
Access = accessibility; and
ENV = environment

Estimation is usually undertaken through multiple regression analysis that provides the parameters (regression coefficients) which are interpreted as the contribution of explanatory factors in the price differential. This contribution (which could be translated into monetary terms) is then included as the benefit or cost values attributable to the project being appraised. Hedonic pricing approach, however, is not suited to the task of assessing non-user or 'conservation' values.

The accuracy and reliability of non-market valuations need to be tested by other means. The main tests are:

- Consistency of results in similar contexts;
- Consistency of results with other benefit estimation techniques;
- Consistency of results with 'real market' experience.

6. Travel Cost Approach

Travel cost models are based on an extension of the theory of consumer demand in which special attention is paid to the value of time. The total cost, for instance, of a visit to a park is comprised of:

- Monetary cost of getting there
- Entry fee, if any
- Cost of leisure time for the period of people visiting the park

The benefit of establishing or improving the park is then derived by estimating how much the willingness to pay will increase if the facility is developed.

7. Mitigating Measure Costing

This approach attempts to assess the cost of preventing environmental damage or the costs of restoring or replacing natural resources. This also involved measuring the cost of actions or behaviours towards avoiding the effects such as moving locations and modifications to the housing units.

Assessment

The general principles for assessing intangible effects are:

a) The population that may be exposed to the intangible effect should be enumerated and described with regard to its sensitivity to the effect concerned. The population may need to be classified into different classes of sensitivity in this respect.
b) The pre-existing level of the intangible effect should be identified and measured where possible to show the existing degree of exposure.
c) The new level of the intangible effect arising from each project option should then be assessed. The impact is then the interaction between the effect itself measured at the location of those experiencing the effect, and the sensitivity of those experiencing the effect.
d) For some intangible factors, performance standards may exist, and these should be taken into account in selecting and evaluating project options.

Presentation

The recommended form of presentation is within a tabular framework or a project balance sheet in which all project costs and benefits are set out using monetary or physical units as appropriate and in which the bearers of costs and recipients of benefits are also shown.

It is important that all significant intangible effects are included whether positive or negative. For example, if a negative effect to some individuals is countered by a positive effect elsewhere, possibly of a very different extent and intensity, inadvertently omitting either of these effects may bias the total appraisal report.

3.4 Externalities

Certain benefits and dis-benefits, which accrue to either road users or non-road users are not readily quantified in monetary terms. These benefits and dis-benefits, which are referred to as externalities and intangible effects, shall be described and, where appropriate and feasible, quantified in their natural units and the extent of the effects shall be quantified, e.g., the number of persons affected. If they are significant, monetary values shall be estimated for these effects.

Indicative values for noise and particulate emissions, to some extent, have been estimated in various studies in Australia and overseas. While there may be a considerable margin of error associated with some of the indicative values for intangible effects, it is still useful to provide an indicative value rather than to ignore a value because it is uncertain. To the extent possible, the indicative values are included in some examples presented in the guidelines. Effects that do not have indicative values can be valued by willingness to pay survey or other market valuation techniques as described above.

In many cases, intangible effects are not amenable to quantitative description. While some information on various impacts are discussed in this section it is by no means comprehensive or definitive. This is because techniques and the state of knowledge is evolving. Specialists in the appropriate disciplines may be required for the evaluation of significant effects. Community consultation and opinion surveys should be undertaken for major projects.

1. Noise

Noise is a disturbing or otherwise unwelcome sound which is transmitted as a longitudinal pressure wave through the air or other medium as a result of the physical vibration of a source. Its propagation is affected by wind and intervening absorbing and reflecting surfaces and is attenuated with distance.

Road traffic noise sources include:

- Engine and transmission vibration
- Exhaust systems
- Bodywork and load rattle
- Air brake and friction brake
- Tyre/road surface contact
- Horns, doors slamming, car audio systems
- Aerodynamic noise

The main factors influencing road noise levels and their respective contributions are as follows:

- Engine - 34%
- Tyres - 30.3%
- Exhaust system - 26.5%
- Air intake system - 9.2%

This criterion provides a framework which guides the consideration and management of traffic noise issues associated with new building development near existing or new roads and new or upgraded road development adjacent to new or planned developments. The framework must enable selection of the best mix of short, medium and long term strategies to meet the appropriate noise level given existing and emerging conditions. Noise impacts and mitigation measures need to be considered early in the planning process. Where planning approaches are appropriate they can be the most effective and lowest cost means of mitigating noise impacts.

The framework embodies a non-mandatory performance-based approach which applies the criteria as the target but recognises that there will be situations where planning strategies are not feasible and that cost effective solutions which can be applied immediately may not always meet the target. For these cases, a longer term perspective needs to be taken to institute ongoing strategies that will minimise traffic noise impacts over time.

The criteria are summarised in the table below:

Table 3.4 RMS Road Noise Level Criteria

Type of Development	Day dB(A)	Night dB(A)	Criteria
New freeway or arterial road corridor	$L_{eq\,(15\,hr)}$ 55	$L_{eq\,(9\,hr)}$ 50	The new road should be designed so as not to increase existing noise levels by more than 0.5dB. Where feasible, noise levels from existing roads should be reduced to meet the noise criteria. In some instances this may only be achieved through long term strategies such as improved planning design and construction of adjoining land use developments, reduced vehicle emission levels through new vehicles, greater use of public transport and alternative methods of freight haulage.
Upgrading existing freeway/ arterial road	$L_{eq\,(15\,hr)}$ 60	$L_{eq\,(9\,hr)}$ 55	It is highly desirable that there is no increase to existing noise levels in these cases. Where feasible, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may only be achieved through long term strategies such as improved planning, designing and construction for adjoining land use developments, reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles, greater use of public transport and alternate methods of freight haulage.
Redevelop existing freeway/ arterial road	$L_{eq\,(15\,hr)}$ 60	$L_{eq\,(9\,hr)}$ 55	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2dB. Where feasible, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may only be achievable through long term strategies such as improved planning, design and construction of public transport and alternated methods of freight haulage.

L_{eq} is the average sound level or the equivalent continuous sound pressure level. The sound of an imaginary continuous signal, (noise) level is calculated within a given time interval that would produce the same energy as the fluctuating sound level that is being measure. The L_{eq} algorithm divides the integrated sound pressure by the total duration of the signal. The result is expressed in **dB.**

Freeway/Arterial refers to roads handling through traffic with characteristically heavy and continuous traffic flows during peak hours. Through traffic is traffic passing through a locality bound for another locality.

New freeway/Arterial refers to a freeway or arterial road which is proposed on a 'corridor' which has not previously been a freeway or arterial road or an existing freeway or arterial which is being substantially realigned.

Upgraded Freeway/Arterial refers to proposals where changes are not designed to increase traffic carrying capacity and are generally changes related to safety or amenity objectives, straightening curves, installation of traffic control devices or minor adjustments to road alignments).

Redevelop Existing Freeway/Arterial refers to an existing freeway corridor where it is proposed to increase traffic carrying capacity or changes in traffic mix through design or engineering changes.

Details of the application of the Noise Criteria are provided in the RMS Noise Policy and Procedures Manual.

The RMS Noise Policy encourages controlling the noise at the source before considering alternatives such as physical noise attenuation measures (noise barriers). The policy also considers equity issues and budget constraints.

Noise Reduction Assessment Methods (NRAM)

Noise reduction schemes may either be components of a larger road scheme or stand-alone schemes. There are two principal methods of evaluation. Noise reduction schemes may be required due to regulations or guidelines specifying the appropriate noise level applicable in a certain area of concern, e.g. road side noise. If there is a commitment to achieve a certain level of noise (see below) then cost-effectiveness analysis is more appropriate to ascertain the most economically effective way of achieving the desired noise level. Alternatively noise reduction schemes may be considered on their merits and an evaluation of the costs and benefits can be undertaken to ascertain whether or not they are economically worthwhile.

Within the RMS both principles of assessment are relevant. There are the Road Traffic Noise policies to follow but it is also necessary to achieve value for money from investment. Thus, where the guidelines are not prescriptive, it is possible to evaluate whether or not noise reduction measures offer economic value for money.

RMS is currently implementing a Noise Reduction Assessment Method (NRAM) to assess the types of noise controls needed for an area adjacent to a road. These procedures are developed for project managers responsible for implementing these procedures. These procedures are used for the following:

- Strategic environmental assessment of projects,
- Planning new roads or changes to existing roads,
- Review of noise estimated in environmental impact statements within 12 months after the opening of a road and in the case of an EIS or REF, the noise levels predicted for the end of the 10th year after opening.

Traffic noise prediction methods are to estimate exposure to road traffic noise. The prediction method can also be used to calculate existing noise levels.

The NRAM is a procedure to allocate a predetermined road traffic noise control budget within a defined area. The aim in having the noise budget is to optimise the amount of noise reduction achieved for all buildings within the noise catchment. NRAM can be used for strategic planning, environmental impact assessment and actual road design.

A five-step procedure for valuing noise abatement works is as follows:

a) Estimate residential property values over the area to be affected by the project.
b) Estimate future traffic noise levels over the area, with and without various noise abatement options.

c) Assess the noise damage impact for each option by calculating the change in property values that will occur with the change in noise levels, estimated at 0.9% per dB.[5] Changes in noise level below 50 dB(A) L10(18h) are considered to have no impact on the community. Estimate the construction cost of each option.
d) Determine the Net Present Value of each noise abatement option.
e) The economically optimum noise abatement expenditure is the project with the highest Net Present Value and a Benefit/Cost ratio greater than one.

Vibration

Vibration refers to the effects of ground borne waves although it is sometimes confused with low frequency airborne noise from heavy vehicles. An assessment of vibration impacts may be required if one or more of the following conditions exist:

- A large proportion of heavy traffic and an uneven road surface
- Heavy traffic passing very close to pedestrians or vibration-susceptible buildings (in the case of pedestrians the effects of air transmitted vibrations may need to be considered)
- Unusual ground or structural conditions that propagate or amplify vibration at frequencies likely to be generated by vehicle/road surface interaction.

Measurement

Vibration is measured using an accelerometer and recording equipment. Peak particle velocity in mm/second and peak amplitude (displacement) are measured.

Certain ground conditions and building structures can amplify transmitted vibration. Vibration must therefore be measured at all locations likely to be of significance.

Impact Assessment

Vibration becomes perceptible between 0.15 and 0.3 mm/s, and is clearly perceptible at 2 mm/s, by which point it will start to cause annoyance. Particle velocities of 55 mm/s or more can cause minor structural damage and rattling.

The results of the assessment should identify number of people and buildings affected and degree of change in conditions.

2. Pedestrian Delay

Traffic causes delay to pedestrians wishing to cross a road. Heavy traffic creates more pedestrian delay and heavy traffic flows may necessitate the introduction of formal crossing facilities, e.g., signalled crossings to both facilitate pedestrian movements and to enhance safety. Pedestrian delay is a function of the number of pedestrians delayed and the mean delay to all pedestrians. Surveys can be undertaken to ascertain existing delays and the number of pedestrians affected. Future delay can either be estimated from the cycle time of the proposed signalled crossing or surveys of other similar crossings can be used. If significant delay or time savings are apparent, an appropriate value of time (see Appendix 4) can be used to estimate the benefit or cost.

Pedestrians are also affected risk and perceptions of risk. However different population groups have different reactions and needs.

[5] Value recommended by RMS based on researches by Resource Assessment Commission 1990, A survey of hedonic price technique, Research Paper, Sept 1990 & Alexandra, A and Barde J.P. (1987) Transportation Noise Reference Book, Butterworth, U.K.

It is therefore recommended that if pedestrian effects are significant or vulnerable groups are affected, then pedestrian groups should be categorised and the expected impacts on them highlighted. Typical pedestrian categories might be:

- School children;
- Shoppers with young children;
- Elderly persons;
- Handicapped.

3. Severance

Pedestrians and the wider community are also affected by severance. Severance refers to the divisive effects a major road or heavy traffic flows have on the community on either side of it. It encompasses more than pedestrian delay since it involves the general weakening in communications between the physically separated areas. The situation most often occurs where an arterial route passes through a small town or suburb, but may also occur in cases of farm access or wildlife corridors split by roads. The impediments to movement can be either physical (i.e. fixed barriers) or psychological (i.e. perceived impediments). Actual severance results in reductions in pedestrian (and other modes of) journey frequency and gives rise to the feeling of being cut-off due to adverse changes in environmental quality.

Assessment of Impact

The immediate effect of severance is for travel across the road to be suppressed or diverted since the experience of crossing is seen to be risky and intimidating, particularly for young and old, or physically impossible.

The consequent effects have been reported to be:

- Disruption of local commercial centres
- Less use of community facilities
- Loss of physical and social identity of the locality.

The degree of severance experienced will be a function of the physical barrier imposed by the road, the crossing facilities provided and the psychological reaction. Part of the assessment of severance will of necessity be subjective; however community consultation and previous experience of similar schemes can be used as an aid to gauge the impact of severance.

To quantify these effects requires information on existing patterns of land use and community structures and interactions, particularly in relation to community facilities such as school, neighbourhood shops, outdoor recreation areas, public transport stops and places of work. Some changes in severance effect can be evaluated in a similar way to road traffic by calculating changes in travel times for pedestrians and cyclists and applying the travel time values given in Appendix 4.

For existing travel routes, severance impacts can be considered on the basis of increased or reduced costs to existing pedestrians crossing the road. The analysis should take into account the additional distance required to walk to a controlled intersection, the time spent waiting to cross and the crossing time.

For major projects, the Regional Environmental Adviser should be contacted in the first instance. A social and town planning study may be required and suitably qualified persons should be used for this task. Major impacts are most likely to arise when a new arterial road link is being planned or when a minor link is proposed for major upgrading in function.

In such circumstances the general principles of urban planning are involved and the contribution of each project option to the aims and objectives of planning goals should be mentioned. The options should be ranked against suitable social and planning criteria.

Reporting of Severance Effects

Any areas affected by severance shall be identified, described and if appropriate, mapped. The location of community facilities and the effects of the projects on the accessibility of these facilities, particularly for pedestrians and cyclists shall be reported. Travel time changes for cyclists and pedestrians should be included with other road user costs in the economic evaluation.

Main crossing points should be marked and the numbers of crossing movements indicated. In the case of projects such as motorways that create major barriers, their effects on overall community structures shall be reported.

4. Visual Intrusion

Visual impacts may be conceptually divided into:

- Visual obstruction (blocking of view)
- Visual intrusion (appearance of the road jars with the surrounding, perceived loss of amenity by persons located close to a road and its traffic, loss of privacy, night time glare from streetlights and vehicle headlights)
- View from the road (aesthetic appearance of the road to the road users)

The view of the road and road traffic and, conversely, the view from the road of the landscape are both relevant visual aspects for assessment. Another visual effect is creation or loss of privacy. Particular aspects of roads that may be considered visually intrusive or degrading to the landscape (urban or rural) include:

- Blocking of the view by passing or stopping vehicles;
- Street furniture - poles, signs, markings;
- Glare from street lights and vehicle headlights;
- Visual incongruity, conflicts of scale, impairment of views and loss of viewpoints;
- Loss of daylight, creation of views into private areas (associated mainly with elevated road structures).

Measurement and Assessment

Physical measurement techniques have been devised which provide solid angle/time measurements of the occupation of the view by traffic. However, these are rather limited in their coverage of visual impact and a wider qualitative assessment by the RMS landscape architect is the preferred method of obtaining an informed opinion of visual effects. The Review of Environmental Factors (REF) also provides guidance on assessing the visual (scenic quality) impact.

Highway designs need to deal with the following:

- The visual appearance of road geometry;
- The integration of the road in the landscape;
- The enhancement of the scenic value of the road to the road user.

This is addressed through geometric design, roadside planting and positioning of the road with respect to natural features.

Reporting of Visual Impact

The visual obstruction and intrusion of projects shall be reported including where appropriate, artist's impressions of the project and the numbers of people affected. The view from the road shall be reported in terms of the quality of scenery visible from the road and the types of people expected to benefit.

Where projects have been modified to protect or enhance their visual impact, the incremental costs and benefits of these measures shall be reported.

5. Air Quality

Air pollutants:

Vehicles emit gases and particles into the environment.

- Carbon monoxide (CO)
- Oxides of nitrogen (NO_x)
- Unburnt hydrocarbons (HC)
- Lead compounds
- Particles such as smokes, tyre and brake wear products

Assessment of Air Pollution

An indication of pollution levels can be obtained from one of several pollution prediction methods. These allow the concentration of pollutants to be estimated from knowledge of traffic volume and speed, and the distance from the roadway to the point of measurement. Given that small particles may stay up in the air for up to two weeks, atmospheric conditions (wind, rain, etc.) are important concentration modifiers.

Valuation of Air Pollution

Mortality costs have been estimated as a 0.101% increase in daily death rates for a 1 microgram/m^3 increase in particulates (PM10). Based on UK costs (assuming similar death rates and adjusting for NSW costs of life), the annual mortality costs are $35.30 per person exposed per year per microgram/m^3 increase in PM10. Health costs at ground level ozone are believed to be an order of magnitude less. Thus, the cost can be calculated as follows:

Mortality costs = 0.001 * Mortality costs = 0.001 * Δ PM_{10} concentration * population exposed * normal death rate * value of life

where Δ PM10 concentration is the change in the average concentration for the period being analysed. These costs are used in assessing the negative effects of generated traffic in urban areas. In particular, they are used for studies of major changes to urban traffic networks which increase traffic into urban areas or which reduce traffic by increasing public transport. Particulate effects are likely to be of most significance in comparing alternative urban transport proposals and in modelling the effects of motorways where these increase traffic (and hence fuel use) in urban areas.

The annual monthly cost was calculated using the following parameters:

Standard death rate in NSW=5.5/1,000 (0.0055), Sydney population (4.7 million) & value of life =$6,369,128 (under WPT, 2014).

6. Water Quality

Factors Affecting Water quality:

- Short term impacts during construction such as modification of river channels, and lake or sea beds causing interruption or change to natural flows and the release of sediment downstream caused by disturbances from engineering works;
- Permanent modifications or river channels, and lake or sea beds, caused by engineering works, and modifications in ground water levels caused by aquifer penetration and changes in permeability or the shape of the ground surface;
- Increased discharges resulting from modifications of natural flows caused by faster rates of run-off from paved surfaces and the use of storm water drains and channels;
- Pollution of surface water and ground water.

Potential impacts on water quality:

- Surface water pollution from surface run-off or spray. Potential pollutants include suspended solids, lead, and other heavy metals, organic materials (such as rubber, bitumen and oil), salt and herbicides or pesticides (from roadside maintenance;
- Surface water pollution from accidental spills;
- Ground water pollution from either soakways which discharge directly into ground water or surface waters which find their way into aquifers. Pollution of ground water can also occur when road construction disturbs contaminated ground;
- Changes to water flows or levels which can increase the risk of flooding, interfere with aquifers, and affect the ecology of surrounding areas.

Measurement of Impacts on Water Quality:

All water effects are directly measurable through clarity and volume measurements (sediments), chemical analysis (water pollution), flow measurement (change in run-off rates), physical observation (some surface pollutants), and ground water level measurements. Appropriate measurement techniques are well established and should be applied to determine the effects of road projects. Appendix 4 provides economic parameters for evaluating water quality impacts.

7. Road Damage Cost

There are two well-known methods of calculating road damage or maintenance costs. One approach is the National Transport Commission (NTC) cost allocation model that sets user charges to recover road expenditures. This is called the Pay As You Go (PAYGO) method and the cost is calculated on the principle of full cost recovery of both capital and operational historic road expenditure in any given year using annual arterial road expenditures of each state and territory every year as well as local government roads.

The other approach is the ARRB pavement life-cycle costing model which compares various maintenance and rehabilitation life-cycle options within the road agency pavement budget constraints.

Based on the NTC method the following road damage costs are estimated: (refer to Appendix 4 section 7 for the steps followed in the derivation and parameter updates).

Table 3.5 Unit costs of road maintenance, by vehicle types (refer to Appendix 4 for parameter updates)

Vehicle types	Unit Costs (cent/vkt)
Cars and motorcycles	4.30
Rigid Truck	
Light (LCV)	4.30
Medium (2 Axle)	9.88
Heavy (3-4 axle)	14.84
Sub-group: Rigid Truck	**5.37**
Articulated trucks	
4 or less axles	14.61
5 axles	16.24
6 or more axles	18.94
Sub-group: Articulated Truck	**18.33**
Combination Vehicles	
Rigid 3 axle plus trailer	16.13
Rigid 4 axle plus trailer	25.10
B-double	24.73
Double Road Train	27.83
B-Triple	34.92
Sub-group: Combination trucks	**24.36**
Buses	
2 axle light bus	4.30
Rigid bus	10.01
Articulated bus 3 axle	11.43
Sub-group: Buses	**8.09**
Special purpose vehicles	**13.48**
Sub-total light vehicles	**4.30**
Sub-total heavy vehicles	**14.78**
Total all vehicles	**4.99**

The unit costs in the above table are based on road expenditure and road use in a one year period. It is assumed that current year expenditure provides a reasonable proxy for the annualised costs of providing and maintaining roads for the current vehicle fleet and road use. NTC has considered this approach is valid as the road network is reasonably mature, without significant expansion works being undertaken and the network condition is not deteriorating significantly. In addition, road network expansion is aligned to natural travel growth and there is no significant maintenance backlog. If these characteristics apply, the current expenditure levels should be reasonably consistent with the past construction and future maintenance needs. If these characteristics do not apply, costs can be adjusted for abnormal cost items or more sophisticated life cycle cost (LCC) approach can be used. It is also worth noting that these unit costs cover both road provision and road maintenance costs.

8. Social Exclusion

Social inclusion refers to people's ability to participate adequately in society, including education, employment, public service, social and recreational activities. Social exclusion describes the existence of barriers which make it difficult or impossible for people to participate fully in society.

Social exclusion recognises that many are excluded from the opportunities they need to create the life they want, and can become trapped in spirals of disadvantage caused by family circumstances, low expectations, community poverty, a lack of suitable and affordable housing, illness or discrimination – often leading to leaving school early, long-term unemployment and chronic ill-health. Some people are at greater risk of multiple disadvantages, such as jobless families, Aboriginal and Torres Strait Islander people, people with disability and mental illness, vulnerable new migrants and refugees, those with low incomes and people experiencing homelessness. The costs of this social disadvantage are high – to individuals, communities and the nation.

The UK government's Social Exclusion Unit (SEU) undertook pioneering research on particular forms of social exclusion and its link to transport[6]. The Imperial College's review of transport aspects of social inclusion led to a recommendation to modify the New Approach to Appraisal (NATA), the UK Government's guidelines on cost-benefit analysis and environmental impact assessment[7]. In the USA, the social exclusion issues are incorporated in "environmental justice" and "just transportations"[8]. In Canada, social exclusion has been regarded as a transport planning and transport equity issue[9]. In Australia, research has been undertaken on social exclusion for specific groups (e.g., children)[10] or specific regions[11]. Social exclusion has not yet been accommodated in formal evaluation and planning process in Australia. However, researches are being undertaken to develop indicators to measure key issues affective social inclusion.

Appendix 11 presents the dimensions of transport-related exclusion and describes a quantified index for comparing social exclusion in different locations and demographic groups. Such an index can help evaluate potential solutions. It would be a useful tool for assessing how resources to improve social inclusion are most effectively invested. It uses six factors that represent various aspects of accessibility, rated from 0 to 5 using various indicators, giving a maximum rating of 30. An individual or group that rates low on this scale could be considered to face significant problems from social exclusion.

9. Disability

Public transport services should recognise the needs of people with a disability and wheelchair users. TfNSW provides accessible travel by investing in train station facilities and wheelchair or mobility device on trains, a Taxi Transport Subsidy Scheme, wheelchair or mobility device on Sydney Buses and Wheelchair Accessible Taxis (WAT). The question for economic evaluation is how the needs of people with a disability should be treated in economic evaluation.

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[6] Social Exclusion Unit, 2003, making the connections, final report on transport and social exclusion.
[7] Social inclusion: transport aspects, Imperial College, 2006
[8] Overview of the American experience with modelling transport equity, appendix in 'social inclusion: transport aspects", Imperial College, 2006
[9] Social inclusion as a transport planning issue in Canada, Victoria Transport Policy Institute, 2003
[10] Investigating the relationship between travel patterns and social exclusion of children in Sydney, Anatoli Lightfoot and Leanne Johnson, ATRF 2011
[11] Transport and social disadvantage in Western Sydney, University of Western Sydney, 2006

Accessible infrastructure provides a person with disability with accessible paths, stairways, ramps underpasses or overpasses to stations, accessible signs for entries, exits, ticketing and amenities, and finally accessible maps and timetables at train stations.
Accessible conveyance provides a person with disability with capacity to move from a platform onto the carriage and back again, allocated seats or wheelchair spaces inside the carriage.

The Australian Bureau of Statistics estimates that, in 2015, approximately 444,200 persons (about 6% of population) in NSW have a profound or severe disability that restricts their ability to perform communication, mobility or self-care activities. In that group, over 50% reported that they do not use public transport even though it is available in their area and of those that use public transport, about 70% reported some difficulty. It is further estimated (based on an earlier study) that over 26,000 wheelchair users live in NSW who make in excess of 119,000 trips on the Sydney rail network per annum.

The accessibility of existing public transport infrastructure is being accelerated through the NSW Government's Transport Access program. The Taxi Transport Subsidy Scheme (TTSS) provides subsidised travel, allowing approved participants to travel by taxi at half fare up to a maximum subsidy (as from 1 July 2016) of $60 per trip.

Rail station lifts are important station facilities for wheelchair access. Research has been undertaken to estimate the benefit of lifts to wheelchair users, people with disability and normal users. Estimated values of benefits from rail station lifts for passengers are presented in Appendix 4.

Disability access is an important dimension of the community values attributable to transport and should be valued appropriately in cost-benefit analysis. This is demonstrated by the subsidy arrangements in place in NSW and community support for the principles underpinning the National Disability Insurance Scheme (NDIS), reflected in the Intergovernmental Agreement for the NDIS and the bilateral agreement signed by NSW in December 2012.

4. Land Use Integration in Economic Appraisal

This chapter discusses the land use and transport framework. The impacts of land use on the transport system are well known and often specified in travel demand models. These models usually divide urban land use into spatial zones, where land use variables and household socioeconomic characteristics are considered generating travels or attracting travels. The provision of the transport system affects land use in terms of improved accessibility. Car oriented land use may lead to urban sprawl which cause changes in the environment, economic development and social impacts.

This chapter is scheduled for consultation and review for Version 2.0 of the Guidelines.

Specific land use outcomes particularly densification or infill development both affect and are affected by transport infrastructure. Land use patterns in turn affect the sustainability of population centres. Land use assumptions are key inputs to strategic transport models such as the Sydney Travel Model (STM) which in turn, provide the demand forecasts for transport CBAs. Land use assumptions describe where people live and work and expectations relating to population and employment growth. These assumptions in turn determine the demand for transport journeys.

With conventional transport CBA, land use assumptions affect the viability of transport initiatives by influencing:

- The total demand for transport trips in any given period
- The origin and destination (OD) of these trips
- Trip purposes
- Mode choice and
- Time of day in which the trip is undertaken.

Conventional transport modelling may inadequately capture the effects of transport infrastructure on land use, such as the changes in population growth, where people work or live, and in the number, length or frequency of trips. If possible, a CBA should allow for the effects of different land use patterns and the changes that a proposed project is likely to imply for the status quo.

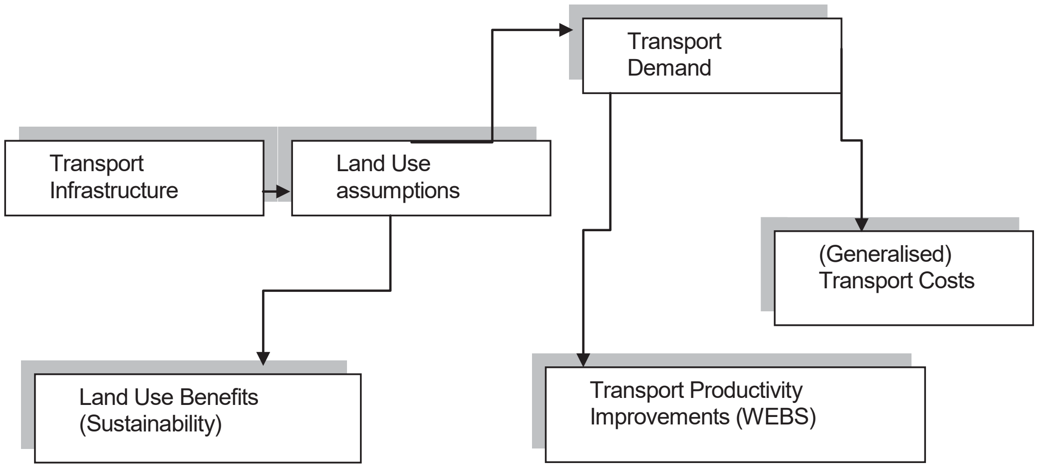
Some practical methods to capture specific land use adaptations include:

- Applying elasticity of demand with respect to changes in particular journey time cost components with a project in order to estimate induced demand, particularly in the case of Greenfield infrastructure and new modes;
- Modelling scenarios comprising different land use patterns. For example, the long term rail plan may be appraised under scenarios reflecting different mixes of greenfield versus in brownfield population growth;
- Using a proxy to reflect the effect of transport oriented development (TOD) by externally adjusting the demand model to increase the public transport mode share at nodes which are expected to comprise transport oriented developments.[1]

This is illustrated in the diagram below, i.e., the feedback loop between transport infrastructure and land use which is affected by whether or not a transport project proceeds.

[1] Evidence of trip generation of TOD is slim. Researches will be undertaken to develop practical approach of this adjustment.

Figure 4.1: Ideal land use transport CBA framework



This framework shows that:

- Land use assumptions are influenced by the presence of the transport infrastructure
- There is a relationship between land use and demand, facilitating a broader menu of transport related development opportunities
- The types of benefits are generalised to include:
  - Conventional transport costs such as in-vehicle travel time, out of vehicle travel time (access, egress and wait times), crash costs, vehicle operating costs, externalities (such as air pollution) and improved amenity such as quality of rolling stock, quality of stations and de-crowding of platforms and carriages;
  - Economic productivity benefits; and
  - Land use benefits.
- Not all benefits are directly linked to forecast demand. For example, land use assumptions can be used to directly estimate cost savings with increased brownfield development compared with the base case.

4.1 Spatial zones

In the urban land use transport analysis, a study area is divided into a set of contiguous travel zones. Representation of an urban area by a set of spatial zones enables estimating trip generating and trip attracting zones. Trip-generating zones are those in which trips originate, while trip-attracting zones are those where trips end.

An urban area can be divided into a larger number of smaller zones, or a smaller number of larger zones. The ideal number of zones is usually decided empirically depending on the level of analysis. A detailed analysis requires a large number of travel zones. In the Sydney Strategic Travel Model (STM), there are just under 3,000 travel zones. The model produces the estimates of travel to and from each travel zone, from and to every other travel zone, as well as travel within zones. In general, the following factors are considered relevant in the design of a zoning system for a study area:

- Zones should contain distinctive land use patterns such as residential or industrial use;
- Characteristics of the activities within a zone should be as homogeneous as possible so that derived zonal means are representative of activity in the whole zone;

- The zone system should conform to census collection areas so that zonal analysis can be aggregated to a higher level of geographic area such as Local Government Areas (LGA).

4.2 Land use variables represented in a spatial zone

The following land use variables are used in travel zones for specifying trip attractions:

- Office floor spaces
- Industry
- Commerce
- Shops
- Education and health
- Open space
- Vacant land

The following socioeconomic variables of households or individuals are used in specifying trip generation models:

- Number of persons by age in the household
- Number of licence holders in the household
- Stage in the family life cycle
- Car ownership
- Household income and individual income
- Occupation
- Employment status or educational status
- Distance from CBD
- Public transport accessibility
- Types of house structure

The Census provides detailed socioeconomic data for specifying trip generation models. Usually, synthesised household scheme is developed for market segmentation and travel forecasting.

Workplaces are one of the key travel destinations. The Journey to Work (JTW) census data prepared by Transport Performance and Analytics provides data for specifying commute trips. It is also important to know where new residential developments are likely to occur in the future, whether they are in greenfield or brownfield areas (for integrated land use transport analysis, it is important to know how the transport system would impact on the land use system).

4.3 Accessibility

Accessibility represents the geographical arrangement of land use and the transport system that serves these land uses. Accessibility is a key consideration in land use planning and transport planning. A high degree of accessibility means that many land use activities are close to each other and transport connections are good. Low accessibility results from the wide dispersion of activities and poor transport connections.

Accessibility measures the ease with which people are able to find and reach the best suited opportunity, either for work, study and others.

Accessibility is a feature of a location, and is commonly considered in the context of passenger transport, although it can be equally relevant to freight.

Factors affecting accessibility include:

- Travel demand: The amount of travel people or business would choose
- Transport options: Car, train, bus, taxi etc.
- Mobility: distance and travel speed by travel mode. Road congestion would make some locations less accessible
- Affordability: Cost of transport relative to income or price

- Transport integration: Degree of integration among transport system links and modes
- Information: Convenience and reliability of transport information

Higher accessibility brings the benefits for a location. It can:

- Reduce travel time and/or distance
- Reduce costs
- Improve prospects of finding suitable jobs, school and services
- Increase local land price.

Locational accessibility can be measured by a form of *accessibility index*, in that the accessibility of one location with respect to other locations is defined as a function of a measure of the attractiveness of other locations and the travel costs for getting there. A simple form of accessibility index of location *j* is given as[2]:

$$A_j = \sum_i \frac{Pi}{f(d_{ij})} \qquad \text{Equation 4.1}$$

Where,

- P_i is a measure of importance of origin i generally represented by population or economic activities
- d_{ij} is the resistance for transport between origin i and destination j in distance, travel time and cost
- $f(d_{ij})$ is the '*impedance function*' which combines travel distance, fare, parking cost, road toll etc. into a single function weighted by trip purpose[3].

It is apparent that any change in land use affecting the distribution of population and economic activities, and any change in the transport system affecting travel time and cost, will result in a change in accessibility. However, the value of the accessibility index is meaningless if viewed in isolation. The index is only meaningful if it is compared with different locations.

Box 1 Land Use and Public Transport Accessibility Index (LUPTAI) in Queensland

The LUPTAI was developed by the Department of Transport and Main Roads Queensland as a user-friendly software tool that provides a measure of transport accessibility for planners. It does this by evaluating how easy it is for people to access key activities such as employment, retail, health, school and recreation from their homes via the public transport and walking network. The LUPTAI methodology is based on random utility and Monte Carlo simulation, which randomises choice sets in order to derive the expected utility of the destination type.

The LUPTAI tool assists planners to respond to the challenges of urban growth by comparing effectiveness of variables including changes to residential population density, different land uses and improvements in public transport infrastructure, services, and frequencies. For communities throughout Queensland this means greater choice in accessing the people, places and things that are important to them.

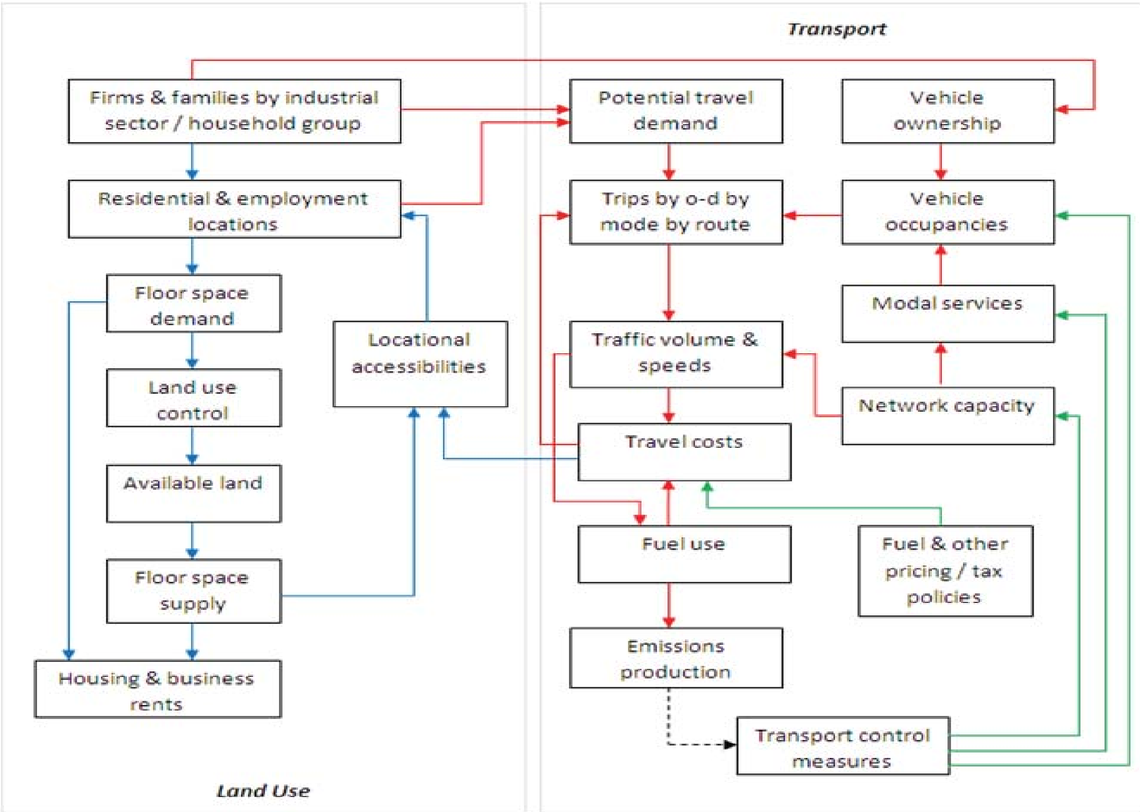
Source: Austroads, Application of accessibility measures, Dec 2011

4.4 Impacts of transport system on the land use system

Figure 4.2 represents an integrated land use and transport system. The land use system, as represented by residential properties, households, industries, floor spaces and location accessibilities, provide drivers for travel demand. Travel costs affect the desirability of different locations which affects choices on where to live, where to work and the economics of supplying different goods and services from competing locations.

[2] Australia Transport Council, national guidelines for transport system management in Australia, part 5, 2006
[3] For details see pages 5-8 in Application of Accessibility Measures, Austroads, 2011

Figure 4.2 Interaction of land use and transport



Impacts of land use on the transport system is often specified in transport demand modelling, but the impacts of the transport system on land use is less apparent. An important consideration is the degree to which roads and vehicle uses contribute to urban sprawl (dispersed, automobile oriented land use development patterns). Table 4.1 summarises the land use attributes in urban sprawl and smart growth developments. Sprawl becomes a problem when individuals do not face the full cost of providing infrastructure services to new locations. In such cases, the true cost associated with servicing a remote community can exceed the costs perceived by its private citizens and businesses and this can lead to inefficient location decisions and excessive dispersal of new settlements.

Table 4.1 Land use impacts

Attribute	Sprawl	Smart Growth
Density	Low density	High density
Growth pattern	Greenfield development	Brownfield (infill) development
Land use mix	Homogeneous land use	Mixed land use
Scale	Large blocks, wide roads	Small blocks and roads
Transport	Car-oriented. Poorly suited for public transport, cycling and walking	Multi-modes. Support public transport, cycling and walking
Planning	Maximise motor vehicle traffic volume and speed	Accommodate a variety of activities

Source: Transport cost and benefit analysis – land use impacts, Victoria Transport Policy Institute

Conventionally, economic appraisals capture land use impacts indirectly. Land use changes will result in transport demand changes whose effects are evaluated in changed travel costs. Transport changes affect land use by improved accessibility, which usually leads to reduced travel cost, improved public transport share, more opportunities for employments and education and increased property prices. In the integrated land use transport system, some of these benefits are captured in a lagged fashion.

However, traditional economic appraisals do not capture changes in employment opportunities, property price, economic development, clustering and agglomeration. In recent years there has been a growing interest in measuring these impacts for the purposes of project assessment and planning. These Wider Economic Impacts (WEI) are discussed in other parts of this document (see Chapter 3 section 3.1.7 and Chapter 5 sections 5.3.1 to 5.3.3).

5. Economic Analysis of Freight Initiatives

Questions:

- How are economic assessments of freight initiatives different from assessments of passenger initiatives?
- What tools are available for use in economic appraisal of freight initiatives?
- This chapter discusses the differences between passenger and freight economic analysis. It presents a benefit-cost analysis framework for freight transportation investments that accounts for the full economic consequences of freight improvements (from user impacts to business reorganization and economic productivity effects).

This chapter is scheduled for consultation and review for Version 2.0 of the Guidelines.

While there is considerable guidance domestically and internationally on preparing economic appraisals for passenger initiatives, there is less guidance on freight project evaluation.

5.1 Freight versus passenger

Some of the key differences between a freight and passenger transport evaluation framework are:

- A freight investment (in particular, rail or sea) tends to have direct effects on heavy road vehicle and rail freight operations;
- In freight, like any commercial markets, prices charged reflect full costs, which include taxes. Thus, for commercial freight, the principal distinction is between financial costs (which drive prices) and resource costs. This differs from public transport evaluations, where perceived costs are generally lower than resource costs because some public transport users are unaware of high levels of government subsidies on fare price (public transport users pay only around one third of true cost). In contrast, commercial freight customers could expect prices to be fully reflected in financial costs. (An exception would be the existence of commercial discounts which are often offset by higher prices elsewhere.) Overall, these practices are driven by market elasticities and the principle that total revenue should cover total costs. Thus, resource costs essentially are financial costs less taxes; and
- The benefits of a freight investment also vary from those of a passenger transport investment. The benefits that are generated from freight investment include, in addition to improvement in journey time:
    - Value of reliability,
    - Value of flexibility,
    - Value of frequency (for fixed schedule transport services),
    - Continuity of transport services, and
    - Information on time attributes of transport services.

For purposes of demand forecasting, a solid and defensible methodology for forecasting trade and freight movements is important. These can be substantiated by road freight surveys and logistic network modelling which captures the interaction between freight, passenger vehicles and public transport.

5.2 Scope and Level of Economic Analysis

An investment in freight networks can fall into one of the following categories:

- Road improvements: Freight trucks share road space with passenger cars;

- Freight railway or freight corridors. Examples include North Sydney Rail Freight Corridor, Container Freight Improvement Strategy, Melbourne-Brisbane Inland Rail;
- Ports, intermodal terminals and warehouse facilities: These are mainly commercial investments in that the private sector will undertake financial analysis to determine the financial return and viability.

Figure 5.1 shows the economic influence of freight investments. Freight transport investments will affect the attributes of the freight system. The impacts include:

- Increased flow capacity;
- Less restrictions on vehicle weight and size and increased road speed limits;
- Relaxed limitation of road access, and logistic industry can access to both road and rail;
- Safety outcome by road accident reduction;
- Improved information systems.

These improvements would result in travel time savings, increased travel time reliability and logistic cost savings. The firm productivity gain may occur as the price of products decreases and demand for products increases. The productivity gains and associated revenue will stimulate the investment on terminal, warehouses and 'last mile'[1] facilities, resulting in savings in warehouse cost and inventory stock. This process is generally referred to logistic reorganisation.

Freight transport demand increases with population and income growth. There is also an induced demand that occurs as the logistic cost is reduced due to freight infrastructure investments. The increased demand would gradually offset the travel time and reliability improvements that would call for a new round of freight transport investments.

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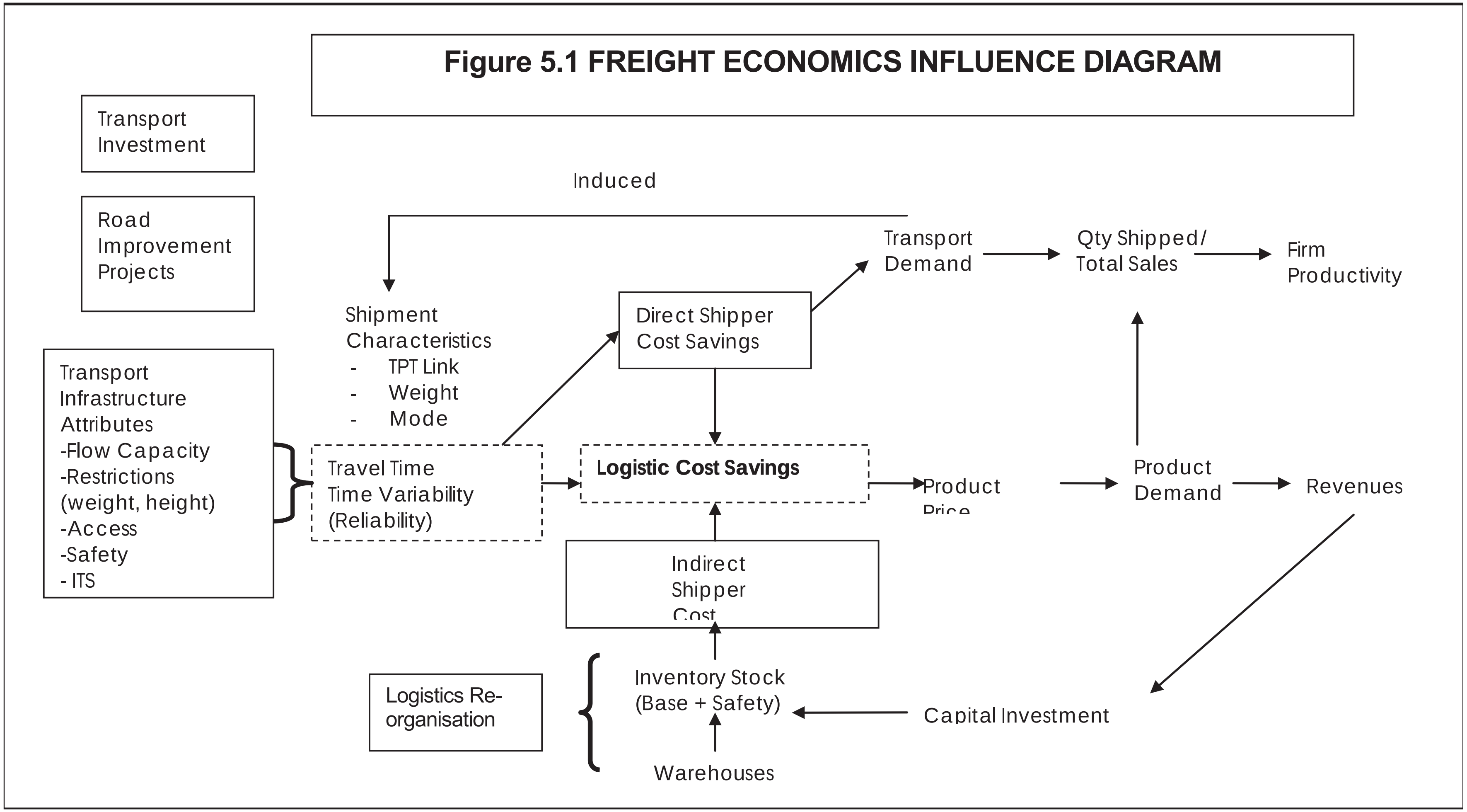
[1] In some cases, the truck size permitted on a highway is not permitted to the freight precinct. Consequently either the freight needs to be double handled, or inefficient vehicle sizes are used on highways. The result is an increase in freight operating costs, excess energy consumption and emissions, and more freight traffic and a loss of potential productivity. This is referred to as the 'first and last mile' issue - the inability to drive a truck the full length of the freight journey. Last mile issues could be seen as a by-product of increases in vehicle sizes on major routes, or as a result of a mismatch between land uses and transport planning. It is an interoperability issue that can lead to supply chain disconnects.

Figure 5.1 Freight Economics Influence Diagram



The cost benefit analysis for freight initiatives should also consider the possible effect of the investment project on logistic enhancement. Commercial firms may reorganise in relation to transport, warehousing, inventories, customer service and information processing following freight investment projects. The CBA should consider the effect of technologies and business processes that permit firms to reduce costs by substituting transport, e-commerce and just-in-time deliveries for large inventories, multiple warehouses (or warehouse consolidation) and customer service outlets (advanced logistics).

Investment on freight infrastructure can bring the following benefits:

- Conventional economic benefits include travel time savings, vehicle operating cost savings and road accident reductions. Freight transport reliability can also bring significant benefits to freight industry in terms of inventory stock and workforce scheduling for loading or unloading freight vehicle at terminals. For freight rail projects that expect to divert traffic from roads, there are significant benefits in road decongestion, accident reduction and reduction in air pollution and greenhouse gas emissions.
- Wider economic benefits include logistic reorganisations, firm clustering and related productivity gains. These benefits are discussed in the Wider Economic Impacts (WEI) framework developed in Chapter 3.
- Regional and trade benefits including employment growth, exports, imports and competitiveness in international markets. These impacts can be assessed using Computable General Equilibrium (CGE) models as discussed in Chapter 5.

The current CBA approach considers the freight component through the separation of traffic flows of cars, and commercial and heavy vehicles. Different travel time values are used for each vehicle type. In addition to travel time costs for heavy vehicles drivers, the cost of the payload is also included in the travel time valuation. Economic parameters for these assessments are provided in Appendix 4.

5.3 Freight demand forecast

Freight demand forecasts are usually undertaken separately for bulk freight and non-bulk freight. Bulk commodities refer to agricultural products (grains, oilseeds, live sheep and cattle and meat), mining products (coal, coke, metallic minerals and non-metallic minerals), oil and petroleum products, gas, steel, non-ferrous metals, cement, timber and fertilisers. Non-bulk commodities are manufactured products, also known as transformed products.

Bulk freight forecasting in a region is a process of estimating production, consumption, import and export. The surplus of production plus imports over consumption gives the amount available for export. The commodity flow matrix for origin-destination pairs can be used to show the flow of imports, exports and consumption goods.

Non-bulk freight forecasting utilises a gravity model. This reflects the assumption that non-bulk freight movements between two regions are related to population growth and income in each region.

The freight forecast produces freight movements between states and regions. The unit for freight forecast is tonne-kilometre or number of containers for non-bulk freight. This might be required to be converted into vehicles or train number during the appraisal. The conversion factor can be derived from truck and train loadings based on industrial standards or surveys[2]. The accuracy achievable in demand forecasts in analysing freight initiatives depends to a large extent on how the market has been segmented and whether relevant information is available.

Freight demand forecasting generally relies on statistical or econometric models specifically developed for a project. These models utilise historical freight movements between regions, information obtained from surveys to freight shippers and customers. Austroads has developed a

[2] ABS Survey of Motor Vehicle Use provides useful statistics for deriving conversion factors

freight simulation model (FreightSim)[3] which has the capacity to forecast bulk and non-bulk freight between regions.

The BTS has developed a Freight Movement Model (FMM) containing freight movements in origin-destination pairs in the Sydney Greater metropolitan Region (GMR) as part of STM inputs.

Freight volume forecasts across the NSW network and through international gateways should be sought from the Bureau of Freight Statistics (BFS) which is the reference point for freight demand modelling. The BFS forecasts freight demand through its Strategic Freight Model (SFM) and uses network and strategic modelling tools to forecast demand for all modes and transhipment points on the freight transport network.

5.4 Identification and measurement of freight benefits

The **benefit measures** relevant to transportation improvement linkage and logistic productivity include:

a. **Direct benefits** - conventional cost reduction related to:
   - Travel time savings
   - Vehicle operating costs (fuel and vehicle wear)

b. **Reliability –** Travel time reliability is defined as reaching the destination in an acceptable time, consistently and dependably, with only modest variability in journey times. Statistical range measures provide information on the range of travel time variability that transport users experience, utilising the standard deviation (δ) statistic. Travel time reliability affects buffer time, which is an additional time allowance a traveller allocates in deciding when to commence a trip.

c. **Better coordination** with consequent impacts on inventories and spatial location within a changing distribution network.

d. **Wider economic benefits**- contribution to economic growth (industrial re-organisation can lead to reduced logistic costs that can be passed on to consumers thereby increasing product demand, or increased production thereby lower product costs which increase demand for the product depending on the price elasticity of demand. In estimating wider benefits, it essential to recognise that some benefits, such as reduced freight cost, have been already captured in standard CBA, and should not be double-counted.

e. **Environmental benefits** – Examples of these are when rail upgrades attract freight from road to rail thus reducing emissions due to lower vehicle kilometres travelled (vkt), reduced fuel consumption per tonne-kilometre or encourage the use of cleaner fuels.

f. **Logistic cost savings** - In competitive markets lower costs flow onto reduced consumer prices and opportunities to expand output and consumption.
   These relationships are illustrated in the freight-economic influence diagram (Figure 5.1) that maps the key variables in analysis of freight and the various relationships that exists between them.

g. **Re-organisation benefits:** Firms re-organise in response to transportation infrastructure improvements in order to reap the rewards of advanced logistics. The likelihood of such re-organisation is an important factor that needs to be considered or included in the economic analysis of policy, program or project proposals.

Table 5.1 Effects of Improved Freight Transport and Logistic Re-organisation

First-order Benefits	Cost reductions to carriers and shippers, including gains to shippers from reduced transit times and increased reliability.
Second-order Benefits	Reorganisation-effect gains from improvements in logistics. Quantity of firms' outputs changes; quality of output does not change.

[3] Forecasting inter-regional freight transport from regional development, Austroads, AP-R226

Third-order Benefits	Gains from additional reorganisation effects such as improved products, new products, or some other change.
Other Effects	Increases in regional employment or increases in rate of growth of regional income.

Source: Freight BCA Study, US Federal Highway Administration

5.5 Evaluation techniques

Cost benefit analysis is used to evaluate the conventional economic benefits which include travel time savings, vehicle operating cost savings and road accident reductions. In addition, there are two techniques that can be used to assess wider benefits and regional economic impacts of freight transport investments.

5.6 Macro and Input Output Approach

Regional, sectoral or economy-wide modelling of large-scale road investment can be useful to supplement or complement standard CBA assessments and can be undertaken once a CBA has been completed. These types of analyses are also useful in providing a more general overview of impacts on various sectors / industries in the economy. These analyses are also required for policy simulations.

The analysis is based on an accounting framework called an input-output (I-O) table. These are derived mainly from two data sources:

- National I-O which show the nature and value of resource flows between households and industries
- Regional accounts based on the national I-O table, but adjusted to reflect the region's industrial structure and trading patterns

This analysis calculates geographically and industrially detailed information on the initial changes in output, earnings or employment associated with the program/project under study.

A regional industry-by-industry total requirement table is produced by calculating the Leontief Inverse[4] from the regional direct requirements table from where final-demand output multipliers will be derived. In I-O terminology, the multipliers account for the sum of direct, indirect and induced effects of a change in final demand. Final demand earnings and employment multipliers can also be derived by multiplying each final demand output multiplier in the total requirements table by the household in the direct requirements table that corresponds to the row industry for the output multiplier. These multipliers are used to estimate the impact of the project on regional output, earnings and employment.

Where an input-output approach is required, an external service provider can be commissioned to conduct community survey and assess the impact of the stimulus expected from the infrastructure proposal on the final demand and employment. The logic and structure of the models used for evaluation and analysis need to be checked before the study is conducted so the results can be generally accepted. This process should include the verification of assumptions, checking data inputs, audit and confirmation of the accuracy of calculations and review/sign off of analysis and report.

An Input-Output model for use in this type of analysis is available and can be commissioned based on a generalised regional input output (GRIT) technique (See Box 2).

[4] Leontief inverse matrix definition: As applied to regional inter-industry or input-output analysis, the values in this matrix (= Leontief coefficients) represent the total direct and indirect (and, possibly "induced") requirements of any industry j (typically in columns) supplied by other industries (i) within the region in order for industry j to be able to deliver $1 worth of output to final demand.

Note that input-output modelling is a 'first cut' approach that needs to be applied with caution. Its reliance on a 'snapshot' of resource flows means that it can fail to adequately reflect price and substitution relationships. It is now widely recognised as being prone to exaggerating the economic benefits of an investment project. The Australian Bureau of Statistics provides a detailed commentary on this.[5]

It is also important to understand how changes in travel performance from highway congestion relief or public transport investment should be used to inform input output analysis. A simplified but incorrect approach is just feeding directly into the I-O model the net increase in regional output that is represented by the total monetised benefits including personal/freight travel time savings. A more appropriate approach is the translation of time savings and other transportation cost savings into business sales and other direct economic impacts which is a more complicated process that requires understanding of the competitive nature of local industry as well as underlying social accounting flows. Even then, the caveats concerning the interpretation and use of the multiplier impacts still apply.

5.7 Use of Computable General Equilibrium (CGE) Models

For of the majority of transport and road projects, knowledge of the project outcomes obtained from estimation of major direct benefits will be sufficient to allow a reliable assessment of costs and benefits for decision making purposes. CGE is a much more elaborate and costly technique, that is generally only appropriate for the largest investment projects For these projects, CGE analysis can serve as an extension to the CBA assessment and provide complementary analysis of inter-industry and economy-wide impacts likely to flow from a major investment with long term implications for costs, resource use and productivity levels.

CGE models are an economy-wide (national, state or regional) mathematical model that reflect the value of resource flows between industries, consumers and governments and, through depicting resource substitution possibilities and movements in relative prices, can estimate the response of an economy to economic changes or policy and other 'shocks'. These shocks may include a large transport infrastructure investment that has the capacity to affect other sectors of the economy, e.g., agriculture, manufacturing, mining, tourism, construction industries both within and across jurisdictions. CGE models can be used to analyse key issues such as policy changes in an integrated national or global economic framework. Box 3 describes the Monash suite of CGE models that can be used for freight investment evaluation. Note that the Centre of Policy Studies (CoPS), which builds and maintains these CGE models, is now hosted by Victorian University in Melbourne.

Box 3 Examples of CGE models commonly used in Australia

MONASH

The Monash (Centre for Policy Studies (CoPS)) model is a top down CGEM model of the Australian economy designed for policy evaluation and forecasting for a wide range of industries. The model produces annual forecasts of the business cycle and of developments in the world commodity markets which can be used to assess the effects of policy changes and changes to base case assumptions. The model is able to generate forecasts for 113 industries and 115 commodities over a variety of regions and households. One such example of the model's use is to forecast the effects of changes in tariffs on motor vehicles.

MMRF (now VURM – the Victoria University Regional Model)

The Monash Multi-Regional Forecasting (MMRF) model is a multi-regional, dynamic CGE model of Australia's six states and two territories and 144 commodities/industries. The MMRF models each region as a separate economy with region specific prices, consumers and industries based on input-output data developed by CoPS, thus the model

[5] See ABS, Cat. 5209.0.55.001 – Australian National Accounts: Input-Output Tables (http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/5209.0.55.001Main%20Features4Final%20release%202006-07%20tables?opendocument&tabname=Summary&prodno=5209.0.55.001&issue=Final%20release%202006-07%20tables&num=&view=)

is ideally suited to evaluating the impact of region specific economic 'shocks'. The model also has enhanced capabilities for environmental analysis. Outputs from the model include projections of GDP, regional gross product and employment, expenditure, and greenhouse gas emissions. MMRF has been used to evaluate region specific infrastructure projects as well as the effects of global trading in greenhouse emissions permits.

TERM

The Enormous Regional Model (TERM) is a multiregional CGE model of Australia. It is a bottom up model which treats each region as a separate economy. One of the key features of the model is its database construction methodology which allows a multiregional database to be constructed quickly with quite limited regional data. In addition it can solve quickly with a large number of regions or sectors. The first version of the TERM Model developed by Monash University distinguished 144 sectors and 57 regions. More recently, its master database has been extended to represent 172 sectors in 206 statistical sub-divisions (SSDs), so that urban areas, water catchment areas and tourism regions may be distinguished accurately. The high degree of regional detail makes TERM a useful tool for examining the regional impacts of shocks (especially supply side shocks) (e.g. drought) and its effect on region-specific prices and quantities. TERM is more transport specific in its detailed treatment of transport costs which makes it useful in simulating the effects of rail or road improvement links sectors. Depending on the analysis, these regions are able to be aggregated. Compared to other CGE models, there is relatively less computation involved. This CGE model has been used internationally.

5.8 Hybrid models

Hybrid models combine conventional cost benefit analysis with regional economic impact in a single framework. An example of such a model is the Transportation Economic Development Impact System (TREDIS) developed by the Economic Development Research Group (EDRG), Boston, USA. It represents a flexible and modular framework for economic impact and benefit/ cost assessment for transport projects, programs, and policies.

TREDIS is an analysis framework that uses scenario level input data to holistically estimate economic impacts, cost benefit measures and the financial impacts of implementing a "build" alternative versus a "no build" or "do minimum" alternative. It provides a consistent system for applying economic analysis across space, time and the economy. It enables multi modal analysis and evaluates economic impacts due to changes in freight flows made possible by proposed investment projects. It covers all modes, including all forms of passenger and freight transport using road, rail, aviation and marine facilities.

For transport investment, TREDIS not only estimates conventional benefits such as value of travel time savings, and vehicle operating cost savings, accident cost reductions, but also job growth, personal income growth, business output and Gross Domestic Product (GDP) growth. It can be used to perform multi-modal freight system evaluations, estimate the economic impact of constructing and operating transport facilities and services, examine alternative strategies for managing transport corridors, and calculate impacts of congestion on households and industries. One such application is a study of a bus rapid transit (BRT) proposal in Sydney. [6]

Evaluation and Assurance Branch, Finance and Investment has developed, in collaboration with the Institute of Transport and Logistic Studies (ITLS) of the University of Sydney and the EDRG, a NSW-based TREDIS modular framework which can be used for economic impact and benefit cost analysis of transport projects, programs and policies.

Box 4 TREDIS APPROACH

TREDIS is a tool for conducting economic impact and benefit cost analysis of transportation projects, programs and policies. It covers full range of key economic factors at local, regional and state levels and can consider multiple time periods. It enables multi-modal analysis and makes realistic project trade-offs considering transportation modes - road, rail, aviation and marine. The tool was designed to address a broad range of passenger and freight projects that serve specific industries, regions and travel modes.

[6] Recognising the complementary contributions of cost benefit analysis and economic impact analysis to an understanding of the worth of public transport investment: A case study of bus rapid transit in Sydney, Australia

TREDIS sorts out different aspects of agglomeration or market access benefits by distinguishing effects on manufacturing shipments (same day delivery markets for just-in-time supply chains), urban market size (labour market access to jobs within normal commuting and retail trip travel times), and intermodal freight connectivity (access to airports, sea ports and rail gateway/ terminal facilities). In the jargon of agglomeration, these include both broad “urbanization” (market size) effects and the more specialized “localization” (connectivity to industry input factors) effects. Another benefit of this disaggregated approach is that it makes it possible to focus on factors that are affected by transport improvements (e.g., changes in the effective density or scale of markets, and changes in the effective accessibility of terminals) as opposed to other agglomeration factors discussed in research literature that are less affected by transport improvements (e.g., availability of land for businesses that desire physical proximity to each other).

Besides agglomeration effects, TREDIS adds sensitivity to gains in business logistics and supply chain efficiency associated with improving transport reliability, gains in technology adoption for clusters that have specific connectivity requirements, and gains in customer markets due to enhanced connectivity via intermodal gateways and terminals.

The TREDIS economic model structure also enables analysis of effects on labour supply, demand and wage rate relationships. It can identify situations where transport improvements are likely to help grow jobs and labour supply participation in areas of high unemployment, as opposed to just crowding out jobs in areas of low unemployment. That makes for a more realistic and even handed treatment of labour supply effects than merely applying a constant “rule of thumb” factor for all regions without regard to their unemployment rates. The model uses information on the economic structure of the state’s economy to more realistically identify the types of local industries that are most affected by improvements in worker commuting flows and/or truck delivery flows. That way, different types of market scale effects can be recognised. (For instance, local commuting markets can be applicable for service industries while longer distance supply chains and freight delivery markets can be applicable for goods producers). This enables more realistic and even-handed treatment of industry productivity calculations than just assuming that all industries experience market agglomeration effects at the same spatial scale.

6. Patronage demand measurement: Estimating Trip Movement

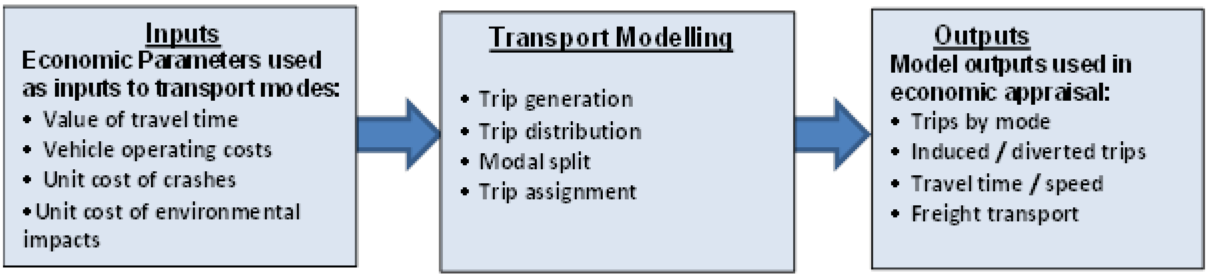
This chapter focuses on the linkages of transport demand modelling and economic appraisals. Transport demand models use economic parameters as inputs, and produce outputs including public transport usage, traffic volume, induced / diverted trips, freight transport, travel time, speed and distance. These outputs are used in economic appraisals to estimate costs and benefits of project initiatives. The transport modelling steps and generalised travel cost specifications are briefly described. Demand models used in NSW transport agencies are categorised as strategic models, road traffic models, rail and bus patronage forecasting models. Two case studies provided in the final section illustrates the use of transport modelling in economic appraisal.

This chapter is scheduled for consultation and review for Version 2.0 of the guidelines

6.1 Linking demand models with economic appraisals

Transport demand modelling and economic appraisal are tightly linked, as shown in Figure 6.1.

Figure 6.1 Links between economic appraisals and transport modelling



Transport models use economic parameters as inputs. These parameters usually include:

- Value of travel time for vehicle occupants, freight, car, trucks, public transport users, in-vehicle time and waiting time
- Vehicle operating costs for cars, buses and trucks
- Unit accident costs by crash types, road categories and user groups
- Road congestion costs or decongestion benefits specified either as average costs or marginal costs

The economic evaluation unit of Transport for NSW collects data and undertakes research and analysis on these parameters. The detailed parameters are provided in Appendix 4 and the values are generally updated annually.

6.2 Outputs

Economic appraisals rely on accurate forecasts of transport demand. The following outputs are frequently used in economic appraisals.

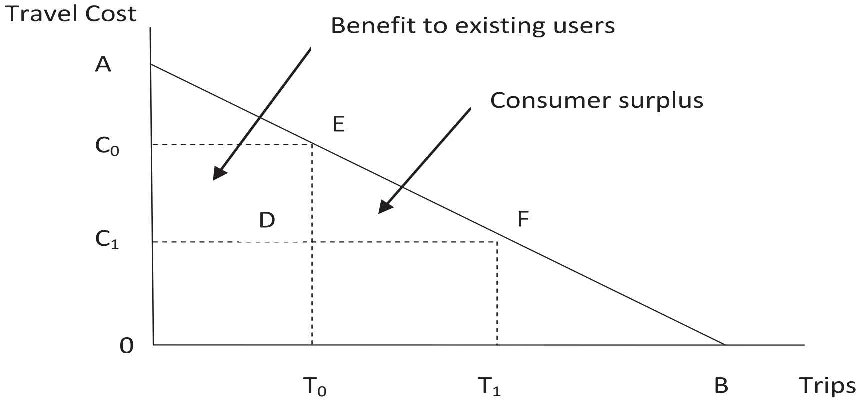
- ***Traffic volume on roads***: In order to determine the value of annual costs and benefits, it is necessary to produce an estimate of future traffic volumes of the base case and project options. Forecast future demand will affect both the extent and nature of the savings.

- ***Public transport usage***: A transport improvement project will impact peoples' modal choice. Important output from demand modelling is public transport (train, bus, ferry or light rail) use with or without the project.
- ***Induced / diverted trips***: The provision of new infrastructure can lead to generated or induced demand. This new demand has benefit or utility for the individual drivers and passengers who undertake the journey, but it may not constitute a social or environmental benefit. An investment in new road system may divert traffic. Drivers switch from one route to another as a result of the project while the origins and destinations are the same with and without the project. To evaluate projects where significant diversions of traffic will occur, the network of affected roads must be analysed. Network effects are most prevalent in urban areas but can also occur in the rural areas. If traffic is diverted from other modes, then the analysis should cover those other modes. In the more complex urban situation involving multiple routes and modes, network modelling is the preferred method. It is important to distinguish the existing trips, diverted trips and generated trips in economic appraisal. In estimating the benefits, the "rule of half" applies for the diverted and generated trips (see Box 5 below). Environmental benefits are expected if car drivers are diverted to public transport as public transport usually generates a lower level of pollution, greenhouse gas emission and noise per person-km.
- ***Freight transport***: An accurate estimate of commercial vehicles is required for economic appraisals. Freight involves different sorts of costs and benefits compared with passengers. Reliability of freight vehicles has implications for warehousing, inventory and supply chain requirements. The value of time for freight is also different from value of time for passengers.
- ***Travel distance***: Vehicle kilometre travelled, journey length for bus and train, walking and cycling kilometres. These are used for evaluating vehicle operating cost, health benefits of active transport, and environmental benefits of public and active transport.
- ***Travel speed***: In road projects, if traffic volumes increase beyond a threshold level, travel speed will decrease due to congestion. The travel time differences between the option and the base case may vary. Average speed is used for evaluating congestion costs.
- ***Travel time:*** including car occupancy in-vehicle time, public transport waiting time and time for access, egress and transfer. These outputs are used for estimating the value of travel time savings.

Box 5 Rule of Half

The Rule of Half (ROH) is based on the estimation of consumer surplus. The use of consumer surplus to value transport project benefits can be illustrated by an example.

A transport project will reduce the generalised travel cost by reducing travel time, vehicle operating cost and transport accident cost. Figure below shows the demand curve with respect of travel cost. In the base case, the travel cost is C_0 and travel demand is T_0. With the introduction of a transport project, travel cost decreased from C_0 to C_1. As the travel cost per trip decreases, the number of trips increases from T_0 to T_1. At the base case without the transport project, for those existing trips, total value of trips is measured by the area of AET_0O, comprising of the area of C_0ET_0O of which the consumers have paid their costs and the area AEC_0 representing consumer surplus.



At the project case with the transport improvement, for those existing trips, total value of trips is still measured by the area of AET_0O. However, consumers now pay the costs of the area of C_1DT_0O. The area of C_0EDC_1 represents the additional consumer surplus attributable to the transport improvement.

The value of those induced trips (also referred as generated trips) is covered by the area of T_0T_1FE, comprising of the area of T_0T_1FD of which the consumers of induced travels are paying their costs, and the area of EFD representing the consumer surplus of the induced trips.

Normally, the number of induced trips is small compared with the number of existing trips. Thus, it is usually assumed that demand curve of the induced trips is linear. The benefits of the induced trips are then calculated as the area of triangle.

The benefits if induced trips = $(T_1 – T_0) \times (C_0 - C_1) / 2$

This formula is known as the "Rule of Half" that have been widely accepted by transport economists in measuring the benefits of induced or generated trips when a new transport improvement is introduced.

For example, a 50¢ per trip transit fare reduction would provide a $500 consumer surplus gain from 1,000 transit trips that would have been made anyway (1,000 x 50 ¢) and a $100 consumer surplus gain if this price reduction resulted in 400 additional transit trips (400 x 50 ¢ x ½). Refer to Appendix 9 of PGEATII for more information.

6.3 Demand forecast

A transport model is a simplified representation of a complex transport system. The four broad categories of transport demand models used in transport planning and project analysis are discussed below.

6.4 Four step transport models

The conventional four step transport model was has been widely used since the 1950s. It is a recursive system with a uni-directional causal relationship of trip generation, trip distribution, modal split and trip assignment, as briefly described below:

- ***Trip Generation/Attraction*** - determines in a time period the level of aggregate demand for trips originating in, and attracted to, each travel zone. Often demand is divided into purposes, e.g., work, shopping, education, recreation, commercial, etc. Explanatory variables used in trip generation models are used on household socioeconomic characteristics, such as income, household size, car ownership and stage of family cycle, and land use variables including offices, industry, shops, education centres.
- ***Trip Distribution*** – distributes the total trips originating in a travel zone to all possible destination zones available. It uses a set of zonal trip productions and attractions, and estimates the way in which production and attraction is linked. The trip distribution matrix is produced with disaggregated trips by purpose and time of day (peak and off-peak hours).
- ***Modal Split/Mode Choice*** – allocates trips between available transport modes e.g. car, train, bus, plane and ferry. The mode choice is based on operational characteristics of transport modes, socio-economic characteristics of travelling population and observed modal split.
- ***Traffic Assignment*** - motor vehicle trips are assigned to routes in the transportation network on the basis of travellers minimising their travel costs. Separate assignments are made for each public transport mode.

Four step models are still widely used in transport demand forecasting, although there were critiques on it. Most critique relates to the uni-directional modelling process starting from trip generation and ending at trip assignment at travel zone level, assuming that each step is independent of the steps below it. Trip generation is specified by income, household characteristics and other variables but the feedbacks of land use change and price based policies are not specified, making the model unsuitable for long term land use transport planning.

6.5 Behavioural travel demand models

Behavioural travel demand models are random utility models representing individual choices when a traveller faces alternatives. Travel related choices include modes, routes, time of travel and trip frequency.

Analysis using behavioural travel demand models is carried out at individual or household level, compared to zonal based analysis carried out in conventional four step transport models. The models are thus derived from micro-economic theory of consumer behaviour. The probabilities of modal choice are estimated from behavioural demand models either from stated preference data, revealed preference data or a combination of both. The merits of different travel modes are derived from behavioural models that can be used to simulate the effects of changes of price based policies. One advantage of behavioural models is that feedbacks are allowed among decisions that are treated as sequential in conventional four step models.

However, the behavioural demand models focus on the demand side of transport system. The supply side is not explicitly represented in the model specification.

6.6 Linked urban land use and transport models

Early version transport models treated land use variables as being exogenous. Linked land use and transport models recognise the relationships and feedbacks between land use and transport systems[1]. A typical modelling approach uses spatial interaction and locational accessibility to simulate relationships between places of work, residence and service activities (shops, education and recreational facilities).

Generalised travel costs are calculated by mapping travel demand on the networks. Generalised travel costs are linked to trip distribution, and recognise land use as an outcome and an influence on the location of employment and service activities. These feedbacks are important improvements to the conventional four step models which assume uni-directional causal relationships. However, the generalised travel cost approach has no feedback to the trip generation step in the linked land use and transport models. As such, travel demand is inelastic with respect to the generalised travel cost. While commuting trips may not be sensitive to travel cost, trips for other purposes are likely to be more responsive.

6.7 Integrated urban land use and transport models

Integrated urban land use transport models recognise complex connections between land use and transport systems. Urban land use usually refers to spatial distribution or geographic pattern of city functions such as residential, industrial and commercial areas. The land use system explains how spatial choices are made for residential and employment locations as a function of locational accessibility, zonal attractiveness and travel costs. The spatial distributions of residents and businesses create travel demands that drive the transport system.

The interplay of demand and supply through transport costs is essential to modelling causes and effects within the transport system. Land use affects the location and volume of travel generation. The transport system affects land use through accessibility in a temporally lagged manner. Changes in travel costs drive the relocation of labour, residence, business and economic activities.

The limitation of integrated land use transport models is that trip chaining has not been addressed fully. Trip chaining refers to the fact that many trip destinations occur in multi-purpose, multi-stop daily travel chains. Trip chaining has time and cost saving effects and impacts on mode choice. For example, if the first leg of trip is made by public transport, the private car is not an option in the second leg of the trip. Activity-based travel modelling can overcome this limitation.

6.8 Generalised cost specification

Generalised travel cost is the most important specification of transport demand modelling. In the four-step modelling, the generalised cost equation affects mode choice and trip assignment in a driver's route choice. In the integrated land use and transport models, generalised travel cost impacts locational choices of residence, labour and businesses which drive long-term urban land use transformation.

The generalised travel costs for car, train and bus can be specified as:

$$GC_{car} = T_{in\_veh} * VTT_{car} + VOC + Toll \qquad \textit{Equation 6.1}$$

$$GCPH = T_{in\_veh} * VTT_{in\_veh} + T_{auxiliary} * VTT_{auxiliary} + T_{waiting} * VTT_{waiting} + P_{transfer} * Transfer + Fare \qquad \textit{Equation 6.2}$$

[1] Bureau of Transport Economics Working Paper 39, Urban Transport Models: A Review, 1998.

where,

GC_{CAR} represents the generalised travel cost of car driver. It consists of three parts: value of travel time, vehicle operating cost and road toll.

- Value of travel time is estimated from in-vehicle travel time ($T_{In\text{-}Veh}$) and the value of travel time of car driver (VTT_{Car}).
- Vehicle operating costs (*VOC*) are estimated from average travel speed and the urban vehicle start-stop model and the freeway model. Average speed is estimated from transport modelling results. The estimated VOC are the unit costs per vehicle kilometre travelled, which are converted to the unit costs per person kilometre by dividing by the average vehicle occupancy.
- Road tolls between origin-destination pairs are also relevant to the trip cost modelling.

GC_{PH} represents the generalised travel cost of train passengers. It consists of five parts:.

- **Value of in-vehicle time** is estimated from in-vehicle time ($T_{In\text{-}Veh}$) and the value of onboard train time ($VTT_{In\text{-}Veh}$). In-vehicle time refers to travel time on a train, bus or ferry.
- **Value of auxiliary time** is estimated from auxiliary time ($T_{Auxiliary}$) and the value of auxiliary time ($VTT_{Auxiliary}$). The auxiliary time is the total of access, egress and transfer walking time.
- **Value of waiting time** is estimated from platform waiting time ($T_{Waiting}$) and the value of waiting time ($VTT_{Waiting}$).
- **Transfer penalty** is estimated from the number of public transport transfers and the unit cost per transfer ($P_{Transfer}$).
- **Fare** for train, bus and ferry should consider ticket type (single, return, weekly, multi-mode), time of day travel (peak and off-peak) and concessions.

Appendix 4 (Economic parameters)) provided values for travel time, waiting time, access and egress time, transfer penalty, vehicle operating cost, Sydney motorway toll rates and average public transport fares. These parameters are recommended for generalised travel cost functions.

6.9 Demand models used in the Transport cluster: Strategic Travel Model (STM)

The STM is developed and maintained by Transport Performance and Analytics (TPA). The STM is a multi-modal strategic model that has been used to analyse network-wide impacts of mode choice and to provide future year growth factors for all transport modes. The STM projects travel patterns in Sydney, Newcastle and Wollongong under different land use, transport and pricing scenarios. It is implemented in EMME transport modelling software.

The STM uses the following datasets as input:

- Population and synthesised households
- Employment from Journey to Work (JTW) census data
- Household Travel Survey (HTS)
- Journey to Work (JTW)
- Freight movement matrix
- Road, rail and bus networks

The modelling process contains population models and travel demand models. It contains a series of demographic and behavioural models to estimate home based travel by travel purpose. It is a tour based model that recognises the travel mode of the return to home trip is mostly determined by the mode used for the home to work trip. It better reflects the relationships and constraints between individual trips in terms of mode and destination choices than in trip based models. The population model aggregates households into market segments based on socio-demographics, car ownership and licence holding that are considered affecting travel choices. Travel demand models estimate travel frequency, destination distribution, modal choice and route assignment. The process is separately run for each travel purpose including work, business, education and shopping.

The output of STM includes, but is not limited to

- Travel demands by mode or origin-destination matrixes
- Traffic volumes by road section
- Travel time / speed by road section
- Travel time by mode be origin-destination by mode and time period
- Rail and bus patronage by line and time period

The STM is better used to examine the impacts of significant proposed changes to land use or transport systems. It is based on travel zones, in which input data and outputs contain approximations. This means that the STM is not the right tool for studies of small area or non-major links. TPA have developed the model PTPM (the public transport project model) for project evaluation and assessments. In addition, feedback to land use changes is not provided in the model which requires estimation outside the model and separate input. For detailed information on the STM, contact TPA@transport.nsw.gov.au .

6.10 Demand models used in the Transport cluster: Strategic Freight Model (SFM)

The Freight and Regional Development Division is developing a Strategic Freight Model (SFM) which forecast freight activity based on production, imports and exports for all modes of transport within NSW as well as inter-state. The SFM can be used to forecast tonnage, trips, infrastructure and fleet requirements based on commodity growth. The model can thus inform decisions on infrastructure investments to improve network efficiency or capacity. The SFM can also support economic appraisal of bridges by comparing the tonne kilometres saved and the subsequent fuel usage and operating cost savings) realised by upgrading specific bridges on the network to higher mass limits.

6.11 Demand models used in the Transport cluster: Road traffic models

The models used by Roads and Maritime Services (RMS) can be categorised into several levels of detail utilising a number of modelling packages as summarised in Table 6.1. Strategic and mesoscopic models are able to model multi-modes, but in this context they are used only as road assignment models incorporating different types of road based transport. Microsimulation, analytical corridor and single intersection models are usually used for traffic analysis only. The detailed model descriptions can be found in *Traffic Modelling Guidelines*, RMS, 2012.

Table 6.1 Levels of traffic modelling

Strategic	Mesoscopic	Microsimulation	Analytical Corridor	Analytical Single Intersection	Rural Evaluation Models
EMME	VISUM	Paramics	LinSig	SIDRA	REVS
CUBE Voyager	DYNAMEQ	VISSIM	Transyt		VEHOP
TransCAD	AIMSUM	AIMSUM	SCATES		TRARR
TRACKS	SATURN				
	CUBE Avenue				

Source: Based on RMS's Traffic Modelling Guidelines, 2012

The choice of modelling level is dependent on the type of project being evaluated. Different modelling levels are suitable for different tasks. Refer to the RMS Traffic Modelling Guideline or consult experienced personnel when selecting an evaluation framework for a proposal. [Traffic Modelling Guidelines]

a. Strategic models

Strategic models determine area-wide effects of policy options concerning investment, pricing and regulation of transport systems[2]. Characteristics of strategic models are:

- Cover large area generally with limited detail.
- Operate at spatially aggregated zones. Zonal aggregation provides a useful means of simplifying a complex transport system, allowing transport planners to focus on transport issues at a broader, more strategic level.
- Have the capability of predicting long-term travel demand impacts. Strategic planning requires a long-term vision as transport infrastructure have a long useful life and lasting impacts on land use.
- Be capable of explaining the impacts of long-term changes in land use patterns, allowing exploration of land use policy options as a way of addressing transport problems.

Strategic models require road network and travel demand as inputs. The modelling process combines the network and demand using volume demand functions (or speed flow curves) to calculate travel time or speed on a link based on the modelled volume capacity ratio.

Strategic models are generally multi-mode models that examine broad transport demands. However, there are models that deal with vehicle flow only, which are referred to as highway assignment models (or Road Assignment Models)[3]. Strategic models used in NSW are implemented in EMME, TransCAD, CUBE and TRACKS.

b. Mesoscopic simulation models

A mesoscopic model covers a large area and includes intersection details to more accurately reflect intersection delays. It can use an equilibrium assignment but may also include the ability to dynamically model route choice.

Like strategic models, mesoscopic models require road network and travel demand as inputs, however mesoscopic models require significantly more detail, for both the network and demand definition.

This includes detailed network layout and intersection coding (including signal times and offsets) and well as time profiled demands. Mesoscopic models use detailed intersection delay calculations along with simplified car following theory to determine the delays on the road network. As such, these models are more suited for the analysis of heavily congested road networks. The modelling packages for used for mesoscopic models include VISUM, DYNAMEQ, AIMSUM, SATURN and CUBE Avenue.

c. Microsimulation modelling

Microsimulation modelling uses vehicle-to-vehicle interactions to estimate delays, allowing the modelling of complex traffic operations. In microsimulation models, the build-up and dissipation of queues and their effect on surrounding congestion and travel time is sensitively modelled, representing queue, congestion, delays in road networks. Real-time on-screen simulation of individual vehicles also makes microsimulation a useful tool when presenting traffic modelling to a non-technical audience.

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[2] Roads and Maritime Services, Traffic Modelling Guidelines October 2011.
[3] Traffic modelling guidelines, RMS, 2012

A microsimulation model requires significant network details (including link, intersection and signal operation) and demands (including zoning, fleet characteristics). The modelling packages used in NSW include Paramics, VISSIM, AIMSUM and SIDRA.

d. Analytical Corridor models

A corridor model assesses the coordinated intersection operations. A corridor model has capacity to model road network including signalised intersections, and in some instances non-signalised intersections, and roundabouts. The RMS has adopted LinSig Version 3.0 as its preferred software for corridor modelling. Other packages include Transyt and SCATES. The details of these models are referred to RMS Traffic Modelling Guidelines.

e. Analytical Single Intersection models

As the name suggests, analytical single intersection models analyse the operation of single intersection. Intersections may be signalised, roundabout or priority controlled. As the intersections are modelled in isolation, the effects of signal coordination cannot be modelled directly. In NSW the most commonly used analytical single intersection model is SIRDA.

f. Rural evaluation model (REV)

A key difference between rural models and urban models is that rural models assume free traffic flows and vehicle travel at steady conditions while urban models assume interrupted traffic flow with stop-start vehicle running. **REVS** (Rural EValuation System) is the model being used by RMS in economic appraisal of rural road projects. The description of REVS in this section draws on RTA REVS User Guide[4] Version 6.

The system is based on the NIMPAC (NAASRA Improved Model for Project Assessment and Costing) road planning model originally developed by the former National Association of Australian State Road Authorities (NAASRA, now Austroads).

REVS is designed to be used on rural and outer urban roads because its internal predictive models assume uninterrupted traffic flow. Nevertheless, it can be used on roads in towns where traffic flow is predominantly uninterrupted. REVS is also designed to handle small networks of interacting roads, where an improvement to a single road can affect traffic conditions on the other roads in the network; in this situation a traffic survey would first be required to establish the redistribution of traffic. External influences such as Stop/Give Way signs, traffic lights, pedestrian crossings and the like will tend to reduce the applicability of REVS in an urban situation.

Two parameter files used in REVS are SWIDE.6 and AWIDE.6.

- SWIDE.6 - a file of parameters which apply over a NSW State-wide basis; and
- AWIDE.6 - a file of parameters which apply on a more localised Area-wide basis - the default areas being based on the Road/Area Category field.

The ".6" in the names of these two files refers to the version of REVS that they are related to.

The contents of the SWIDE file includes:

- Road user cost parameters: prices for petrol, diesel, oil and tyres, costs for vehicle repair and serving, new vehicle price and sales tax, depreciation rates based on time distance travelled.
- Time and accident parameters: values of travel time (commercial and private), vehicle occupancy, average accident cost.
- Road maintenance cost coefficients.
- Financial factors: discount rate, price year, evaluation period.

[4] RTA Rural Evaluation System – REVS, User Guide, by Transport Planning Section, June 2010

The AWIDE file includes:

- Routine maintenance parameters
- Fuel / oil cost variation
- Pavement performance versus age
- Traffic parameters
- Maintenance cost factors
- Major rehabilitation cost factors

REVS calculates the following economic measures of effectiveness for each proposal:

- Benefit-Cost Ratio (BCR);
- Net Present Value (NPV);
- First Year Rate of Return (FYRR);
- Internal Rate of Return (IRR); and
- Payback Period.

TfNSW publishes economic parameters on value of travel time, accident cost and road user costs, which are used to update the recommended SWIDE file on an annual basis.The standard file of SWIDE is maintained by RMS Transport Planning Section. REVS users are expected to specify localised AWIDE file. A case study has been provided to demonstrate the process of REVS. For further assistance on the standard SWIDE file, specification of AWIDE and running the REVS model, contact RMS Transport Planning Section,

g. VEHOP

VEHOP is the Vehicle Operating Cost Model. The same as REVS, VEHOP is based on the NIMPAC (NAASRA Improved Model for Project Assessment and Costing) road planning model originally developed by the former National Association of Australian State Road Authorities (NAASRA, now Austroads).

Input to the VEHOP model is a price file that contains the following information:

- Petrol cost
- Diesel cost
- Engine oil cost
- Tyre cost (new tyre and retread tyre)
- Repair and maintenance cost
- New vehicle price and sales tax
- Time and distance based depreciation
- Traffic composition (proportion of car and truck)

The VEHOP price file is reviewed and updated annually to estimate the vehicle operating cost for a recent price year.

Vehicle operating cost can be estimated by combining the following variables:

- Vehicle type: e.g. car, 2 axle 4 tyre truck, 2 axle 6 tyre truck, 3 axle, 4 axle, 5 axle, 6 axle trucks and B-Double.
- By different volume capacity ratios ranging from 0 -1

- Different road grades: from 2% to 10%
- Different travel speeds, 10km/h to 110km/h
- Different road curve conditions: Curve design speed from 110 km/h to 30 km/h
- Different road surface types: Sealed pavement, gravel pavement and earth, pavement condition from very poor, poor, fair, good and very good, roughness from 49 (very good) to 200 (very poor) roughness meter scale.

h. TRARR

TRARR is an abbreviation of Traffic on Rural Roads, a micro-simulation model of traffic flow on two-lane roads, which was originally developed by the Australian Road Research Board (ARRB) in the late 1970s. TRARR has been used extensively in Australia and overseas to investigate overtaking lane projects, to develop speed-flow relationships, to assess route suitability for medium or large combination vehicles and to estimate travel time costs of possible road alignments. These costs combined with estimates of accident costs, construction costs and fuel consumption can aid decisions about rural road design.[5]

TRARR can be used to simulate the traffic operations on a real road in some detail, and to investigate the effects of changes in road and traffic characteristics. By changing the road geometry, the benefits of alternative improvement options can be compared. By changing the traffic characteristics, the user can investigate the effects of increased volumes, increased heavy truck traffic, or long term changes in vehicle size and power. Observed traffic characteristics include speed, travel time, vehicle bunching or platooning, time spent following, overtaking rate and fuel consumption.

TRARR requires the following input files:

- Road file: Barrier lines, overtaking lanes, speed index, sight distance and grade
- Traffic file: vehicle type, directional traffic flows, desired speed
- Vehicle file: Vehicle types and individual vehicle parameters include power, acceleration, headways, overtaking speed, overtaking safety factor and fuel assumption.

TRARR produces the following outputs:

- Summary statistics for point data for traffic passing each observation point (spot speeds and percent following)
- Summary statistics for interval data (travel times, journey speeds, percent time following, overtaking and fuel consumption)

6.12 Demand models used in the Transport cluster: Rail patronage forecasts

Rail patronage forecasts are at the strategic and station-to-station level[6]. The strategic forecast is provided by:

- Sydney Strategic Travel Model (STM) developed and maintained by TPA
- Public Transport Project Model (PTPM) developed by TPA for projects like, Metro NW, City and South West Metro, CBD & South East light rail, Newcastle Light Rail etc
- Train Crowding Model: Developed by AECOM using CUBE software to improve route choice assignment by taking account of travel time, frequency, perceived cost of interchanging and on-board train crowding

[5] Sourced from Austroads Report, TRARR06 Model Interface 9T06): User Guide and Tutorial, may 2006
[6] Station to Station forecasts are produced by Bureau of Transport Statistics (BTS), TfNSW.

The station to station demand forecasts are estimated by the Harbourlink Model (HLM) developed and maintained by RailCorp. It has been used to provide detailed analysis of CBD station and platform demand and passenger forecasting.

The rail patronage forecasts require the following inputs:

- Land use forecast – population and employment forecasts at the travel zone level.
- Future transport provision – future bus service provision, road options and rail infrastructure
- Train operating plans
- CityRail station to station matrix

The patronage models produce the following outputs:

- Travel time and cost for economic evaluation
- Lone loads and training crowding
- Platform crowding

6.13 Bus patronage forecast

Transport Services within TfNSW developed a procedure for estimating bus patronage as a variable in bus route design[7]. The procedure has been implemented in ArcView, a Geographical Information System. When a bus route is specified, relevant travel zones are captured along the route. The number of people living or working in selected travel zones is used to forecast the potential bus patronage. The definitions of travel zones are the same as the Bureau of Transport Statistics travel zones. The potential patronage can be weighted by bus frequency, thus more frequent bus services lead to increased patronage.

The current procedure has three limitations. It does not consider the competing travel modes (e.g., train and car) and potential patronage increases from more direct routes. The procedure uses the number of people living and working in the catchment areas, but does not use the socio-economic characteristics of individuals of households (e.g., car ownership, student status, trip purpose, etc.) thus cannot forecast the segment of patronages such as student travellers. However, the procedure is particularly useful for comparing bus routes in that change in patronage rather than the total number of potential patrons along different routes, is the focus.

6.14 Fixed Trip Matrix and Variable Trip Matrix Techniques

The first step of the project evaluation is defining the base case and project options. The base case is usually defined as 'do-minimum' in that no capital investment is assumed.

The project option is defined as a capital investment for a transport project. Number of trips for the base case and project option are forecast in transport modelling on origin-destination matrixes. The number of trips in a project option includes existing trips and induced trips.

Fixed matrix technique refers to a situation where the number of induced trips is assumed to be insignificant, thus the number of trips in the base case and the project option is assumed to be the same.

In conventional 4-step transport models, there are three ways in which the matrix can change.

- Trip generation. More trips or induced demand
- Trip distribution. People travel to different locations
- Modal-choice. People change the mode

[7] Advice from Transport Services Division, TfNSW

Fixed trip matrix techniques ignore these impacts. **Variable matrix methods** differs from the fixed trip matrix techniques in that these effects are considered. As a consequence, demand in the project option matrix is generally higher than that in the base case matrix for a given forecast year.

6.15 When to use the variable trip matrix

Variable trip matrix techniques are recommended by the UK Department of Transport and the New Zealand Transport Agency for all complex improvements. The variable trip matrix should be used if:

- The level of induced trips is high. The difference in benefit between the fixed trip matrix technique and variable trip matrix is frequently 10% or more.
- A substantial level of congestion is present, i.e. congestion would add at least 10 percent to the typical peak hour travel times compared to free-flow conditions. A 10 percent travel time change equates to a five percent traffic volume change at typical travel demand elasticity. Such a traffic volume change between the base case and option has a substantial effect (at least 25 percent) on the benefits.

It is usually appropriate to use a fixed matrix for small minor projects.Transport for NSW recommends using a variable trip matrix for large transport improvement projects that are likely to result in significant induced demand, mode shifts or route changes.

6.16 Variable trip matrix in transport modelling

The following methods are used for variable trip matrix techniques

- Elasticity methods
- Growth constraint techniques
- Activity demand model

A lengthy discussion of these techniques is not provided here because these techniques are applied in complex transport modelling origin-destination matrix operations which are not easily represented in a short description.

The variable matrix evaluation can be adopted for the following two options:

- A matrix-based analysis, where cost is computed for each origin-destination pair.
- A link-based analysis, where costs are computed separately for each link or groups of links.

6.17 Benefit estimate in variable matrix technique

In the fixed matrix evaluations, benefits are the savings in resource costs between the base case network and the option. Resource costs are estimated by removing taxes and subsidies from market prices. It is basically assumed that travellers are either changing travel modes or routes but the total number of trips remains unchanged.

Where variable matrices are involved, there are changes in both the number of trips as well as the cost of undertaking them. Since the decision to make more fundamental changes in travel behaviour is based on the costs perceived by car users, the measure of the benefits is also based on **perceived user costs** (See Appendix 4 for economic parameters of perceived costs). This is usually computed as the change in road user consumer surplus. It is also necessary to include a term to compute the total social benefits including externalities, since road users do not take full account of the effects of their decisions on others.

The benefit calculation formula is:

Equation 6.3

$$Benefits = (Base\ Trips\ x\ Base\ Resource\ Cost - Option\ Trips\ x\ Option\ Resource\ Cost) + \tfrac{1}{2}\,(Base\ Perceived\ Cost + Option\ Perceived\ Cost)\ x\ (Option\ Trips - Base\ Trips)$$

Thus, the benefit calculation requires the following information

- number of trips in the base case (usually do-minimum)
- number of trips in the option
- resource cost of travel in the base case
- resource cost of travel in the option
- perceived user cost of travel in the base case
- perceived user cost of travel in the option

For a fixed matrix evaluation (assuming number of trips in base case and option are the same), the second term in above formula is zero and this formula becomes the simple difference in resource costs (the first term in the formula) between the base and the project option.

The above formula indicates that, essentially, the variable matrix technique is a resource cost correction for induced travel.

6.18 Economic parameters to support variable matrix technique

While the fixed matrix technique only requires the resource costs to estimate project benefits, the variable matrix technique requires both resource costs and perceived costs.

Three sets of economic cost parameters for use in economic appraisal are presented in Appendix 4 of these Guidelines. They show:

- Resource costs: To be used in economic appraisals and fixed matrix technique
- Perceived costs: Represent behavioural values and to be used in variable matrix techniques and modal choice analysis.
- Full financial costs: To be used for financial analysis. These are adjusted to derive resource costs.

In general, the relationships between the perceived costs and resource costs are likely to be:

- Value of business time: Perceived Cost = Resource Cost
- Value of private time: Perceived Cost = 1.15 x Resource Cost
- Vehicle operating cost: Perceived Cost = 1.2 x Resource Cost

7. Estimating Travel Time Reliability

Travel time reliability can be a significant component of total project benefits. Despite this, reliability benefits have often been omitted from economic appraisals because methods cannot handle reliability well enough to take its characteristic into consideration and the practical problems in forecasting the size of the benefit.

This chapter sets out the methodology for estimating travel time reliability improvement due to transport investments which not only reduce the average travel time but also the variability in travel time. The inclusion of reliability effects is likely to increase the benefits of many transport projects, including those that increase capacity but also the less traditional projects such as improved incident removal, better management of transport systems, improvements in transport operations or provision of information systems.

This chapter is scheduled for consultation and review for Version 2.0 of the Guidelines

Travellers are sensitive to the consequences of long waiting times, missed connections and arrival at the destination either before or after the desired or expected arrival time. Thus, in the recent years travel time variability has become an increasingly important issue among transportation experts. Travel time variability is quantitatively important and cost-benefit analysis should account for it in order not to imply a bias towards projects that do not reduce travel time variability. Omitting the cost of travel time variability is not the neutral option.

The definition of the travel time variability (TTV) is a variation in journey times that travellers are unable to predict.

Variability of travel imposes an economic cost on travellers and therefore must be included in cost-benefit analysis of transport investments. The inclusion of a reduction in variability in travel time or reliability benefits can affect the result of a transport infrastructure investment and may influence the viability and ranking of projects and may therefore have significant real implications.

There are basic theories in place that allows values to be assigned to travel time variability. These are formulated in terms of travel time and either departure time or arrival time, since formulating utility in terms of departure time and arrival time emphasises that it is these things that matter to travellers, rather than the travel time itself. It is assumed that travellers always prefer to depart later and to arrive earlier, *ceteris paribus*. The utility that depends on departure time is that utility accumulated at home until the time of departure and similarly the utility that depends on arrival time is the utility accumulated after the time of arrival.[1]

TfNSW supports the estimate of travel time reliability benefits if the data allows.

Statistical measures provide information on the range of travel time variability that transport users experience. One of these is the standard deviation (δ) statistic. The travel time reliability can be assessed as a buffer time, which is an additional time allowance a traveller makes decision on when the trip begins.

The valuation of travel time reliability considers the buffer time that the travellers have budgeted before departure. It is worth noting that, in this framework, the values of travel time reliability does not include other logistic costs such as worker's cost at warehouses waiting for loading or unloading freight vehicles.

Travel time reliability depends on many factors including road capacity, traffic accidents, road work, weather, traffic controls, special events and traffic fluctuations. This means that the travel time reliability, as measured by standard deviation, is constantly changing.

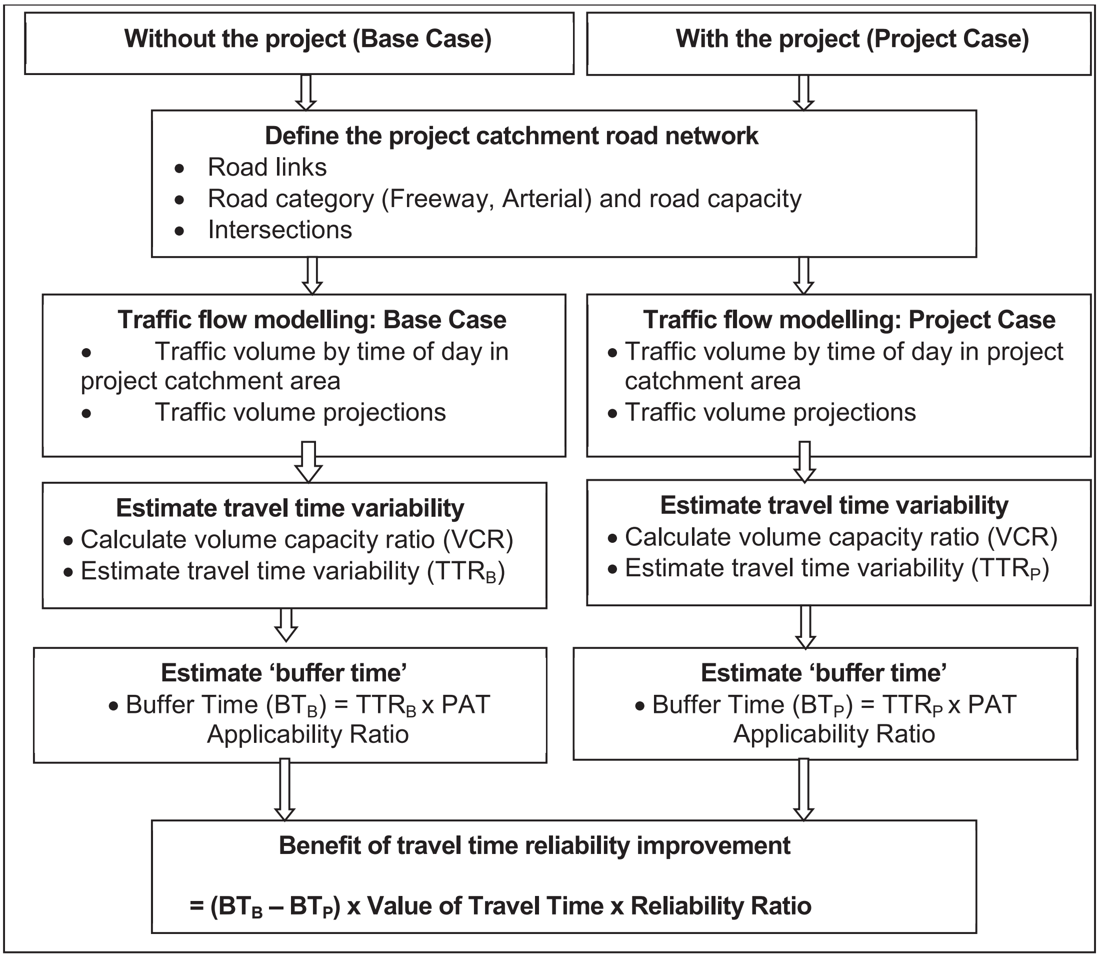
[1] The valuation of travel time variability, Mogens Fosgerau, OECD Roundtable, Discussion Paper 2016-04, November 2015, Paris

7.1 Framework for Estimating Travel Time Reliability Benefits

Figure 7.1 below presents the framework for estimating economic benefits of travel time reliability associated with a road improvement from day to day traffic variation (DTDV).

This framework allows the use of a simple model that meets the standards of classical micro-economics, and allows the discussion of the cost of travel time variability in a meaningful way. This framework is applicable to commute trip from home to work, and to any trip. The models describe passenger transport but may just as well be used to describe freight transport trips. Empirically, it is very important to account for the diversity of trip purposes as some trips are much more sensitive to delays than others: e.g. freight trips with perishable goods that may lose their value due to delays or about passenger trips accessing a flight connection at an airport or urgent trips to the hospital.

Figure 7.1 Framework for estimating travel time reliability benefits



There are several causes of travel time variability. Below is a list of these sources and their descriptions.

- **Day to day variability of traffic conditions (DTDV)** (e.g., demand, driver behaviours) - Day to day traffic demand variation is unpredictable. Characteristics of drivers, and vehicles and the interactions between drivers and the network are constantly changing. Road capacity expansion or traffic management programs can improve traffic condition and reduce day to day travel time variation.
- **Traffic incidents** - Incidents are unpredictable as drivers cannot predict when and where an incident will happen. Better road environment can reduce these incidents.
- **Roadwork** - Predictable to some degree as location and duration of roadwork are usually known before the start of journey and the delay is generally expected.

- **Extreme weather** - Uncertain as drivers expect delay in extreme weather conditions but extreme weather can be difficult to foresee.
- **Special events -** Largely predictable as rivers expect delay caused by special events (e.g., parade, sports event, etc.).

Only the first cause of delay, namely day to day variability (DTDV), is considered in this section. This cause is considered to be 'unpredictable' in terms of its impact on journey time. Traffic incidents are considered unpredictable but the theory on these impacts is not mature thus they are excluded in the appraisal framework. Roadworks, extreme weather and special events are considered to be predictable in some degree in that drivers can expect to be delayed in advance of making the trip. In addition, a transport improvement has little impacts on these causes thus the effects on the base case and project case tend to cancel out each other. There is no practical point to collect data on roadwork, bad weather and special events in travel time variability analysis for economic appraisals unless these causes are the subject of the evaluation.

7.2 Key Steps in Estimating Travel Time Reliability Benefits

This section outlines the key steps in estimating travel time variability (TTR) and buffer time (BT) which are the parameters presented in the framework above. Road volume capacity ratio is calculated by dividing the volume of traffic by theoretical road capacity. The value of travel time savings for business and private trips and reliability ratio can be found in Table 1 of Appendix 4.

In order to include improved travel time reliability in benefit-cost analysis as an economical benefit, the following are needed:

1. A measure for travel time reliability
2. A value for reliability
3. A method for predicting future reliability
4. A method for estimating changes in reliability due to a project

The key steps of estimating travel time reliability benefits are:

- Estimate the expected travel time variability (or uncertainty in trip journey times) in the base and project cases
- Estimate buffer time in the base and project cases
- Estimate economic benefits of travel time reliability improvement due to the project

7.2.1 Estimate the expected travel time variability

There are several approaches to estimating travel time variability. Unlike other travel time attributes, reliability is less easy to measure and predict. The following five measures have been the most frequently used:

- Average Mean Lateness (AML)
- Schedule Delay Early (SDE) and Schedule Delay Late (SDL)
- Reliability ratio (RR) defined as the ratio of standard deviation of arrival times around the mean arrival time and the value of travel time savings.
- Buffer Index
- Customer Journey Time Delay

The UK method, which was originally developed by the UK Department of Transport as part of a 1993 London Congestion Charging study, has also been used. The UK model might only fit the London road network and traffic condition, such as the use of constant average free flow (44.5

km/hr), and may not transfer to other cities.[2] The UK Department of Transport recommends that the model be calibrated to local conditions, but such calibration has not been done for NSW.

The approach outlined in the following sections is the estimation of travel time variability recommended by the Australian Transport Council in the NGSTM. This is based on the methodology in use in New Zealand and contained in the NZ Economic Analysis Manual, (NZ Transport Agency 2013[3]).

This method assumes that drivers have a *Preferred Arrival Time (PAT)* and with the optimal departure time found by minimising the expected disutility of arrival early or late. The travel time from an origin to destination has a probability distribution with a mean and standard deviation. Drivers 'predict' the average travel time based on their day to day experience of the route. Non-predictive factors result in travel time variability which is measured by the standard deviation (SD).

Separate SD estimates were made for road links (between two intersections) and at intersections for each intersection movement. Only Day to Day Traffic Variation (DTDV) is included in the measure. Unreliability due to road crashes and other traffic incidents are not included.

The model requires separate calculation for each road link and intersection approach. Since a road project can affect the traffic flow of a large area with many road links and intersections, this method could require a lot of data and could be time consuming. Despite this, the estimated travel time variability using this approach is relatively more accurate and thus recommended by TfNSW.

The model estimates the travel time variability using the logistic relationship between the SD of travel time and the volume/capacity ratio presented in equation 7.1. Since volume capacity ratios are readily available for all road types, the model can be used for estimating travel time variability for motorways, urban arterial and other roads and signalised intersections.

$$SD_{Travel\,Time} = S_0 + \frac{S - S_0}{1 + e^{b(VCR-1)}} \qquad \textit{Equation 7.1}$$

where:

SD = Standard Deviation of travel time for the same route for the same time period due to day to day traffic volume and traffic condition variations

S*, S_0** and ***b are equation parameters estimated for different road types (as shown in Table 7.1 below)

VCR = Volume capacity ratio.

Table 7.1: Equation parameters for estimating travel time variability

Road type	S(1)	S_0(1)	b(2)
Motorway	0.90	0.083	-52
Urban Arterial	0.89	0.117	-28
Urban Other (50km/h)	1.17	0.050	-19
Rural Highway (70-100 km/h)	1.03	0.033	-22
Signalised Intersection	1.25	0.120	-32
Un-signalised Intersection	1.20	0.017	-22

Notes:
(1) S_0 and S are the minimum and the maximum standard deviations observed on NZ road links.

[2] The UK model forecasts the SD of journey time based on travel time and distance as shown in following equation: $SD_{ij} = 0.0018 \cdot T_{ij}^{2.02} \cdot D_{ij}^{-1.41}$ where: ***SD**ij* = Standard deviation of travel time from origin location *i* to destination *j*, in seconds, ***T**ij* = Travel time from origin location *i* to destination *j*, in seconds and ***D**ij* = Distance from origin location *i* to destination *j*, in km.

[3] NZ Transport Agency (2013) Economic Evaluation Manual

(2) b is estimated model constant for equation (7.1) by fitting NZ road travel time variation data of different road and traffic control types. Source: NZ Transport Agency (2013).

This model for estimating travel time reliability in road project appraisal requires only the knowledge of the volume capacity ratio for the road in question.

For a journey passing through a number of road links and intersections, the SD of journey time can be estimated as:

$$Variability_{Trip} = \sqrt{\sum_{L=1}^{n} SD_L^2 + \sum_{I=1}^{m} SD_I^2} \qquad \textit{Equation 7.2}$$

where**:**

SD$_L$ = Standard deviation of a road link defined as the road section between two intersections for arterial roads (usually about 300-400m), or one kilometre road section for motorways. Ensor (2004)[4] indicated that the journey time variability is relatively insensitive to the length of the link. A trip from origin to destination can be divided into *n* links (i.e., *L=1,2,…,n*).

SD$_I$ = Standard deviation of intersections, assuming there are *I=1,2,…,m* intersections from origin to destination.

To estimate the network-wide variability cost, multiply the total trips for each O-D pair by the standard deviation of travel time and sum over the matrix.

7.2.2 Estimate the buffer time applied by drivers as a collective group

Buffer time is defined as the extra time that should be allowed for an on-time arrival when travel times vary. Thus, the buffer time is determined by the expected travel time variability and whether a traveller has a Preferred Arrival Time (PAT). That is:

$$Buffer\ Time = Expected\ travel\ time\ variability\ x\ PAT\ AR \qquad \textit{Equation 7.3}$$

where:

Expected travel time variability is the square root of the summation of standard deviations calculated for all the links and intersections. (Refer to equation 7.2).

PAT AR is the *preferred arrival time applicability ratio* which considers whether travellers are likely to budget a buffer time for on-time arrival. However, there is little research in this area. Business, morning peak commute and educational trips may have strict PATs whereas for recreational, afternoon commuter and shopping trips, the PAT may be quite flexible.

Table 7.2 below lists the assumed buffer time applicability ratios for different trip purposes. In a practical economic appraisal, the PAT applicability ratio should be estimated from the number of trip by trip purposes which are generally available for travel demand modelling.

[4] Ensor, M. (2004) A procedure for evaluating the trip reliability benefits from individual roading projects, Beca Infrastructure, New Zealand.

Table 7.2 Applicability ratios of buffer time for different trip purposes

Trip purpose	Purpose share	Assumption of arrival time constraints	Buffer Time Applicability Ratio	Share of trips with buffer time
Work related business	10.3%	Have PAT for all trips	100%	10.3%
Serve passenger	29.3%	Have PAT for all trips (e.g. to school, to station, etc). All these trips should have the preferred arrival time (PAT)	100%	29.3%
Commute	23.7%	Have the PAT to work but have some constraint for return journey (e.g. pick up children from childcare)	60%	14.2%
Educ /Childcare	14.3%	Same as commuter trip	60%	8.6%
Other purposes	22.4%	No PAT	0%	
Total	**100%**			62.4%

Source: Household Travel Survey (HTS) datasets. The data was extracted for Sydney SD from 3 year pooled data (2008/09, 2009/10 and 2010/11) including vehicle trips only (excluding trips using bus, train, ferry and other public transport).

The scheduling models just presented assume that travellers are able to select their departure time optimally, as is the case for car drivers. Travellers who use scheduled services are constrained in their choice of departure time and this affects their value of reliability.

7.2.3 Estimate the economic benefit of travel time reliability

The benefit of a reliability improvement can be estimated by first multiplying the buffer time by an applicability ratio, then by a reliability ratio and finally by a dollar value of travel time:

Equation 7.4

Benefit of Travel Time Reliability = (Buffer Time in Base Case – Buffer Time in Project Case) x Reliability Ratio x Value of Travel Time ($/Person Hour OR $/Vehicle Hour)

The Reliability Ratio measures the sensitivity of travel time variability to 'standard' travel time. Appendix 4 Table 79 provides a summary of studies of the value of travel time variability. Empirical evidences indicate that the valuation of travel time reliability varies. The value of Reliability Ratio ranges from 0.10 to 3.23.

TfNSW recommends that the value of travel time variability be set at the same value as in-vehicle travel time, that is, the **Reliability Ratio is equal to 1**. This recommended value is based on a review of international evidence.

The value of travel time is based on the wage rate plus on-costs for business travel and 40% of the wage rate for non-business travel (see Table 1 in Appendix 4).

The ATC recommended New Zealand approach also suggests adjustment factors for cases where an investment project does not represent the full length of most journeys in which case the changes in time reliability will be overestimated. An estimation of the variance of trip times which occurs outside the evaluation area must be made and appropriate correction factor must be applied. The trip time variability benefit is adjusted by multiplying the calculated variability by the factors presented in the Table 7.3 below.

Table 7.3 Adjustment factors for variability calculations

Percentage of variance outside the study area	Factor for benefit calculation	Indicative transport network model coverage
<20%	100%	Regional model

Percentage of variance outside the study area	Factor for benefit calculation	Indicative transport network model coverage
20%	90%	Subregional model
50%	70%	Area model
75%	50%	Corridor model
90%	30%	Intersection model

Source: NZ Transport Agency (2013) Economic Evaluation Manual

The NZ approach needs to include the possibility that travellers from A to B will choose different routes. This means the number of calculations required are Z^2*T*P*Y*R*L*V where Z is the number of zones, T is the number of time periods, P is the number of purposes, Y is the number of years, R is the number of routes per OD pair, L is the average number of links used per route and V is the number of variables involved (V/C and trips).

The National Guidelines recommended approach was tested in the analysis of smart motorways by using network based traffic model outputs for 4-hour am peak, 5-hour inter-peak period, 4-hour pm peak and 11-hour evening period. The calculations did not yield discernible variability change between the base case and the project case.

Thus, it is recommended that for an appropriate assessment of travel time variability using the National Guidelines/NZ model, traffic analysis undertaken at 15-minute intervals may be required, which is justified for large transport investment projects.

7.3 Other Models for Estimating Travel Time Reliability Benefits

7.3.1 RMS-ISG Model

For the strategic phase of project development, and probably for smaller scale projects, a more granular travel time reliability modelling which can use broad time of day segments may be more applicable. A model developed for Roads and Maritime Services (RMS) by Industrial Services Group (ISG)[5] was tested through its application for the smart motorway initiatives.

The model is based on a multiplicative regression model where the standard deviation of travel time is a product of delay and volume capacity ratio, i.e.

$$STD = \beta_1 \; x \; Delay \; \beta_2 \; x \; VCR \; \beta_3 \qquad \textit{Equation 7.5}$$

where:

STD = standard deviation of travel time
Delay = vehicle delay time calculated as the mean travel time minus free-flow travel time
VCR = Volume Capacity Ratio
β_1, β_2 *and* β_3 are regression model coefficients with values as follows:

Table 7.4 Regression coefficients – ISG Model for Reliability Calculations

Variable	Coefficient	Standard Error
β_1	0.5443	0.0375
β_2	0.5971	0.0067
β_3	0.1696	0.0084
R squared	0.9196	
Adjusted R squared	0.9195	
Root mean squared error (RMSE)	1.4393	

7.3.2 UK Model

The UK model was originally developed by the UK Department of Transport as part of a 1993 London Congestion Charging study. Some modifications have subsequently been made to the model. The model aims to predict journey time variability from all sources for urban situations. The model forecasts the SD of journey time based on travel time and distance as shown in following equation:

$$SD_{ij} = 0.0018 \cdot T_{ij}^{2.02} \cdot D_{ij}^{-1.41} \qquad \textit{Equation 7.6}$$

where:

SD_{ij} = Standard deviation of travel time from origin location *i* to destination *j*, in seconds

T_{ij} = Travel time from origin location *i* to destination *j*, in seconds

D_{ij} = Distance from origin location *i* to destination *j*, in km.

For specific projects, the UK Department for Transport (2014)[6] recommends that the model be calibrated to local conditions. It is worth noting that the model was developed for urban roads where DTDV is more important and traffic incidents less important. For motorways, dual carriageways and rural single carriageways, alternative routes around a traffic incident are less

[5] Assessing network reliability & benefits through Smart technologies, Research Centre for Integrated Transport Innovation (RCTI) and The Industrial Sciences Group (ISG), June 2015

[6] Department of Transport (2014) Transport Analysis Guidance (TAG), TAG Unit A1.3, User and Provider Impacts

available or have constrained capacity that makes diversions far less feasible. The equation was also based on London conditions that may not transfer to other cities. For example, the model assumes a constant average free flow speed of 44.5 km/hr.

The data for estimating reliability benefit are (i) details of the road (existing and proposed) namely road class (arterial, sub-arterial and other), (ii) traffic volumes and composition (car, rigid truck and combination vehicles) and (iii) road incident data.

7.4 Using Public Transport Information and Priority Systems (PTIPS) and OPAL data in measuring travel time variability

A study undertaken to measure the expected reliability benefits of a bus program (Northern Beaches B-Line Program) [7] estimated the cost of in-vehicle travel time variability for combinations of defined origin destination pair of transport transit stops, day/time band and route variant during the analysis period using the Public Transport Information and Priority Systems (PTIPS) data to calculate the standard deviation of in-vehicle travel times. This has been done for every transit stop combination on the selected corridor, i.e., transit stop from A to B, transit stop A to C, transit stop B to C.

Opal data was then used to weigh these standard deviation values by the number of passenger trips taken on the corresponding transit stop combinations before the value of expected travel time variability is applied.

The PTIPS and OPAL data were used in the model specified by Ernst and Young as:

Equation 7.7

$$Variability\ cost\ for\ analysis\ week\ (VC^{\,rtod}) = n_{rtod} * \sigma_{rtod} * \frac{VoT^{y}}{60} * Reliability\ ratio$$

where:

- $n_{r,t,od}$ is the number of bus passenger trips on the route variant indexed by r, and the day/time band indexed by t between the origin-destination transit stop pair indexed by od during the analysis week.
- $\sigma_{r,t,od}$ is the standard deviation of trip time in minutes on the route variant indexed by r, and the day/time band indexed by t between the origin-destination transit stop pair indexed by od during the analysis week.
- VoT^{y} is the value of time per bus user per hour in year y. This value is divided by 60 to convert to a per minute value.
- $Reliability\ ratio$ is the relativity of value of travel time reliability to the value of normal time. It is included in the calculation of variability cost in order to value the buffer time that the travellers have budgeted for before departure.

The benefit from variability reduction due to the project was estimated by deducting the standard deviation of travel time post project from the standard deviation of travel for the time period (am peak, pm peak, off peak) at the section of the transport network. The post project standard deviation was estimated based on the average variability of in-vehicle travel time during uncongested times before the morning peak and after the evening peak.

TfNSW Recommendation

ATC NZ model estimates the travel time variability using the logistic relationship parameters and Volume Capacity Ratio. The model can be used for estimating the travel time variability for motorways, urban arterial and other roads and signalised intersections. However, the estimate requires separately calculation of each road link and intersection approach. A road project can

[7] Final Business Case for the Northern Beaches B-Line Program (B-Line), Ernst and Young, 2015

affect the traffic flow of a large area with many road links and intersections. Thus the ATC and NZ model requires a lot of data and could be time consuming. However, the estimated travel time variability using this model is relatively more accurate. Thus, this approach is recommended by TfNSW. Because of the significant computing requirements of this approach, TfNSW is exploring the calculation of the reliability benefits within the traffic modelling software which will also consider the application of the rule of half on induced demand for reliability benefits.

The UK model was initially developed in 1993 as part of London Congestion Charging Study. The main advantage of the model is that it uses travel time and distance to calculate the travel time reliability thus the input data can be easily obtained from travel demand modelling. However, it might only fit for London road network and traffic condition. The UK Department for Transport (2014) recommended that the model be calibrated to local conditions. Such calibration work had never been done in Sydney. In UK, estimates of reliability benefits using this method are allowed in the Appraisal Summary Table (AST) but not permitted in the main CBA. TfNSW does not recommend this model for estimating travel time variability in Sydney and other urban areas in NSW.

Future studies will be undertaken to estimate the coefficients of the ATC - NZ model using Sydney data to generate the coefficients most suitable for Sydney – NSW applications.

8. Practice Guide – Case Studies

This chapter demonstrates the application of the most relevant approach for a selection of investments. The case studies outline the major steps and using the relevant economic parameter values calculate the costs and benefits of each option. The results of economic appraisal will be presented in summarised form. Each case study will feature techniques which are portable to other studies.

8.1 Economic Appraisal of Road Upgrade and Maintenance

8.1.1 HW10 Pacific Highway Devils Pulpit Upgrade[1]: REVS Case Study

The project is the upgrading of the Pacific Highway at Devils Pulpit, between Iluka Road and Woodburn. The proposal is broken into three stages:

- **Stage 1**: Chainage 65.6km – 71km north of Grafton. Includes new southbound carriageway from 65.6km - 71km north of Grafton, new northbound carriageway from 68km to 69.6km, and the reuse of existing carriageway between 65.6km - 68km and 69.6km – 71km. It also involves the earthworks between 71km – 73km.
- **Stage 2**: Chainage 71km – 73km north of Grafton. Includes completion of the new southbound carriageway from 71km – 73km over the existing earthworks. It also includes the construction of two new southbound bridges at 71.4 and 71.8km north of Grafton.
- **Stage 3**: Chainage 72.6km – 75.6km north of Grafton. This stage includes the installation of median wire rope by widening the existing carriageway on the western side of the existing highway, resealing, line-marking and the installation of 3km of median wire rope safety barrier.

Both the existing highway and the proposed upgrade have a speed limit of 100 km/h throughout.

The REVS (Rural EValuation System) was used to evaluate the benefits for through traffic on the Pacific Highway produced by the additional capacity & lower accident rate provided by the new carriageway, plus the lower accident rate over the section to be treated with wire rope median. These were estimated to comprise savings in:

- Vehicle operating cost
- Travel time (private and commercial)
- Accidents.

In accordance with accepted life-cycle costing procedures, the effects of future expenditure on rehabilitations, reseals and routine maintenance were also considered in the REVS analysis.

Data Sources & Assumptions

a) Traffic Volume

A 2008 traffic volume of 7,800 vehicles per day, derived from RTA traffic count station 04.233 located 12.9km south of Woodburn, was adopted for the economic analysis.

[1] It is acknowledged that this case study is provided by RMS Transport Planning Section

b) Traffic Growth
Analysis of the traffic growth pattern was undertaken by Northern Region. It indicated a linear growth rate of 2.6% pa. The REVS analysis undertaken for the Pacific Highway Upgrade Study used the following traffic growth profile, based on this growth rate.

Table 8.1(a) Traffic Forecast

Year	Traffic Volume (vehicles per day (vpd))
2008	7,800
2010	8,205
2015	9,219
2020	10,233
2025	11,247
2030	12,261

Sensitivity testing at 20% lower (i.e. 2.08% pa) and 20% higher (i.e. 3.12% pa) traffic growth rates was also undertaken in the economic analysis.

c) Traffic Composition
The heavy vehicle proportions were extracted from 12-bin classification data collected at RTA count Station 04.233, 12.9km south of Woodburn. The following values were used for the REVS analysis:

Table 8.1(b) Traffic Composition

Vehicle Class	Assumed Percentage
Cars	78.6%
Light Commercials	1.9%
Rigid Trucks (2-axle 6-tyre)	2.9%
Rigid Trucks (3-axle)	1.3%
4-axle rigid (or semi)	0.6%
Semi-Trailer (5-axle)	0.7%
Semi-Trailer (6-axle)	8.0%
B-Doubles	6.0%
B Triples	-
TOTAL	**100.0%**

d) Construction Cost
The October 2010 construction cost estimate for the proposal (including contingency) was $92,478,882. The cost was distributed as:

Table 8.1(c) Capital Cost

Year	Estimated cost ($2010)
Prior to 2010/11	$7,000,000
2010/11	$8,000,000
2011/12	$50,000,000

2012/13	$27,478,882
TOTAL	**$92,478,882**

Sensitivity testing at lower (i.e. minus 10%) construction cost was also undertaken in the economic analysis. Testing at a higher estimated cost was not undertaken, since the original estimates contained a contingency allowance.

e) Geometric Data
The gradient and horizontal curvature data for the existing section of the Pacific Highway was extracted from the RTA's GipsiTrac road geometry database using the RGA (Road Geometry Analyst) program.

f) Pavement & Cross-Section Data
Pavement type, condition, age and cross-sectional information for the Pacific Highway was extracted from the RAMS-Q database.

Cross-section data for the proposed new one-way carriageway sections was assumed to be 2 x 3.5 metre lanes, with an outside shoulder of 2.5 metre width and a 0.5 metre inside shoulder. The 2-way wire rope section (Stage 3) was assumed to be 2 x 3.5 metre lanes, with a 2.0 metre painted central median and outside shoulders of 2.5 metre width.

g) Accident Rates
Analysis of crash data for the period 1999-2009 undertaken in Northern Region indicated that the historic crash rate for subject length of the Pacific Highway is 23 crashes per 100Mvkt. This value was used in the base case in REVS. For the improved case, the REVS program predicted a rate of 14 crashes per 100Mvkt on the dual carriageway sections and 18 crashes per 100Mvkt on the wire rope section.

Analysis of the accident severity data indicated a higher than expected proportion of fatal accidents (5 fatal crashes out of 40 total crashes) on the subject length. Using the Willingness to Pay valuations for fatalities and serious injuries, at the time, the weighted average accident cost was found to be $977,645, well above the state-wide average of $339,800.

h) Other Data
The Federal Government preferred discount rate of 4.4% was used in the analysis[2]. Sensitivity testing was also conducted at the NSW Treasury reference rate of 7.0%. All costs and benefits were discounted to a base year of 2010.

All other parameter values used (e.g. fuel, oil, tyre, time, accident costs; vehicle occupancy rates, etc.) were the then most recent standard RTA values (ref: update to Appendix B of the RTA Economic Analysis Manual, released 1 February 2010). The analysis included the recently-adopted higher accident costs based on the Willingness to Pay principle, i.e. $6,123,000 per rural fatal crash and $571,000 per rural serious injury crash.

Results

The summary results (at 4.4% discount rate) and the sensitivity analysis are outlined below (Please note that this economic analysis was undertaken as part of submission to the Commonwealth Government which requires discount rate of 4.4% as the base discount rate at the time).

[2] As advised by the Project Manager.

Table 8.1(d) Summary of Results of Pacific Highway Upgrade REVs Study

Present Value of Benefits (PVB)		$78.1 M
Present Value of Construction Costs + Maintenance/Rehab Savings (PVC)		$87.9 M
Benefit Cost Ratio (BCR)		0.9
Net Present Value (NPV)		-$9.8 M
First Year Rate of Return (FYRR		4.3%
Proportion (%) of PVB Attributable to Accident Savings		64%
Proportion (%) of PVB Attributable to Travel Time Savings		23%
Proportion (%) of PVB Attributable to Vehicle Operating Cost Savings		13%
SCENARIO		**Result**
Adopted Traffic growth = 2.6% pa (at 4.4% discount rate)	*NPV* *BCR*	**- $9.8 M** **0.9**
Discount rate = 4.0%	*NPV* *BCR*	- $5.5 M 0.9
Discount rate = 7.0%	*NPV* *BCR*	- $29.6 M 0.6
High Traffic growth = 20% above adopted rate (i.e. **3.12% pa**)	*NPV* *BCR*	- $1.3 M 1.0
Low Traffic growth = 20% below adopted rate (i.e. **2.08% pa**)	*NPV* *BCR*	- $17.4 M 0.8
Low Construction Cost (-10%), with adopted traffic growth	*NPV* *BCR*	- $1.4 M 1.0

The above results show that, on the basis of Pacific Highway road user savings (travel time, vehicle operating costs and accident costs) and ongoing RTA maintenance & rehabilitation expenditures, the proposal is marginally economically justified based on Government's commitment on Pacific Highway Upgrade. At 4.4 per cent discount rate, the project BCR is 0.9, and the NPV is - $9.8 M. The BCR remains close to or equal to unity under all sensitivity testing situations.

While the prevailing overall crash rate on the subject length of the Pacific Highway is not particularly high, the severity of the crashes is very high. As a result, accident savings are the major contributor to the total road user benefit in the absence of any significant distance savings or geometric improvements.

Travel time savings account for less than one-third of the total road user benefit. This is not typical of most rural upgrading works, and reflects the generally adequate capacity provided by the current highway for existing and anticipated traffic demands, and the unchanged speed limit. The travel time benefit is estimated to be 17 seconds for cars and 46 seconds for semi-trailers.

8.2 North Sydney Rail Freight Corridor Program Economic Evaluation

Background

The North Sydney Freight Corridor (NSFC) Program comprised a number of projects over three stages to improve rail services along the Sydney to Newcastle rail corridor. The stages of the Program with individual projects are summarised in Table 8.2(a)

Table 8.2(a) North Sydney Freight Corridor Stage projects

Stage 1	Stage 2	Stage 3
North Strathfield Rail Underpass	Rhodes to West Ryde 3rd Track (Dn)	North Strathfield to Epping 4th Track (Up)
Hexham Passing Loop	Thornleigh to Hornsby 3rd Track (Dn) unwired	Strathfield Junction Passenger Underpass
Epping to Thornleigh 3rd Track	Berowra to Hawkesbury River 3rd Track (Up)	Epping Modified Train Turnaround
Gosford North Passing Loop	Signalling Enhancements	Epping to Hornsby 4th Track (Up)
Islington Passing Loop	Hornsby Freight Bypass	Hornsby to Berowra 3rd Track
		Wyong Passing Loops
		Signalling Enhancements

Source: North Sydney Rail Freight Corridor Infrastructure Australia Project Submission July 2010

Currently, the Main North line between Sydney (Strathfield) and Newcastle (Broadmeadow) is an important strategic link to the main freight line along the east coast interstate rail network, managed by Australian Rail Track Corporation (ARTC). Sydney Newcastle is part of the passenger network (Sydney Trains and NSW Trains). Freight services are restricted to off peak times when they enter the NSW Trains owned network.. Current operations face a number of key challenges such as geography (steep terrain), operations limiting freight travel to outside passenger peak times and network configuration such as few holding loops to 'park' freight trains.

A 'do minimum' base case was defined as no implementation of additional capital investment in transport infrastructure, unless already committed by the government (e.g. North West Rail Link), and with assets maintained to a safe operable level. The base case was compared with the NSFC project case and incremental costs and benefits are estimated.

Forecast Freight Demand

A NSFC Program demand study forecasts potential demand for each of the six market segments that form part of the east coast freight: Interstate (containerised), regional (containerised), steel, grain, coal and building products. Interstate container freight has the largest number of trains and out of all the market segments is forecast to experience the highest levels of growth with 50% market share of interstate freight on rail by 2018. This is due to the improved availability and reliability of freight paths and potential increases in energy costs. Growth in coal volumes and building products are dependent on future mining developments and potential new projects thus are harder to forecast. Over the long term, the steel market is predicted to remain stable and the grain market is forecast to grow in response to domestic consumption related to population growth. Demand forecasts for the market segments were determined in annual tonnage, shown in Table 8.2(b).

Table 8.2(b) Forecast demand (annual tonnage)

Market Segment	2008	2018		2028		2038	
		Low*	High*	Low*	High*	Low*	High*
Interstate intermodal	1,659	5,035	9,738	6,388	15,297	8,098	20,979
Regional intermodal	782	970	1,081	1,165	1,315	1,388	1,629
Port of Newcastle (2020)	0	0	0	4,320	4,320	4,320	4,320
Steel	1,215	1,392	1,615	1,572	2,057	1,771	2,607
Grain	568	628	641	690	715	738	776
Coal	5,150	6,881	14,903	5,253	14,657	1,000	15,503
Building products	160	160	1,180	160	1,680	160	1,680
Total	**9,534**	**15,066**	**29,157**	**15,299**	**40,041**	**13,155**	**47,314**
Total (excluding Wyong)	9,534	15,066	24,157	15,299	35,041	13,155	42,314

Total (including Port of Newcastle)	9,534	15,066	29,157	19,549	44,361	17,475	51,634

Source: North Sydney Rail Freight Corridor Infrastructure Australia Project Submission July 2010
* Low demand forecast includes the rail share of interstate container and coal volumes. High demand forecast includes additional building products for potential new projects along the corridor.

Project Benefits

The main benefits quantified by the NSFC Program include:

- **Rail and road truck operating costs savings** – operating cost savings represent the greatest proportion of benefits (57%), due to a reduction in freight rail cost and increase in rail market share as a result of a switch from road to rail freight as well as a reduction in road maintenance expenditure.
- **Freight transit time savings –** improvement in transit times for freight trains and reduction in waiting time in terminals.
- **Road freight decongestion cost savings** – decrease in road congestion, capacity improvement for freight services on the Main North Line as well as the reduction in bottlenecks between Sydney and Newcastle. (See Section for guide in estimating of de-congestion benefit)
- **Freight customer reliability and availability benefits** – improvement in freight train reliability and availability as well as greater flexibility in rail arrival and departure times due to fewer restrictions on freight services during passenger peak periods.
- **Reduced externality costs** – reduction in air pollution, greenhouse gas emissions and noise.
- **Road freight crash cost savings**– decrease in road accidents improving safety.
- **Passenger benefits –** improved service frequency through the possibility to run two additional peak services as a result of NSFC and improved reliability through reduction in passenger delays from freight services.

Economic Evaluation Results

Table 8.2(c) highlights the results from the economic evaluation at each stage, including Wider Economic Benefits (WEBs) which may comprise of additional benefits such as labour market and productivity impacts. The results are discounted at a rate of 7%, in 2010 year prices with a 30 year evaluation period.

Table 8.2(c) North Sydney Freight Corridor Summary of Economic Results

	Stage 1	Stage 2	Stage 3
Total undiscounted capital costs ($m)	862	2,864	4,358
Project costs (PV $m):			
Capital costs	650	1,904	2,596
Maintenance costs	107	180	214
Total project costs	**757**	**2,084**	**2,810**
Freight benefits (PV $m):			
Transit time savings	9	11	25
Operating cost savings	1,320	1,936	2,358
Road freight decongestion	14	21	26
Customer reliability benefits	80	443	755
Externality cost savings	162	242	299
Crash cost savings	195	290	359
Sub total	**1,780**	**2,943**	**3,823**
Residual value (PV $m)	52	141	149
Passenger benefits	-	-	164
Total benefits (PV $m)	**1,832**	**3,084**	**4,136**
Summary (excluding WEBs):			
NPV ($m)	**1,075**	**1,000**	**1,326**
NPVI	**1.7**	**0.5**	**0.5**
BCR	**2.4**	**1.5**	**1.5**
IRR (%)	**16%**	**10%**	**10%**
BCR (including WEBs)	**2.5**	**1.6**	**1.6**

Source: North Sydney Rail Freight Corridor Infrastructure Australia Project Submission July 2010

8.3 Economic Appraisal of Growth Buses, Interchange and Parking facilities, Intelligent Transport Systems (ITS)

8.3.1 Bus acquisition CBA tool

The bus acquisition tool provides cost benefit analysis guidance for the purchase of buses. The tool uses real data (FY10/11) such as the average patronage and number of services for each route. The user inputs the number of buses to be purchased and the route number. The patronage and number of services for the selected route is then retrieved for both peak and off peak hours, for both the base case and the option case. The headway is then calculated based on the number of services per hour. As the result of the purchase of an additional bus, this increases the number of services, reduces the headway which reduces the waiting time. Cells shaded grey indicates parameter inputs which can be changed.

This tool can be used to evaluate the costs and benefits associated with the purchase of buses as well as a policy tool to establish the best route to place additional buses based on patronage and services data to deliver the most economic benefits.

Description of model

The base case is defined as the level to maintain the current level of service for the selected route. The option case is the purchase of buses. Both base and option cases are estimated. Bus services (supply) and passenger trips (demand) are forecasted for peak and off peak periods, since the effects can vary. The number of existing trips is retrieved from the data set. The number of induced trips is calculated using the bus use elasticity as provided in Appendix 4 and change in the generalised cost of travel due to the reduction of waiting time. Of the induced trips, 60% are assumed to be new trips, 30% are diverted trips from car to bus and 10% (these are default model value and users can revise based on real project data) are diverted trips from rail to bus. Depending on the route selected, the trip distance is estimated and used to determine the benefits and costs. The evaluation period is 15 years after the capital cost is incurred.

Assumptions

The following are some of the assumptions used in the model:

- Waiting time is half of headway time implying that passengers arrive at random.
- Annual passenger growth of 1.5% is applied, which is in line with population growth.
- The rail and bus fare is the same therefore there is no benefit from diverted rail to bus users.
- Crowding only occurs during the peak period. More services may alleviate crowding in the form of standing passengers. De-crowding benefits exists when the base case is crowded and the option case causes no crowding (large benefits) or if there is still crowding but to a lesser degree (small benefits).
-

Costs and Benefits

Capital costs consist of bus acquisition costs. Operating/recurrent costs include driver time, fuel and repair and maintenance and imputed rent costs.

Benefits from the purchase of additional buses include:

- Waiting travel time savings - Due to more services waiting time is reduced for existing passengers.
- User cost change – This benefit represents the vehicle operating cost savings net of the bus or rail fare cost. This applies to diverted trips from rail and car to bus.
- Environmental cost savings – Greenhouse gas and air pollution savings from car usage. This benefit applies to diverted trips from car to bus.
- Parking cost savings – This benefit applies to diverted trips from car to bus. By not using the car, potential parking costs are saved.
- Accident costs savings – Bus accident costs are lower than car accident costs. This benefit applies to diverted trips from car to bus.
- Benefits from new users – This includes the fare revenue generated from induced users as well as the consumer surplus (using the rule of half).
- De-crowding benefits –additional services provide de-crowding benefits during the peak period.

The main results of the CBA which include NPV and BCR are presented as incremental to the base case, using a discount rate of 7%. An overview of the costs, benefits and impacts of the base case and option are presented in the summary worksheet.

Download the **Excel Tool Here** or contact the Evaluation and Economic Advisory team in Finance and Investment Division for a copy of the model.

Bus Acquisition Cost-Benefit Analysis Tool

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8.3.2 Interchanges - Assessment and Ranking

An economic appraisal methodology has been developed and presented below to assess a number of interchanges for funding under the parking space levy fund. The objective is to assess and rank a package of 21 interchanges based on value for money and transport goal achievement criteria.

Scoping studies were undertaken for 21 interchanges across Greater Sydney. These studies identify existing deficiencies in each interchange and improvement options and upgrades and recommend preferred options.

The objectives of the scoping studies are:

- Review existing Interchange demand and operations
- Estimates of future demand for the interchange
- Deficiency analysis to identify key areas of improvement;
- Review current transport and access initiatives
- Key stakeholder consultation including government agencies, bus operators
- identify future interchange user requirements and design objectives
- Compare options for the interchange upgrade and provide cost estimates based on an indicative work program.
- Preparation of interchange options, and recommendation of preferred interchange improvements.
- Preparation of concept plans for options that will accommodate the forecast demand

Project Costs

Individual project costs were estimated based on construction of projects and the components included in the concept plans which comply with the TfNSW Public Transport Interchange Facilities Guidelines. Total cost of the projects include construction cost, 20-30% contingency allowance applied to base costs inclusive of 10% land, 10% project management cost, design costs and15% contingency. Maintenance cost of 1% (of capital cost) per annum was assumed for each interchange.

Project costs include:

- Unit rates for standard facility configuration (e.g. bus shelter),
- Allowance for signage which depend on size, number, placement,
- Power requirements
- Allowance for steel structures
- Allowance for managing / protection construction activities in relation to public use activities such as traffic management issues and separation of construction activities
- Facilities such as lifts, CCTV cameras

The scoping studies used approximate quantities and published construction cost rates taken from Rawlinson's Construction Handbook 2006.

The maintenance cost of 1% p.a. of project cost was assumed for all program components plus contingency.

Project Benefits - Economic Benefits

Improving bus–rail interchange is often an integral part of wider local strategies to bring about economic regeneration, or improve environmental quality.

The following broader economic benefits are anticipated from the implementation of the Interchange Program:

- Development of brownfield sites, coupled with a reduction in the generalised cost of commuting by public transport, leading to higher employment levels in regeneration areas;
- The presence of good transport links at a site can often be commercially attractive for potential developers;
- Wider availability of transport alternatives coupled with a reduction in commuting times & increasing the number of productive hours in a working day;
- Reliability benefits which will produce most benefits for commuters;
- improve links between business centres;
- Environmental benefits –enhanced interchanges and seamless travel attract current and potential future car users into public transport (park and ride opportunities). By encouraging mode shift from private car to public transport, the program will contribute towards:
  - Removing cars from the road, reducing the energy consumption of transport;
  - Reducing rate of traffic growth, minimising congestion
  - Achieve a switch to less fuel intensive transport, achieve better air quality

Widely accepted methodologies for valuation of economic benefits predominantly relate to travel time savings, vehicle operating costs, safety benefits and environmental impact which have universally accepted resource cost valuation. To the extent that these can be estimated economic benefits due to improvement in interchanges should be estimated, including travel time savings and safety benefits where applicable.

To assess the economic desirability of the Interchange Program, Appraisal Summary Technique (AST) was used. The AST provides the information needed to make a judgement about the overall value for money of the option or options in achieving the Government's objectives. Providing the information in this way enables a consistent view to be taken about the value of projects.

The AST does not only cover value for money, but summarises the effects in each area so that decision makers have a clearer and more transparent basis on which to make a judgement.

The next section outlines the analytical approach used in the study.

Project Scoring Process

An Appraisal Summary Table (AST) is prepared for each interchange project and sets out simply and concisely how each will address the transport objectives.

In addition, the resource options available for the project and its readiness for implementation were included as decision criteria.

A key set of assessment criteria are developed against which to measure the expected contributions of each interchange project in achieving transport strategic objectives. An assessment was undertaken of the degree to which the transport objectives are likely to be achieved. The degree to which goal achievement is likely to be achieved has been translated into project score.

Example

Each interchange project is first scored separately using **Transport Factors**

- o Accessibility
- o Impact on safety
- o Wider economic impact
- o Sustainable level of service (LOS)
- o Environment and
- o Integration

Maximum Score = 28

Projects are then scored on **Planning Factors**

- o Economy
- o Resource funding options
- o Land use policy
- o Project readiness /deliverability

Maximum Score =12
Total Maximum Score = 40

The table below presents these objectives, the assessment criteria under each objective and the recommended score for each criterion. The scoring approach is recommended for programs with project components which are widely variable. The maximum score is presented under each objective. For instance, under accessibility objective, the interchange which cater to more than 50% of trips in bus and rail is given the highest score of 3, while the interchange with less than 20% of trips are bus and rail is given the lowest score of 1.

Table 8.3(a) Appraisal Summary Table (AST): Transport Objectives, Criteria and Suggested Scores

OBJECTIVE / CRITERIA	SCORE
1 ACCESSIBILITY	
Option value (Choice)	
Only travel alternative	2
Alternative to private modes	1
Alternative to other public transport	0
Mode Share of Journeys (Bus + Rail)	
>50%	3
>20%	2
<20%	1
Improvement to travel	1
Remove serious constraint	1
Reduction in community severance	1
Maximum Score	**8**
2 SAFETY	
Improve personal security	1
Overall safety benefits / reduce accidents	1
Encourage healthy modes / lifestyle	1
Maximum Score	**3**
3 WIDER ECONOMIC IMPACT	
Journey purpose	
Work	5
Education / training	4
Shopping / personal business	3
Health / medical/welfare	2
Leisure (social / recreational)	1
Business / Industrial Access Benefits	
Improves connectivity to markets, business centres	1
Contributes to local business expansion	1
Maximum Score	**7**
4 ENVIRONMENT	
Improves landscape, townscape, special sites	1
Net improvement in noise environment	1
Improve localised air quality	1
Maximum Score	**3**
5 FUTURE POTENTIAL	
Patronage trends	
Increasing Passengers	2
Stable passenger number	1
Decreasing passenger number	0
Maximum Score	**2**
6 INTEGRATION	
Supports Metro Strategy	

Global	5
Regional	4
Major Multi Access	2
Multi Access	1.5
Local interchange	1
Maximum Score	**5**
7 ECONOMY	
Cost per passenger ($ per 100 passengers)	
<100	6
100-250	5
250-500	4
500-750	3
750-1000	2
>1000	1
Maximum Score	**6**
8 RESOURCE OPTIONS	
Funding / resource alternatives	
No funding / resource alternatives	2
Potential for sharing of internal resources	1
Potential for external funding (government grants)	0
Maximum Score	**2**
9 LAND USE POLICY	
Contribution to LU policy	
Supports local / regional / national Land Use Policy	1
Does not support LU Policy	0
Maximum Score	**1**
10 READINESS / DELIVERABILITY	
within 12 months	3
Within 2 years	2
2 years +	1
Maximum Score	**3**
TOTAL MAXIMUM	**40**

Project Scoring Panel

Here, a panel of 4 staff have been assigned to score the attributes of the interchanges (as detailed in the scoping studies). The panel members scored 5 interchanges each (1 scored 6) according to the criteria and score presented in the table above.

To achieve scoring consistency, the studies were rotated among the panel members who discuss any discordant scores and agree on a common score. If a common score could not be achieved, the average score is used on that attribute.

Calculation of B-C Score

Transportation and planning factor scores are summed (maximum of 40) and divided by project cost (in millions of dollars) to derive the B-C score. It would be useful to normalise the project costs by converting these to net present values. For example, an interchange with a total score of 26 and normalised cost of $09.5m has a B-C score of 2.74.

The subsequent value is then scored from 2 to 10 points based on the values below and added to point total (from 2 to 10 points can be added to the maximum score of 40, summing to as high as 50 points which is the best score).

Table 8.3 (b) Points for Hybrid B-C Score

Hybrid Benefit-Cost Ratio [1]	Points
Equal or Greater than 30	10
Equal or Greater than 20	8
Equal or Greater than 10	6
Equal or Greater than 5	4
Equal or Greater than 1	2

[1]This is calculated as Project Transportation and Planning Points ÷ Project Cost, in $m

Summary of Project Scoring Results

All the impacts of the intervention are brought together in the Appraisal Summary Table in the matrix format to present scoring for all the interchanges together. This presentation reduces the risks that some of the impacts will be overlooked or that some may be given disproportionate emphasis.

The raw scores for each interchange project which range from 18 to 29.5 out of maximum score of 40 are presented in column 1 of the table following the matrix. To incorporate the efficiency (value for money) criteria in the appraisal methodology, a **hybrid benefit – cost ratio** was constructed by dividing the goal achievement scores (which are tantamount to benefits) with capital and maintenance costs. These are called **B-C Scores** which are in fact normalised scores.

It should be noted at this point that the B-C scores are all greater than 1, which adopting the usual economic evaluation convention, is an indication that each of the projects included in the program is economically viable.

This particular step normalises the results for the variability in costs. Total costs range from $0.5m to $10.6m, with the average capital cost being $4.6m. The B-C scores were assigned points which were then added to the raw scores, with the results forming the total APT scores.

As indicated above, each of the project are economically viable and thus worth undertaking. The APT results can assist in prioritising improvements and in developing action plans to deliver the projects over the short, medium and long term, subject to PSL budget constraints.

Table 8.3(c) ASSESSMENT OF PROJECTS /PROGRAMS / OPTIONS BASED ON QUALITATIVE ATTRIBUTES SCORED QUALITATIVE ASSESSMENT MATRIX

			A	B	C	D	E	F	………	U
OBJECTIVE	**CRITERIA**	**SCORE**								
ACCESSIBILITY	***Mode Share of Journeys (Bus + Rail)***									
	>50%	3	3							
	>20%	2		2	2		2	2		
	<20%	1				1				1
	Improvement to travel	1	1	1	1	1	1			1
	Remove serious constraint	1	1		1					
	Reduction in community severance	1								
	Maximum Score	**6**	**5**	**3**	**4**	**2**	**3**	**2**		**2**
SAFETY	Improve personal security	1	1	1	1	1	1	1		1
	Overall safety benefits / reduce accidents	1	1		1	1	1			
	Encourage healthy modes / lifestyle	1	1	1	1	1	1	1		1
	Maximum Score	**3**	**3**	**2**	**3**	**3**	**3**	**2**		**2**
WIDER ECONOMIC IMPACT	***Journey purpose***							TBA		TBA
	Work	5		5		5	5			
	Education / training	4								
	Shopping / personal business	3	3		3			3		3
	Health / medical/welfare	2								
	Leisure (social / recreational)	1								
	Business / Industrial Access Benefits									
	Improves connectivity to markets, business centres	1								
	Contributes to local business expansion	1						1		
	Maximum Score	**7**	**3**	**5**	**3**	**5**	**5**	**4**		**3**

FUTURE POTENTIAL (SUSTAINABLE TRANSPORT)	***Patronage trends***									
	Increasing Passengers (>10%)	4								
	Increasing Passengers (5% to 10%)	3	3							
	Increasing Passengers (<5% but >0.5%)	2		2	2	2		2		
	Stable passenger number (0 to 0.5%)	1								1
	Decreasing passenger number (negative)	0					0			
	Maximum Score	**4**	**3**	**2**	**2**	**2**	**0**	**2**		**1**
INTEGRATION	***Supports Metro Strategy***									
	Global	5								
	Regional	4	4.5							
	Major Multi Access	2			2		2			
	Multi Access	1.5				1.5				1.5
	Local interchange	1		1				1		
	Maximum Score	**5**	**4.5**	**1**	**2**	**1.5**	**2**	**1**		**1.5**
ENVIRONMENT	Improves landscape, townscape, special sites	1	1	1	1	1	1	1		1
	Net improvement in noise environment	1								
	Improve localised air quality	1								
	Maximum Score	**3**	**1**	**1**	**1**	**1**	**1**	**1**		**1**
ECONOMY	***Cost per passenger***									
	< $500	6	6	6	6					
	$500-$1,000	5				5	5	5		5
	$1,001 - $2,000	4								
	$2,000 - $3000	3								
	$3,000-$5,000	2								
	>$5,000	1								
	Maximum Score	**6**	**6**	**6**	**6**	**5**	**5**	**5**		**5**

RESOURCE OPTIONS	***Funding / resource alternatives***								
	No funding / resource alternatives	2	2	2	2	2	2	2		2
	Potential for sharing of internal resources	1								
	Potential for external funding (gov't grants)	0								
	Maximum Score	**2**	**2**	**2**	**2**	**2**	**2**	**2**		**2**
LAND USE POLICY	***Contribution to LU policy***		1	1	1	1	1	1		1
	Supports local / regional / national Land Use Policy	1								
	Does not support LU Policy	0								
	Maximum Score	**1**	**0**	**0**	**0**	**0**	**0**	**0**		**0**
READYNESS / DELIVERIBILITY	within 12 months	3		3	3		3			
	Within 2 years	2	2			2		tba		2
	3 years +	1								
	Maximum Score	**3**	**2**	**3**	**3**	**2**	**3**	**0**		**2**
		MAX SCORE								
	TOTAL SCORES (Raw)	**40**	**29.5**	**25**	**26**	**23.5**	**24**	**19**		**19.5**
Additional Comments	***<Provide any additional comments that could serve as supporting information for the intangibles>***									
			BENEFIT COST SCORE [1]							
Discounted Project Costs NPV@7%			**$6.333m**	**$1.313m**	**6.045m**	**2.552**	**4.287**	**2.816**	**2.703**	**10.609**
B-C SCORE (Raw Score ÷NPV Project Cost, in $m)			**5**	**9**	**16**	**3**	**12**	**38**	**4**	**4**

Hybrid BCR was calculated by adding the B-C Qualitative Assessment Score to the BCR derived from the usual quantitative cost benefit analysis study.

TABLE 8.3(d): Appraisal Summary Table- Interchange Projects Scores

	Interchange Project	**NPV TOTAL COSTS $m**	RAW SCORES	**B-C SCORES (Normalised)[1]**	**B/C Points[2]**	**TOTAL APT SCORE**
1	A	6.333	29.5	5	4	33.5
2	B	3.043	28.0	9	4	32.0
3	C	1.313	21.0	16	10	31.0
4	D	10.609	29.0	3	2	31.0
5	E	2.079	24.0	12	6	30.0
6	F	0.522	20.0	38	10	30.0
7	G	6.045	27.0	4	2	29.0
8	H	4.287	25.0	6	4	29.0
9	I	9.485	26.0	3	2	28.0
10	J	2.177	22.0	10	6	28.0
11	K	**2.552**	23.5	9	4	27.5
12	L	4.287	23.5	5	4	27.5
13	M	4.833	23.0	5	4	27.0
14	N	0.658	18.0	27	8	26.0
15	O	9.500	23.5	2	2	25.5
16	P	9.019	23.5	3	2	25.5
17	Q	2.816	21.0	7	4	25.0
18	R	5.359	23.0	4	2	25.0
19	S	2.703	18.5	7	4	22.5
20	T	5.144	18.0	3	2	20.0
21	U	4.244	18.0	4	2	20.0

[1] Normalised BC Score-derived by dividing the raw scores with the project costs (in $m)
[2] BC points are assigned to normalised scores

The following table below presents both the scores and the individual project and cumulative costs. An optimisation approach could be applied at both the strategic and project level analysis. Optimisation is achieved by calculating the benefit cost ratio (in this case the B-C scores for all projects, then rank the projects by the by total scores and funding the highest priority projects, in turn, until funds were exhausted. The funding level is essentially determined as the appropriate level of investment determined during the strategic planning stage.

At $50m budget, for instance, all projects ranked from 1 to 11 are all capable of being funded. This could be further refined by annually programming the costs based on construction schedule instead of just looking at the total costs.

Table 8.3(e): Ranked APT Scores and Costs

	Interchange	**TOTAL APT SCORE**	**NPV TOTAL COSTS**	**CUMULATIVE TOTAL COSTS**
1	A	33.5	6,333,422	6,333,422
2	B	32.0	3,042,867	9,376,289
3	C	31.0	1,312,718	10,689,007
4	D	31.0	10,609,285	21,298,292
5	E	30.0	2,078,910	23,377,202
6	F	30.0	522,397	23,899,600
7	G	29.0	6,045,250	29,944,849

8	H	29.0	4,287,062	34,231,911
9	I	28.0	9,484,933	43,716,844
10	J	28.0	2,176,656	45,893,500
11	**K**	**27.5**	**2,552,113**	**48,445,613**
12	L	27.5	4,287,062	52,732,674
13	M	27.0	4,833,432	57,566,107
14	N	26.0	658,050	58,224,157
15	O	25.5	9,500,134	67,724,290
16	P	25.5	9,018,913	76,743,203
17	Q	25.0	2,815,742	79,558,946
18	R	25.0	5,358,827	84,917,773
19	S	22.5	2,703,307	87,621,080
20	T	20.0	5,144,474	92,765,554
21	U	20.0	4,243,714	97,009,268

Contact the Economic Policy Strategy & Planning, FINANCE for assistance in conducting similar analysis. Refer to Appendix 8 for the AST Table.

8.3.3 Intelligent Transport Systems – CCTV

Intelligent Transport Systems – CCTV Tool
Intelligent Transport Systems represent technologies that are able to provide transport users to be better informed as well as providing a safer and intelligent use of transport networks. The primary user benefit of CCTV is the travel time savings. As a result of an incident being identified by CCTV, this allows traffic incident response teams to clear the incident faster, reducing incident duration.

Description of model
The CCTV tool provides cost benefit analysis (CBA) guidance for the installation of CCTV at a specified road. The installation of CCTV contributes to a reduction in average incident duration. The user is able to input specific project data in the Project Profile section. The main inputs required are the Annual Average Daily Traffic (AADT) along the section of road where the CCTV is to be installed, the number of incidents per year at the specified location and average incident duration time.

The model has the capacity to take into account peak and off peak periods, which can greatly vary the outcome of the benefits. The model also takes into account the travel time savings attributed to each traffic composition (e.g. car, rigid trucks, articulated trucks, B-Double).

Assumptions
The following assumptions are incorporated into the model and are seen as conservative:

- Number of incidents at proposed CCTV location is required as an input from the RMS CrashLink database.
- Incident delay is 39.98 minutes sourced from RTA 2011 Annual Report (p29).
- Reduction in incident duration from CCTV is 10% (i.e. 3.99 minutes reduced per incident).
- A traffic growth percentage of 1.1% is also applied annually.
- Defect rate of 2% to account for the fact that CCTV is not operational in some instances.

Costs and Benefits

Costs and benefit parameters are taken from TfNSW Appendix 4 to Economic Evaluation Guidelines. The capital costs include the cost of CCTV purchase/installation and the recurrent costs which include the associated maintenance/operating costs.

The benefits from the CCTV installation include:

- Travel time savings – CCTV is able to identify the incident sooner and able to aid in the navigation of response teams to clear the incident quicker.
- Vehicle Operating Cost savings in terms of reduction of time spent waiting for accident to clear. VOC in vehicle idling state has been estimated at $9.25/hr.
- Environmental costs savings – As the incident is cleared faster, there is decreased carbon equivalent (Co2-e) emissions from reduced idle time or at slow traffic speeds. Co2-e captures all emission types including CH_4, N_2O, NO_X, CO, VOC, PM_{10}, SO_2 and CO2. Co2-e at idling state is estimated at 4.6kg/hr. The carbon price was assumed at $52.4/tonne.

The CBA Results page highlights the main results which include NPV and BCR. The results are incremental to the Base Case (defined as no CCTV in the selected location) discounted at 7%.

Download the **Excel Tool Here** or contact the Evaluation and Economic Advisory, Finance and Investment Division for a copy of the model.

ITS-CCTV Cost-Benefit Analysis Tool

Read Instructions

Update Inputs and Assumptions

View CBA Summary Results

View Detailed Costs & Benefits Analysis

Sensitivity Tests

Evaluation & Assurance
Finance and Investment
Transport for NSW
June 2018

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8.3.4 Intelligent Transport Systems – Variable Message Signs (VMS)

Variable Message Signs (VMS) are electronic signs along major roads which provide information to motorists usually warning them of upcoming delays or accidents in the area. VMS are a component of Intelligent Transport Systems. The major benefit of VMS is travel time savings as motorists are able to alter their route when there is an incident.

Description of model

The VMS tool provides cost benefit analysis (CBA) guidance for evaluating VMS implementation. The model has the capacity to account for peak and off peak effects, which may vary the outcome of benefits. The Average Annual Daily Traffic (AADT), number of annual incidents causing delay on the specified road location and average time taken to clear incident are required as main data inputs. The evaluation period is 10 years after the capital cost has been incurred and an annual traffic growth percentage is also applied.

Assumptions

The following assumptions are incorporated into the model and are seen as conservative:

- Number of incidents causing delay per year is required as an input from a reliable data source such as the RMS CrashLink database.
- Incident delay is 39.98 minutes.[3]
- Driver response (% that makes a diversion as a result of VMS) is 20%. The benefit is calculated on the assumption that 20% of traffic makes a diversion (alters their route) as a result of viewing the VMS which saves time, as it is unrealistic to assume that all motorists who view the VMS will respond and change their route.
- Delay time saved from diversion is 50% of incident delay time (19.99 minutes).
- In the peak hours, an incident will cause additional 10% secondary accidents[4]. The VMS will reduce 40% of secondary accidents. In the off peak hours, an incident will cause additional 5% secondary accidents.[5] The VMS will reduce 20% of secondary accidents.
- Annual traffic growth of 1.1%
- Defect rate of 2% to account for the fact that VMS may not be operational in some instances.

Costs and Benefits

Costs and benefit parameters are taken from TfNSW Appendix 4 to Economic Evaluation Guidelines. The capital costs include the cost of VMS purchase/installation and the recurrent costs which include the associated maintenance operating costs.

The benefits are reliant on the percentage of traffic that makes a diversion as a result of observing the VMS. Benefits include:

- Travel time savings – Since motorists are aware of an upcoming incident as a result of VMS they are able to make a diversion and travel an alternate route to avoid any delay resulting from the incident. The model also takes into account the value of travel time savings attributed to each vehicle composition (e.g. car, rigid trucks, articulated trucks, B-double).
- Accident cost savings – The implementation of VMS may reduce the number of a secondary accidents occurring. A secondary accident is one that occurs upstream of another incident. The number of secondary accidents is estimated using the percentage reduction in secondary accidents from VMS installation and the average two vehicle

[3] RTA 2011 Annual Report

[4] Virginia Centre for Transportation Innovation & Research (2011), Primary & Secondary Incident Management: Predicting Duration in Real Time, April 2011.

[5] US DOT, Intelligent Transport Systems for Traffic Incident Management, US Department of Transportation

accident cost. By taking an alternate route as a result of observing the VMS, this reduces the chance of another accident stemming from the first incident.

- Vehicle operating cost savings in terms of the reduction in time spent at slow traffic speeds waiting for accidents to clear.
- Environmental cost savings (carbon dioxide equivalent emissions) due to time saved from taking a diversion as a result of VMS.

The key CBA results such as NPV and BCR are discounted at 7% and are presented in the CBA Results page and are incremental to the base case (which is defined as no VMS installation in the area).

Download the **Excel Tool Here** or contact the Evaluation and Economic Advisory team in Finance and Investment Division for a copy of the model.

ITS-VMS Cost-Benefit Analysis Tool

Read Instructions

Update Inputs and Assumptions

View CBA Summary Results

View Detailed Costs & Benefits Analysis

Sensitivity Tests

Evaluation & Assurance
Finance and Investment
Transport for NSW
June 2018

For any feedback or comments, please send an email to EconomicAdvisory@transport.nsw.gov.au

8.3.5 Bicycle facility CBA tool

The bicycle facility tool provides cost benefit analysis guidance for the construction of infrastructure for bicycle usage. A bicycle facility in this tool includes a separated cycleway, separated contra-flow cycleway, separated cycleway in park, shared path on verge, shared path in park or a cycle lane. For specific projects, user can input construction cost and maintenance cost. The user inputs the construction costs, maintenance costs, type of bicycle facility, its length in kilometres and duration of construction. The associated costs and benefits for the option case are retrieved based on the inputs. The costs and benefits are evaluated and summarised into PV costs and benefits, NPV, benefit cost ratio, IRR, NPVI and FYRR.

Description of model

The base case is a 'do nothing scenario' where no new bicycle facility is constructed. The option case is the construction of a bicycle facility. Incremental costs and benefits of the option scenario are estimated. Increase in number of kilometres ridden per annum is forecasted. Based on the type of bicycle facility the demand, benefits and costs vary. The evaluation period is 30 years after the capital cost is incurred.

Assumptions

The following are some of the assumptions used in the model:

- The default annual maintenance cost is 1% of the capital cost of construction. The user can input the maintenance cost on project-by-project basis.
- Annual rider growth is assumed to be 1.1%; which is same as NSW population growth of 1.1% in 2010-11.
- It is assumed that bicycle facility in parks will only be used by riders for recreation, whereas bicycle facility in places other than parks will be used for commuting, education, shopping, visiting friends/relatives and other purposes.
- The bicycle use on new facilities needs to be modelled and estimated on project to project basis. The assumed values are used in the current model.
- Value of Travel Time Savings is assumed to be zero in the model as choosing to ride a bike is aimed at improving health and gaining other social benefits but not to reach a destination faster.

Costs and Benefits

Capital costs consist of bike facility construction cost. Bicycle facilities usually use existing road corridor space or public land, (e.g. park) thus normally no land acquisition cost would be incurred. Recurrent costs include maintenance, education and promotion and other recurrent costs.

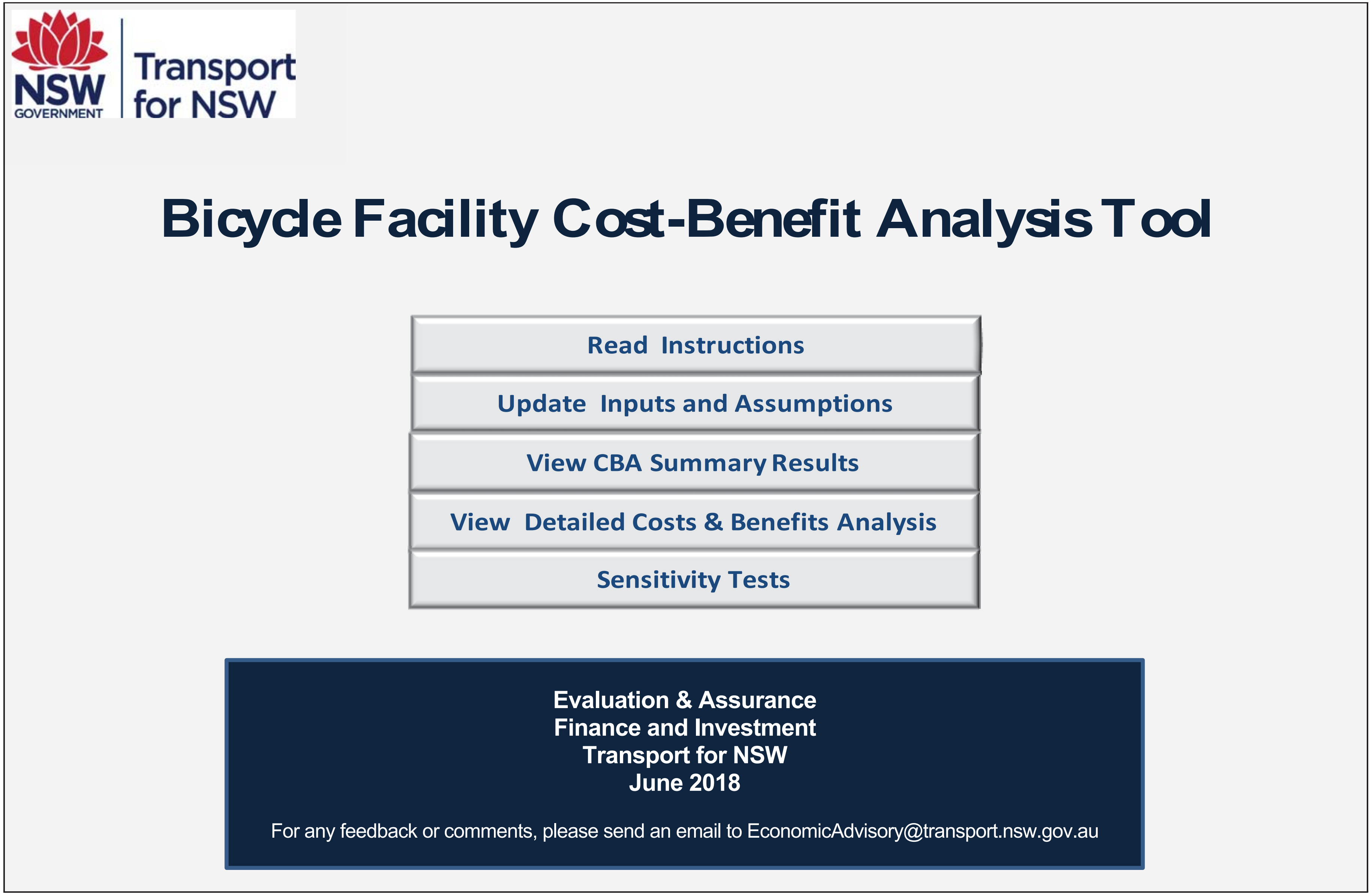
Main benefits from the construction of bicycle facility include:

- Parking cost savings – This benefit applies to diverted trips from car to bike. By not using the car, potential parking costs are saved.
- Congestion cost savings – Decreased number of cars in roads results in congestion cost savings.
- Reduction in vehicle operating cost (including fuel) – Bicycle riders save on MV operating cost by switching from cars to bicycle.
- Roadway provision cost savings – Reduced use of cars lead to lesser need for the government to spend on roadway provision.
- Public transport fare cost savings – Bicycle riders save public transport fares by switching from buses and trains to bicycles.
- Tolling cost savings – Bicycle riders save on tolling by switching from cars to bicycles.
- Environmental cost savings – Reduced use of car leads to reduced emission of greenhouse gas, and decrease in air, water, and noise pollution.

- Improved Health – Increased cycling leads to improved health as well as reduced morbidity and mortality.
- Accident costs – The accident rates are higher for cycling than driving or public transport, there are negative net benefits for trips diverted from car, bus or train. However, many new cycleway aims to improve safety and cycling ambience. The accident rates in new cycling facilities would be lower off-road cycleway and separated bicycle lanes. The net safety benefit is assumed for re-assigned bicycle trips (that is, previous bicycle trips diverted to new bicycle facilities. In the current model, 50% accident rate reduction is assumed.

The main results of the CBA which include NPV and BCR are presented as incremental, using a discount rate of 7% and sensitivity rate tests of 4% and 10%. An overview of the costs, benefits and impacts of the option are presented in the summary worksheet.

Download the **Excel Tool Here** or contact the Evaluation and Economic Advisory team in Finance and Investment Division for a copy of the model.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Bicycle Facility Cost-Benefit Analysis Tool
Read Instructions
Update Inputs and Assumptions
View CBA Summary Results
View Detailed Costs & Benefits Analysis
Sensitivity Tests
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8.3.6 High Occupancy Vehicle (HOV) Lanes

High Occupancy Vehicle (HOV) lanes require a minimum number of occupants in the vehicle in order to use the dedicated lane. They are more commonly known as T2 or T3 in the Sydney road network. The use of HOV lanes is a form of demand management to give vehicles carrying more people priority, providing a faster, more efficient journey. HOV lanes also encourage car pools to increase the average number of occupants per vehicle and as traffic volumes increase, protect high occupancy vehicles from increasing congestion.

The HOV Cost Benefit Analysis (CBA) model provides procedure, parameters and templates of estimating costs and benefits for the implementation of HOV lane on an urban arterial road.

Description of model

The model assumes three general purpose lanes on an urban road in the base case. The base case is defined as continuing with three general purpose lanes for all traffic. The option converts one general purpose lane to a HOV lane which can be only used for vehicles travelling with 3 or more occupants (also known as a T3 lane). The model only considers peak period traffic.

The main inputs of the model include the percentage of traffic that uses the HOV lane, Average Annual Daily Traffic (AADT) along the specified road and the length of the HOV lane. The model then calculates the costs and benefits of converting a general purpose lane to a HOV lane. The percentage of traffic that uses the HOV lane is a variable which can be changed. This must be less than the percentage of traffic per lane in the base case, otherwise there will be no benefit in implementing the HOV lane. The greater the percentage of traffic that uses the HOV lane, the greater the benefits, up until an optimal point where the HOV lane starts to become as congested as the other general purpose lanes.

A HOV lane may change travel time on both the HOV lane and the other general purpose lanes. Traffic speed is a function of the volume to capacity ratio and the free flow speed. In the base case, each lane travels at similar speed. When one lane is converted to a HOV lane, the speed in the HOV rises because there are fewer vehicles travelling the HOV lane. Consequently, the speed in the other lanes may fall (compared to the base case) due to increased traffic volume in a fewer general purpose lanes. This impacts the travel time and vehicle operating costs which are a function of speed.

The model contains parameters which can be varied according to their use. The project evaluation period is 30 years after the capital costs are incurred.

Assumptions

- Traffic growth of 1.5% is used to project traffic demand.
  - The model only considers peak traffic (period of 7 hours) which is 68% of Annual Average Daily Traffic (AADT).
  - The distribution of traffic on three lane roads are 30%, 35% and 35% from left to right lanes, recognising that left lane usually has less traffic .
  - There is no induced traffic as a result of the HOV lane (only a shift in traffic between HOV lane and two other general purpose lanes). The environmental benefits are negligible since the number of kilometres travelled is the same.
  - Additional maintenance cost for HOV lane for maintaining road surface painting and roadside signs is 10% of capital cost.

Costs and Benefits

Costs and benefit parameters are taken from TfNSW Appendix 4 of this document

Costs include:

- Capital costs involved in converting a general purpose lane to a HOV lane which may include materials such lane marking, signs, project costs.
- Additional maintenance/operating costs involved to operate a HOV lane.

Benefits include:

- Travel Time Savings – Since the travelling speed in the HOV lane is greater than in the general purpose lanes, the HOV lane provides travel time savings for a greater number of occupants in the vehicle. Travel time savings represents the majority of benefits.
- Vehicle Operating Cost Savings – A higher average speed is achieved by using the HOV lanes compared to travelling in the general purpose lane in the base case. As a result of higher speeds, the vehicle operating costs is lower when travelling in the HOV lane as predicted by the urban stop-start model.

Whilst HOV lanes generate benefits to those using them, they also provide a negative benefit to users travelling in the general purpose lanes due to increased traffic. These users suffer from an increased travel time as well as higher vehicle operating costs since the average speed in the general purpose lanes is lower compared to the base case. In addition, these users are also likely to suffer from increased congestion costs due to increased traffic volumes. However, greater benefits are accrued to those travelling in the HOV lane as there are more occupants per vehicle compared to those travelling in the general purpose lanes.

The main results of the CBA which include NPV and BCR are presented using a discount rate of 7%. An overview of the costs, benefits and impacts of the base case and option is presented in the summary worksheet.

Download the **Excel Tool Here** or contact the Evaluation and Economic Advisory team in Finance and Investment Division for a copy of the model.

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HOV Cost-Benefit Analysis Tool

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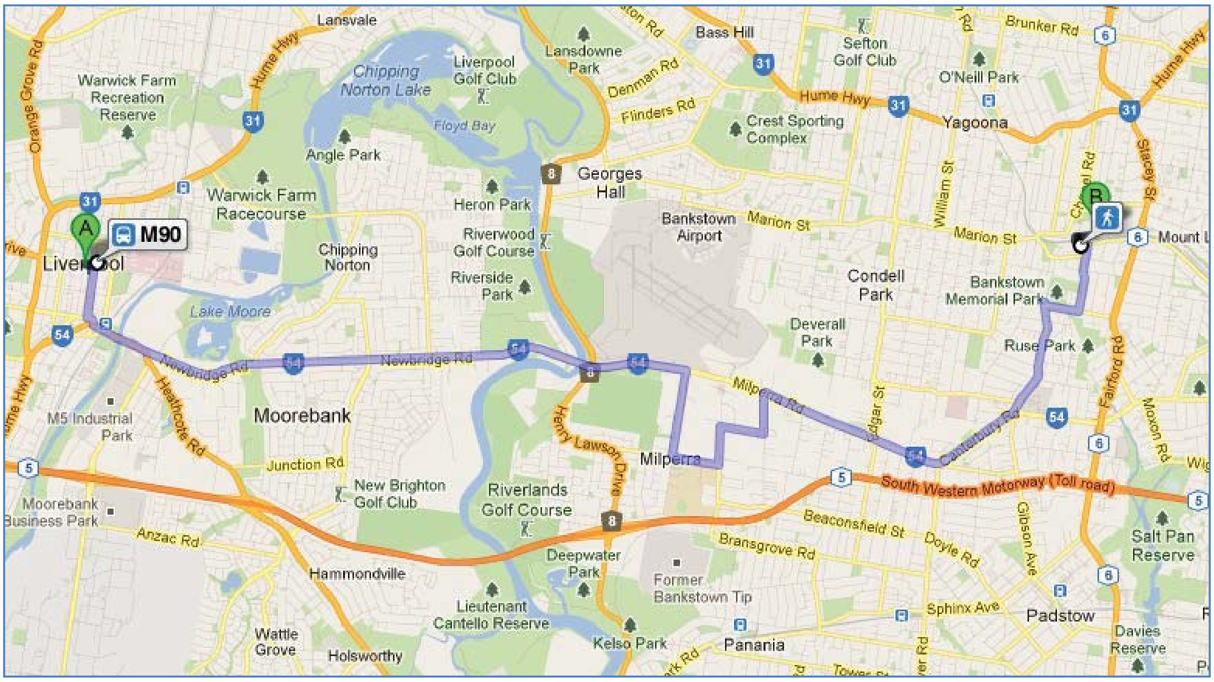
8.3.7 Strategic Bus Priority Measures

The 2004 Review of Bus Services in New South Wales (the "Unsworth Report") identified a network of fast, frequent, direct and convenient bus services. Liverpool to Bankstown bus corridor, shown in Figure 8.1 below, was one of 43 strategic bus corridors identified in the review. Bus priority measures were planned in these strategic corridors. Bus priority uses both electronic technologies and physical infrastructure measures to improve bus reliability and increase travel speed.

This case study outlines the economic evaluation undertaken in 2004 for bus priority measures in Liverpool to Bankstown bus corridor. The purpose of the case study is to demonstrate the methodology of economic appraisal of PTIPS rather than to precisely evaluate benefits and costs of this project.

Figure 8.1 Liverpool to Bankstown bus route



Define the base case and project options

Base case was defined as maintaining status quo for Liverpool to Bankstown bus route. In the base case, buses in the corridor are delayed with the average speed of 21 km/h.

Two project options were identified.

Option 1: This option includes the implementation of the Public Transport Information and Priority System (PTIPS) which uses Global Positioning System (GPS) to track late-running buses and alters traffic signals to give priority to these buses. Physical infrastructures are also built which attract capital costs and cause additional delays for cars and trucks using general traffic lanes. However, at this stage, bus priority signals and GPS are not coordinated which means that benefits of electronic technology and physical infrastructure measures were constrained. Option 1 was referred as "**PTIPS**" in this case study.

Option 2: Implement both electronic technology measures and physical infrastructure measures, including dedicated bus lanes on the approaches to congested intersections (see Figure 7.1), bus bypass lanes (e.g., left turn only, buses excepted), priority traffic signals, bus only links, additional bus lanes, transit lanes and clearways. The SCATS based traffic signal system and GPS are coordinated to track bus movement and give delayed buses priority to improve reliability. This option is referred as “**PTIPS + Infra**” in this case study.

bus

Figure 7.2 Bus lane

Base year and evaluation period

The economic evaluation was undertaken in 2004. The base year of the evaluation was 2004. The evaluation period was 15 years considering the economic life of electronic technology measures were around 15 years. It is likely that the economic life of physical infrastructure measures is longer, in which residual value of physical infrastructure can be considered at the end of evaluation period. Economic parameters used in this case study are in 2011/12 dollars. Thus, results reported in this case study are in 2011/12 values.

Costs

The capital, operational and maintenance costs in the case study are listed in Table 8.3(f).

Table 8.3(f) Capital, operational and maintenance costs

Items	**Options that the cost was applicable**	**Costs**	**Notes**
Capital costs			
PTIPS	Options 1 & 2	$115,500	GPS device cost for 33 buses used in the corridor. Average $3,500 per bus
Physical Infrastructure	Options 1 & 2	$8,188,680	Strategic estimates for physical infrastructure measures by Robert MacDonald & Association
Operational and maintenance costs			
Incremental maintenance cost for red lanes	Option 2 only	$165,000	Every 7 years
Pavement	Option 2 only	$85,000	Every 10 years
Signals	Option 2 only	$20,000	Per annum
Operations	Options 1 & 2	$24,850	Per annum

Benefits

1. Value of travel time savings

Outputs of transport modelling for this project were used for estimating the value of travel time savings. The transport modelling generated travel time and average speeds in AM and PM peak hours for buses and other vehicles (cars and trucks) of the base case, PTIPS and PTIPS + Infra options, in 2004 and 2011, as shown in Table 8.3(g).

Table 8.3(g) Travel time and average speeds

	2004			2011		
	Base Case	PTIPS	PTIPS+Infra	Base Case	PTIPS	PTIPS+Infra
Cars and trucks						
Travel time (veh Hr)	3,542,464	3,652,185	3,677,900	4,763,488	4,850,065	4,830,613
Average speed AM peak (km/h)	36.32	37.10	34.37	26.87	26.34	28.29
Average speed PM peak (km/h)	35.06	35.66	36.81	24.74	22.65	23.14
Buses						
Travel time (veh hr)	23,279	22,986	22,552	24,977	24,956	23,741
Average speed AM peak (km/h)	21.12	21.58	21.59	19.01	19.23	20.81
Average speed PM peak (km/h)	19.01	19.26	20.81	17.00	16.17	18.00

Results indicated that, travel time for cars and trucks would increase in project options PTIPS and PTIPS + Infra, and travel speeds decreased accordingly. This is because PTIPS infrastructure measures involved the conversion of one general purpose lane to red bus lane in some locations, which pushed cars and trucks to other general traffic lanes. This would cause additional travel time costs to cars and trucks.

Offsetting these additional costs to cars and trucks is the reduced travel time and increased speeds for buses. Due to increases in bus speed, there are induced bus users under the PTIPS + Infra option which also contributes to additional travel time savings. As transport modelling only generates results for 2004 and 2011, benefits are calculated for 2004 and estimated growth rates are used for interpolating benefits of other years. Economic parameters used to estimate the values of travel time savings in project options PTIPS and PTIPS + Infra are (refer to Appendix 4 for details):

Value of travel time for bus passengers = $13.76 per hour
Value of travel time for cars and trucks = $27.04 per vehicle hour
Bus capacity = 40 passengers
Bus occupancy rate = 90%, i.e., on average, bus occupancy is 36 passengers

2. Vehicle operating cost (VOC) savings

Transport modelling for the project also generated the vehicle kilometres travelled by buses and other vehicles in the base case and project options for 2004 and 2011 as shown in Table 8.3(h).

Table 8.3(h) Vehicle kilometres travelled

	2004			**2011**		
	Base Case	PTIPS	PTIPS+Infra	Base Case	PTIPS	PTIPS+Infra
Cars and truck (vkt)	128,812,572	128,772,576	128,648,649	146,449,596	146,317,791	145,709,064
Buses (vkt)	477,770	476,880	478,485	462,972	459,063	474,280

The vehicle kilometres of cars and trucks were reduced in project options PTIPS and PTIPS + Infra, as some car trips were diverted to buses with the improved bus services. Bus kilometres were expected to reduce as bus bypass lanes can cut vehicle kilometres even if the frequency of the services remained the same. Estimated bus operating cost savings included reduction in annual service hours adjusted for timetabling factor reducing the number of buses required, reduction in labour costs, other fixed bus costs (such as depot, insurance, registration) and bus capital costs. The majority of VOC savings was attributed to reduced vehicle kilometres for cars and trucks and were estimated by applying relevant economic parameter (vehicle operating costs for cars and trucks = $0.348 per vkt).

3. Safety benefits

The vehicle kilometres in Table 8.3(h) were used to estimate the safety benefits. There were two considerations in evaluating the safety benefits. Firstly, as the vehicle kilometres were reduced, the number of crashes was expected to decrease, assuming the crash rate per mvkt was constant. Secondly, when buses were separated from other traffic due to bus priority lanes and bus bypass lanes, the bus crashes were expected to decrease. The second benefit was acknowledged but not estimated in this case study due to data limitation in identifying the reduced crash rate of bus priorities. The safety benefits of reduced vehicle kilometres are based on the following parameters:

- Average crash rate for cars, truck and buses = 0.885 per million vkt
- Average cost of bus crashes = $94,300 per crash involving a bus
- Average cost of bus crashes = $58,400 per crash involving a car

4. Environmental benefits

In estimating the environmental benefits of reduced vehicle kilometres of cars, buses and trucks, the emission rates per vkt and associated unit costs as shown in Table 8.3(i) were used.

Table 8.3(i) Emission rate and unit cost of emission

Emission items	Emission rate: cars (g/vkt)	Emission rate: buses and trucks (g/vkt)	Unit costs in 2011/12 dollars ($/tonne)
Carbon dioxide (CO_2)	158.4	308.55	$54.73
Carbon monoxide (CO)	20.96	19.25	$3.45
Oxides of nitrogen (NO_x)	1.35	2.36	$2,182.00
Particulate matter (PM_{10})	0.03	0.03	$347,275.30
Total hydrocarbons (THC)	1.21	1.15	$1,093.30

Source: The unit costs were sourced from Austroads Guide to Project Evaluation, Part 4, Project Evaluation Data.

Economic evaluation results and conclusions

Table 8.3(j) presents the economic evaluation results for project options PTIPS and PTIPS + Infra. It shows that option PTIPS generates negative NPVs and BCRs. Both electronic technology measures and physical infrastructure measures have been built for this option, which incur the same amount of capital cost with the PTIPS + Infra option. The benefits are constrained as bus priority signals are not coordinated with GPS.

The option PTIPS + Infra is able to generate positive NPVs and BCRs more than 1 at the discount rates of 4%[6], 7% and 10%. This option can realise the full benefits of bus priority measures as all required technologies and infrastructures are in place and traffic signal system and GPS are integrated and coordinated.

[6] NSW Treasury changed the range of discount rates in 2017 from 4, 7 and 10% to 3, 7 and 10%.

Table 8.3(j) Economic evaluation results

Discount rate	PTIPS		PTIPS + Infra	
	NPV ($ million)	BCR	NPV ($ million)	BCR
4%	-34.9	-3.1	$23.4	3.6
7%	-30.3	-2.5	$13.2	2.5
10%	-26.9	-2.2	$6.3	1.7

The option PTIPS + Infra is recommended based on the economic evaluation. It is worth noting that this evaluation result is conservative. The target bus speed of bus priority measures is 25 km/h. However, transport modelling of this project indicates that the bus speed only slightly increases from 21.12 km/h in the base case to 21.59 km/h in option PTIPS + Infra, representing a 2.2% increase. In addition, fare revenue of induced bus trips was not included as a benefit. Residual value of physical infrastructure measures after the evaluation period is considered small and excluded in this case study.

Download the **Excel Tool Here** or contact the Evaluation and Economic Advisory team in Finance and Investment Division for a copy of the model.

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Bus Corridor CBA Model

- Read Instructions
- Summary - PTIPS
- Summary - PTIPS + INFRA
- Travel Time Calculations
- Vehicle Operating Cost Savings
- Safety Benefits
- Environmental Benefits
- Sensitivity Testing

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8.3.8 Economic Appraisal of Clearways Proposals

Clearways restrict stopping or parking on the kerb side lane, providing greater road capacity and improving traffic flow on congested corridors. There are currently 780 km of clearways implemented on over 2,800 km of state roads on Sydney's road network[7]. Clearway operation is typically during the morning and afternoon peak periods in weekdays with a push to extend to inter-peak on weekdays and weekends on congested routes. While overall traffic volume has increased very few clearways have been added or expanded. The Sydney Clearways Strategy The Sydney Clearways Strategy announced on 1st December 2013 to address the need to improve travel time and road congestion on the Sydney road network identifies a number of high priority locations in the most constrained strategic corridors in the NSW. Any proposed Clearway (new or extension) should align with these routes. The identified State roads proposed as clearways should meet the following criteria[8]:

- Roads with high traffic flow: traffic flow exceeds 800 vehicles/hr/lane;
- Low speeds experienced: less than 30km/hr during peak periods;
- The road is a strategic bus and/or freight transport corridor; and
- Alternative public parking close to local businesses can be identified.

Strategic Merit Test

In the preliminary stage, the Clearway proposal should be subject to a Strategic Merit Test. The strategic merit test is a qualitative assessment of whether a specific project proposal aligns with transport objectives, policies and strategic plans and other important factors so that proposals can be ranked. This is a *decision-support system* that has the following aims:

- To present all relevant information, both quantitative and qualitative that will aid in the ***decision making process.***
- To provide a ***first pass assessment*** of clearway projects to come up with a list of possible projects that will go through the second stage assessment that includes full economic appraisal.
- To allow easy ***comparison*** of clearway proposals for the purpose of prioritisation, based on broad strategic decision criteria. These criteria are grouped into the following categories:

The following are the criteria considered to be relevant for the Clearways Program.

1 STRATEGIC: Proposed clearway is part of a constrained strategic corridor, a strategic bus and/or freight transport corridor. The relative importance is also captured to reflect the priority of a route in meeting people and goods movement. The proposed clearway supports integration in terms of being clearing for intersection, multi access facility, and major multi access facility.
2 ELIGIBILITY: Proposed clearway is in road with high traffic flow (exceeds 800 vehicles/hr/lane) and is experiencing low speeds (<30km/hr during peak) based on the ccurrent and projected traffic.
3 CONNECTIVITY: Connects to people and communities, i.e. demand generators and the presence of alternative public parking close to local businesses.
4 SUSTAINABLE TRANSPORT: Transport can support the projected traffic growth in the link and surrounding routes / network.

[7] Sydney Clearways Strategy December 2013
[8] Sydney Clearways Strategy December 2013

5 CONFLICTING ROAD MANAGEMENT INITIATIVE: Are there current and other planned works along the route that would lead to meeting the same objectives and outcomes as a clearway restriction?
6 ENVIRONMENT: The proposed clearway contributes to reduction in local traffic congestion, noise abatement, improvement in landscape, townscape, etc.
7 SAFETY CONSIDERATION: The proposed clearway is located in a blackspot area or in the vicinity of a blackspot area that may be reduced by clearway restrictions such as a history of rear end and side swipe crashes. Does the route experience a high level of unplanned incidence? Also include consideration of number and severity of incidents.
8 RESOURCE OPTIONS: Whether there are funding sources available, i.e. transport internal budget, sharing with local resources, Federal grants.
9 READYNESS / DELIVERIBILITY: Technical consideration of ease of implementation. Whether the project can be completed in 12 months, within 2 years, +3 years.
10 COSTS: Whether this is required and how it is to be included, i.e. whether to give high score to smaller projects.

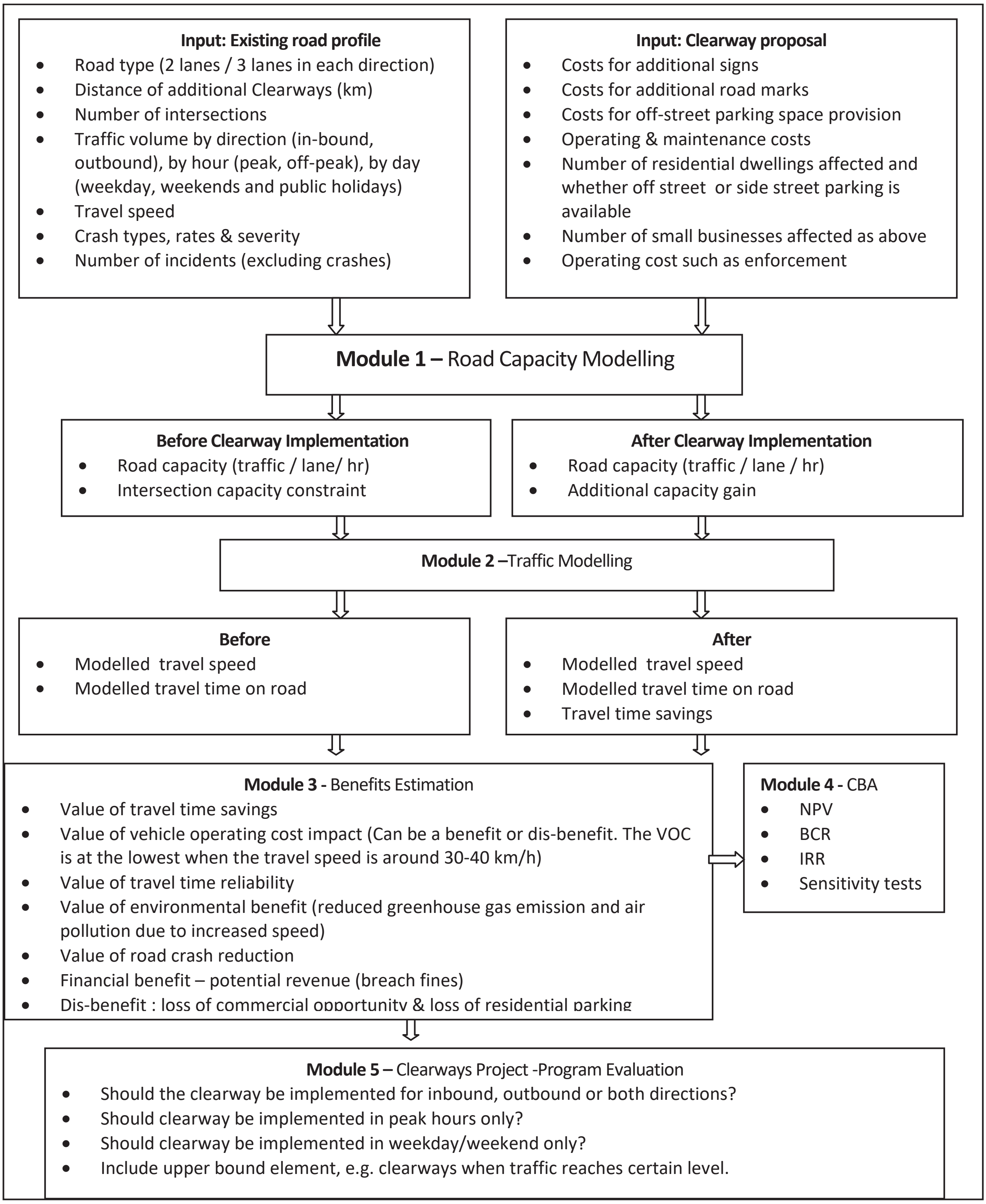
The economic appraisal of Clearways encompasses:

- Development of detailed methodology for benefit estimation considering traffic volume distribution by time of day and direction and other road characteristics such as road capacity and speed flow relationships.
- Analysis on intersections and links for economic evaluation of clearway proposals which could be useful for prioritisation of individual projects as well as capability to combine individual links and aggregate them to provide a program level BCR.
- Development of a cost benefit analysis (CBA) model utilising localised traffic data to provide key economic evaluation results such as BCR and NPV. The CBA model for clearways estimates the economic benefits such as travel time savings based on speed flow relationships, vehicle operating cost savings, environment savings as well as other benefits such as accident cost savings. The model relies on estimating speed flow relationships from key data such as traffic volume.
- The speed-flow model can accommodate different scenarios:
    - Changing the clearway periods, e.g., peak hours only to 12 hour or 24 hours clearway
    - Changing clearway direction, e.g., Eastbound to Westbound or in both Eastbound and Westbound
    - Changing clearways from weekdays only to full week including weekends
    - An alternative modelling approach is using SIDRA which has the capacity to model the traffic changes in the intersections as well as the road links. Guidance on which traffic model to adopt can be found in the table below.

The key inputs to the Clearway CBA model include:

- Average hourly traffic volume separated by light vehicle, heavy vehicle and buses for both weekday and weekend.
- Current clearway operation on weekday and weekend (i.e. current parked cars or existing clearway operation and operating time)
- Proposed clearway operation (i.e. clearway operation on weekends, extension of clearway times)
- Distance of additional Clearways
- Road capacity
- Number of lanes
- Capital and operating costs
- Number of annual crashes

Figure 8.3: Framework for economic appraisal - Clearway Program



Steps

1. Obtain traffic volume data for each hour from traffic survey counts for weekdays and weekends for both directions of traffic flow separated by light vehicle, heavy vehicle and buses
2. Using the traffic volume for each hour, calculate the volume capacity ratio

3. Estimate the travel time and speed (being the inverse of each other) for each hour using the Austroads speed flow relationship (a function of free flow speed, delay parameters such as ramps and traffic signals and volume capacity ratio). Speed-flow model can effectively capture the benefits of improved traffic flow reflected in the increased travel speed in road links (between intersections). The model is limited to links only and did not include traffic changes at intersections.

4. Estimate travel time cost, vehicle operating cost and environmental cost for both the Base Case and Option.

5. The difference between the Base Case and Option is the benefit (i.e. road cost saving) as a result of the Clearway proposal.

Travel time costs
Travel time cost is estimated by multiplying the travel time (function of distance of additional Clearways and average speed) with the value of travel time and the traffic volume separated out for cars, trucks (rigid and articulated) and buses. The value of travel time for cars includes the travel time cost for private and business car trips (87% private car trips and 13% business trips)[9].

Similarly, bus travel time cost includes passenger private trips (97.6%) and business trips (2.4%) as well as bus driver value of travel time. The average number of passengers per bus was taken into account in the calculation of travel time benefits for each bus passenger. The annual bus patronage, the bus routes identified in the road section and the number of bus trips on the Clearway route were used to calculate the average bus occupancy.

The total travel time cost is then aggregated for each hour and for both directions.

As speeds improve as a result of Clearways, there may be a small increase in diverted trips to car or induced trips. However, it is not expected that diverted or induced trips will be large because the Clearway proposal impacts a relatively small section of road. Thus this impact on traffic cost is likely to be miniscule thus not considered in the modelling.

Vehicle Operating costs
The Urban Stop-Start Model was used to estimate the vehicle operating cost for arterial roads. The vehicle operating cost values used in the Urban Stop-Start Model were weighted using the traffic composition of cars, trucks and buses. Under urban conditions, vehicle operating costs generally decrease when speed increases until a certain speed threshold is reached, then vehicle operating costs start to increase again.[10]

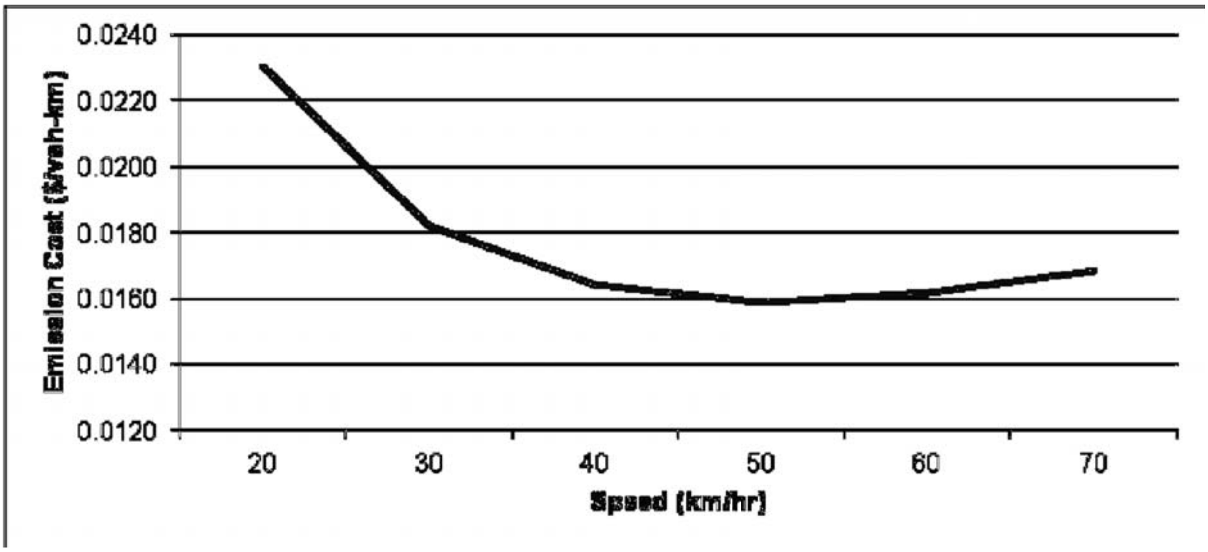
Environmental costs
The environmental cost is estimated by using the relationship between speed, fuel consumption and greenhouse emissions. Environmental emissions such as greenhouse gases and air pollution generated from fuel burned are expressed as a carbon dioxide equivalent (CO_2-e). Fuel consumption of vehicles by speed was estimated and multiplied by the CO_2-e conversion factor[11]

[9] Data provided by Bureau of Transport Statistics, 2010/11 Household Travel Survey, trips by mode and purpose
[10] TfNSW (2013) Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Appendix 4
[11] 2.3kg of CO_2-e produced from 1L of fuel burned

and the carbon price ($57.30/tonne)[12] to obtain the emission cost by speed. Figure 8.4 shows the estimated relationship between speed and environmental costs.

The difference between the total travel costs (travel time cost, vehicle operating cost, environment cost and accident cost) between the Base Case and the Project Option (i.e. incremental) is the effect of the Clearway proposal. Total travel costs were then annualised using an appropriate cost expansion factor and traffic growth of 1.2% is applied each year.

Figure 8.4 Environmental emission cost by speed



Parking utilisation and traffic flow impact
In some road locations, parking is not frequently utilised during non-clearway periods which may be due to the use of service lanes, a non-shopping strip location or high volume of traffic on road deterring parking. Effectively, vehicles are still able to use the kerbside lane frequently outside Clearway hours, as opposed to no vehicles travelling in the kerbside lane as modelled (due to parked cars outside Clearway hours). As a result, the full benefit from modelling is adjusted as a percentage of vehicles are still able to travel in the kerbside lane in the Base Case and a factor (i.e. traffic impact factor) is applied to the benefits to reflect this.

The traffic impact factor has been used for assessing the impacts of parked vehicles in the kerb lane and associated vehicle manoeuvres for parking (including reverse parking) and leaving (including merging to traffic flow). The traffic impact factor is calculated based on the following information:

1. Calculation of Parking Utilisation (%) from data collected by parking studies conducted for the Clearway road proposal. Typically parking impact will differ depending on section of the road i.e. retail/shopping strip or non-retail/residential area as well as day of week. Thus it is important to calculate parking utilisation for different sections of road and for weekday and weekends. Parking utilisation in this model is calculated as the percentage of cars parked at any time, as opposed to the percentage of car spaces occupied, since the effect parked cars have on traffic is not evenly distributed (i.e. drivers will still need to change lanes regardless of whether there is 1 or 5 cars parked.
2. The average from the parking utilisation rate calculated above (from parking survey/study) and when there is a car parked at any time of the day (i.e. 100%) is

[12] TfNSW (2013) Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Appendix 4, Table 54, indexed to 2013/14 dollars.

calculated. This is because the parking study is based on a few observations days and may not be reflective of the whole year.

3. These results were then weighted by retail/non-retail road distance as well as number of weekday/weekend, to arrive at the overall traffic impact factor which is applied to the total annual benefits.

Table 8.3(k) Traffic modelling evaluation tools and methodologies

	TYPE OF PARKING OBSERVED ALONG ROUTE:		
	Isolated parked vehicle(s)	Parked vehicle(s) near traffic signals	Linked based model but no capacity for handling intersection analysis, can model isolated parked vehicles and vehicles parked along the entire length
Evaluation tool	Microsimulation programs such as: • VISSIM • Paramics • AIMSUN	• SIDRA (using Network mode where there are more than one set of nearby signals) • TRANSYT • Linsig	Simple speed/flow calculation based on volume/capacity calculations
Required input data	• Hourly traffic volumes in the direction of the proposed Clearway (broken into *light* and *heavy* as a minimum) • Bus volumes and occupancies - useful in determining the appropriate weighted average value of travel time. • Parking utilisation information (if available) to permit modelling of deceleration effects	• Hourly turning movements at the traffic signals, broken into *light* and *heavy* as a minimum • Bus volumes and occupancies are also useful in determining the appropriate weighted average value of travel time • Signal phasing information • Queue length information (useful for model validation) • Travel time information (useful for model validation)	• Hourly traffic volumes in the direction of the proposed Clearway (broken into *light* and *heavy* as a minimum) • Bus volumes and occupancies - useful in determining the appropriate weighted average value of travel time.
Relevant outputs	Estimates of: • vehicle-hours travelled • number of vehicle stops • fuel consumption • use of the Surrogate Safety Assessment Model (SSAM) add-on can use vehicle trajectory information from microsimulation programs to estimate number of lane changes and conflicting movements (an indicator of crash potential)	Estimates of: • vehicle-hours travelled • number of vehicle stops • fuel consumption • emissions	Estimates of: • changes in vehicle speeds with and without Clearway • change of vehicle travel time in road section • changes in VOC
Likely cost	• Expensive to set up and calibrate • Best results when good speed distribution data is available for the traffic stream at that location • Can also model the effect of parking manoeuvres (e.g. deceleration before parking) if parking utilisation data is available • May be possible to develop a generic travel time & VOC model based on typical urban vehicle compositions	Fairly low. SIDRA is very user-friendly.	Minimal – desktop calculation.

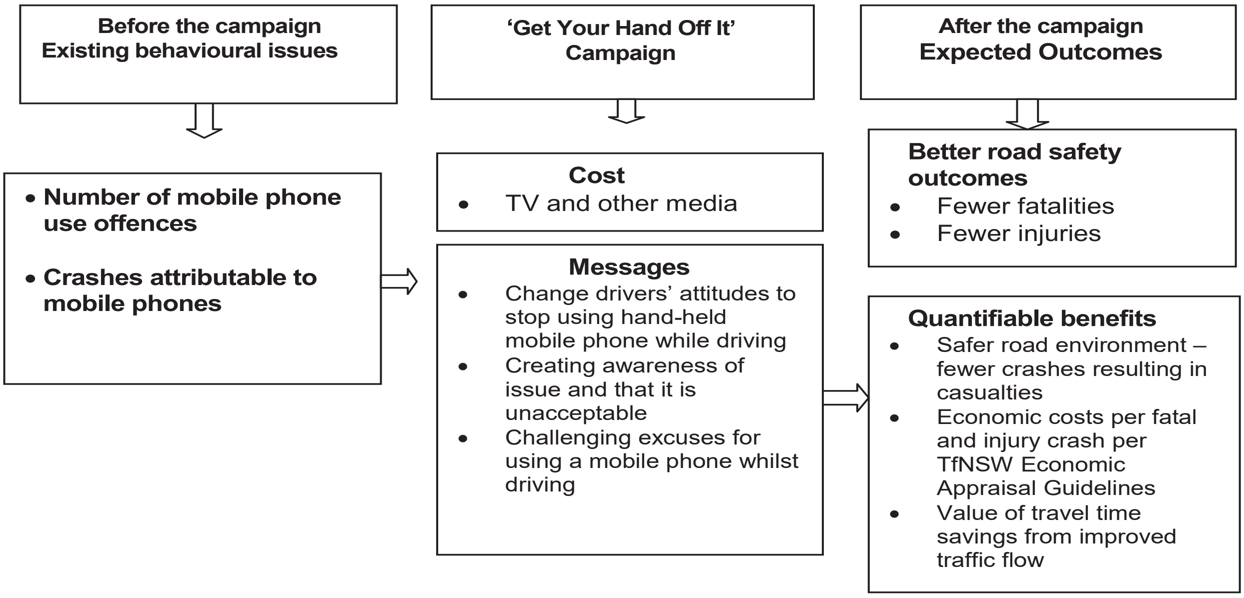
8.3.9 Economic Evaluation of Road Safety Campaigns

The following are the steps suggested in conducting economic appraisal of road safety campaigns.

Step 1- Develop a framework for the CBA.

This framework encompasses identifying the existing issue or problem, what the campaign is about and what outcomes are likely to result from the advertising campaign. The cost-benefit analysis framework for a typical road safety campaign is conceptually presented in the figure below. It illustrates the example of a recent mobile phone campaign called "Get Your Hand off It" from before the beginning of the campaign to the impacts of the campaign and the expected outcomes after the campaign.

Figure 8.5: Conceptual framework of Cost Benefit Analysis for 'Get Your Hand Off It' campaign



Step 2- Collect data

Data on crashes and other data relevant to the campaign (e.g. offences) either from previous phases of campaign if any or historical data from the Centre for Road Safety are to be collected. Crash data should be at least over the last 5 years to understand any fluctuations in yearly data. Outcomes of similar campaigns elsewhere may also be useful. Also, collect data about the campaign in terms of background information, campaign budget (both media and production costs), the time frame for implementing the advertising campaign and any breaks during the campaign.

Data on crashes is available from the CrashLink database or a request has to be made to the Centre for Road Safety. For example, Table 8.3(I) shows the crashes attributable to mobile phone use over the last 5 years by injury severity. This data can be used to develop the Base Case forecast without the campaign.

Table 8.3(l) Crash History

Crashes attributable to mobile phone use			
	Fatal	Injury	PDO
2008	0	9	18
2009	0	10	21
2010	3	31	22
2011	0	25	25
2012	1	21	30
Average	0.80	19.20	23.20

Data about the campaign should also be collected in terms of the campaign time frame, media spending each month and any breaks during the campaign. Table 8.3(m) summarises the campaign budget for a typical advertising campaign over two years. Media cost is relevant for estimating the crash reduction benefits as shown later in Step 5. It comprises advertising across channels such as television, outdoor, radio and online/digital.

Table 8.3(m) Costs of Advertising Campaign ($m)

	2013/14	**2014/15**	**Total**
Production & research	0.41	0.91	1.32
Media cost		2.05	2.05
Total	0.41	2.96	3.37

Step 3 - Identify the Base Case; the Base Year, Evaluation Period and the Option Case.

Base Case – Do Nothing

The Base Case is usually defined as the case without the advertising campaign. The number of crashes without the campaign is forecast based on the crash trend of the past 5-10 years for specific crash types. The number of crashes for the next three years is predicted from trend analysis (rather than the current number or an average level of crashes). The trend, in its essence, is the forecast of business as usually which captures the effects of normal engineering measures, average level of police enforcements and past road safety campaigns (if any).

Figures 8.6 and 8.7 below show typical underlying trends for injuries and property Damage Only (PDO) crashes. Similar trends may also be developed for fatalities or fatal crashes.

Figure 8.6: Base case trend chart for injury crashes

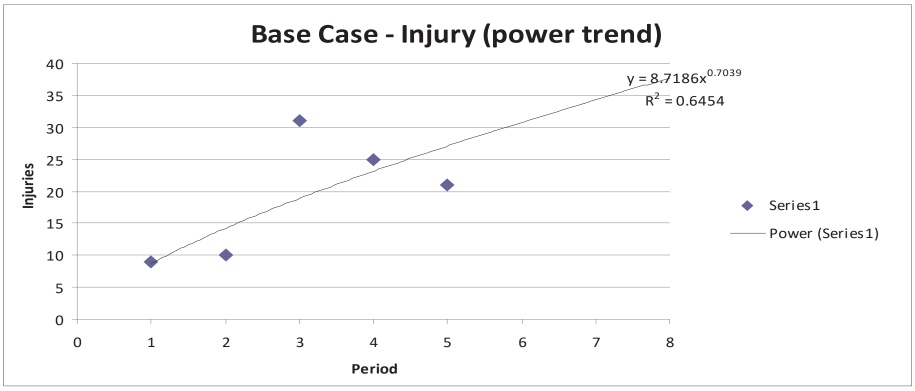


Figure 8.7: Base case trend chart for PDO crashes

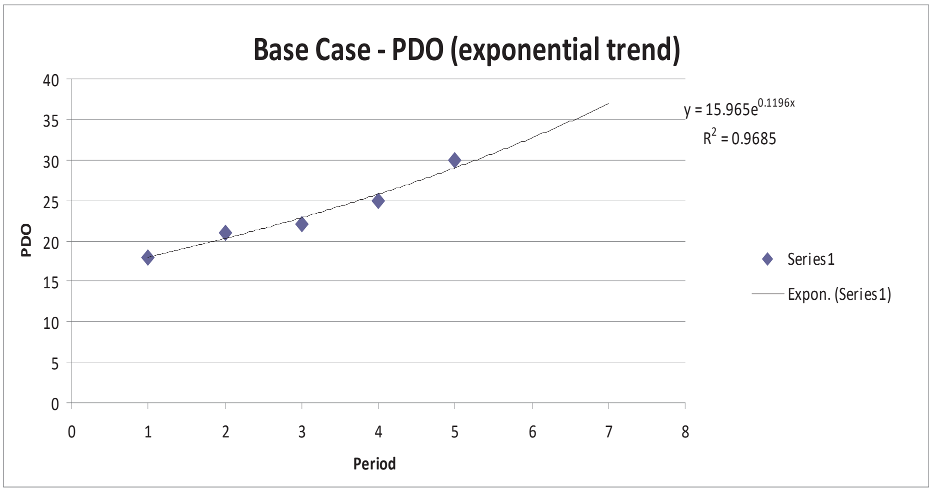


Table 8.3(n) shows the Base Case under a 'Do Nothing' scenario which reflects the forecasts in the trend for Fatal, Injury and PDO crashes when nothing is done. There is a general upward trend in injury and PDO crashes. The definition of the Base case ensures that the net effect of the 2014/15 campaign is captured in this economic appraisal.

Table 8.3(n): Base Case Crashes due to illegal mobile phone use

Base case projection - do nothing			
	Fatal Crash	Injury Crash	PDO
2013/14	0.8	30.8	327
2014/15	0.8	34.3	369
2015/16	0.8	37.7	416

Source: NSW Crash data, Centre for Road Safety. A significant increase in injury crashes was observed in 2010 (from 10 in 2009 to 31 in 2010). This could be a statistical outlier however this data has been used for forecasting the future trend.

Option Case – With Advertising Campaign in 2014/15
The Option case is defined as the addition of the advertising campaign in 2014/15, which is expected to reduce adverse behaviour or offences resulting in reduced road crashes. As a result, the incremental effect (difference between Option and Base Case) will be the pure effect

of the campaign. The target audience of the advertising campaign has to be identified as well. It may be all road users or users in a certain category (e.g. Drivers under 25).

Base year

The Base year for the CBA is usually the current year i.e., 2014/15 financial year. All costs and benefits need to be discounted to the base year for estimating the Net Present Value (NPV) and the Benefit Cost Ratio (BCR).

Evaluation period

The evaluation period is the number of years the campaign is likely to have an impact on the target audience. It may be as little as one year or up to 3 years. Empirical research13 indicates that the effects of advertising campaign decay rather quickly and there would be only miniscule effects left after 3 years.

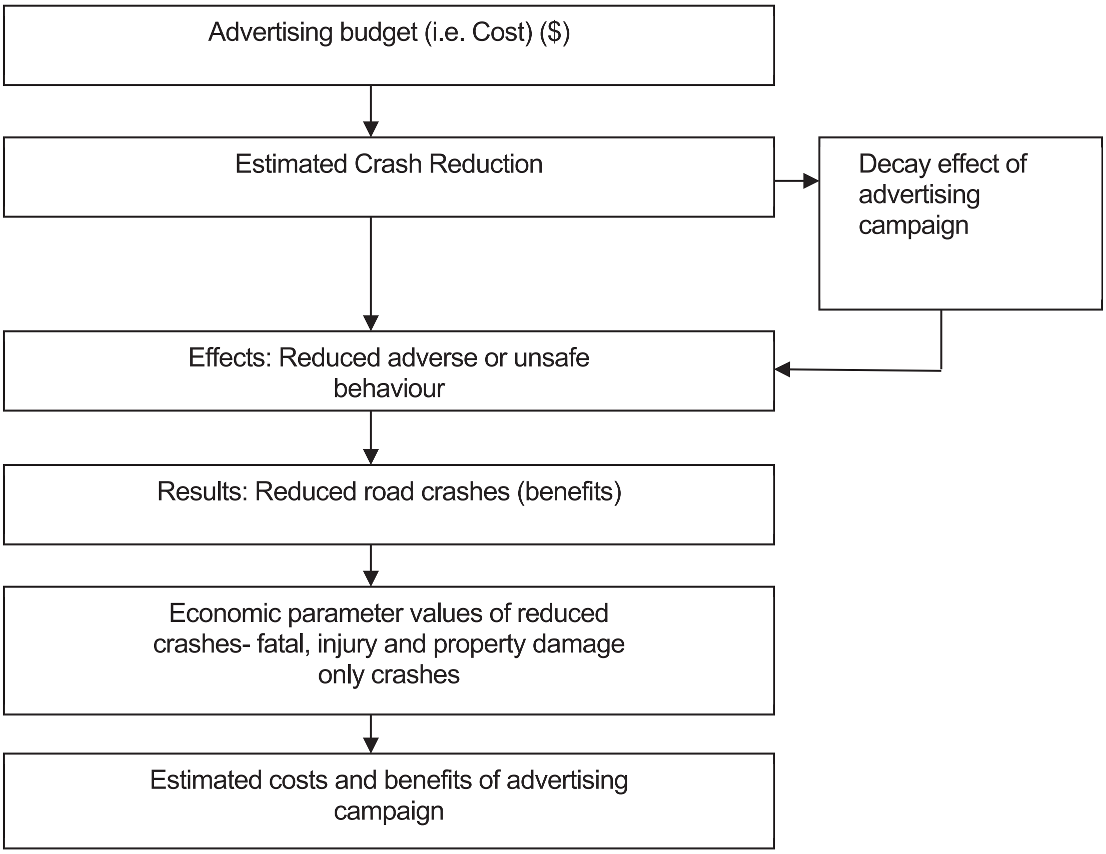
Step 4 – Estimate crash reduction attributable to the campaign. This is not straight forward because other factors may also play a part in the reduction of crashes or outcomes other than the campaign. This step illustrates four possible methods that may be used to estimate the likely crash reduction.

In road safety analysis, it is generally assumed that road crash reductions are attributable to three broad factors: engineering, enforcement and education (i.e. campaigns). In forecasting the number of road crashes in the future, it is conservative to assume that the number of crashes will be maintained at the same level as now in an absolutely ‘do nothing’ scenario, that is, no additional engineering measures, no additional enforcement and no new campaign. In fact, it is reasonable to assume that road crashes might go up with the population growth and associated travel increase. To reduce the number of crashes from the current level, the Government has to do more by enhancing engineering measures, increasing police enforcement, using media campaigns or adopting a strategy by combining the above road safety measures.

A flow chart outlining how media campaigns may affect crash reduction is shown in Figure 8.8. Usually, the benefits are linked to the advertisement Budget and the level of exposure. As with all CBAs, this effect will fade out (or decay) over time for majority of road users but a certain level of long term behaviour change can be expected. The campaign is linked to better road safety outcomes based on empirical research evidence, leading to an estimate of reduced road fatalities and injuries. Using the approved economic parameters, the economic benefits can be estimated.

[13] (1) Braun and Moe (2012) On-line advertising response models: incorporating multiple creatives and impression histories. (2) Wakefield et al (2011) Effects of mass media campaign exposure intensity and durability on quit attempts in a population-based cohort study, Health Education Research

Figure 8.8: CBA of Advertising campaigns



In conducting an economic appraisal of proposed road safety campaigns, there are four broad methods for estimating the effectiveness of the campaign on road crash reduction.

Fully controlled before and after analysis
Road safety outcome is observed during a previous campaign period. A similar period is identified as the control period in that all other conditions are the same and the only difference is the campaign itself. The reduction of crashes is 100% attributable to the road safety campaign if there was no increased enforcement in the campaign period and other road safety measures are similar and remain broadly at the same level (e.g. no change in mobile speed camera enforcement and no new installation of fixed speed cameras in the observed period compared with the controlled period).

Partially controlled before and after analysis
In many cases, fully controlled before and after analysis is not possible because the observed campaign is mixed with other road safety measures which make it difficult to isolate the effect of the campaign itself. For example, there may be other types of campaigns being run concurrently with the road safety campaign of interest or a comparable period may not be easily identified when the campaign was not run. For the purpose of economic appraisals, the observed road crash reductions need to be apportioned to the three key factors (engineering treatments, enforcement activities, and education), resulting in the application of an attribution factor to estimate the proportionate impact of the campaign on the overall road crash reduction). Table 4 below provides an indicative breakdown for attributing proportionate reductions of each of the key factors to the main behavioural issues identified in NSW road crashes. The methodology

accounts for key differences between these behavioural issues (e.g. lack of legislation and enforcement for light vehicle driver fatigue).

Thus from Table 8.3(o), only 15% of crash reduction can be attributed to advertising for the Speeding and Drink Driving Campaigns and 40% in the Fatigue campaign. These are indicative attribution rates based on internal TfNSW experience and professional judgement.

Table 8.3(o): Contribution of Key Factors in Selected Road Safety Campaigns

	Speeding Campaign	**Drink driving Distraction**	**Fatigue Campaign**
Engineering	35%	10%	60%
Enforcement	50%	60%	0%
Education	15%	30%	40%
Total	100%	100%	100%

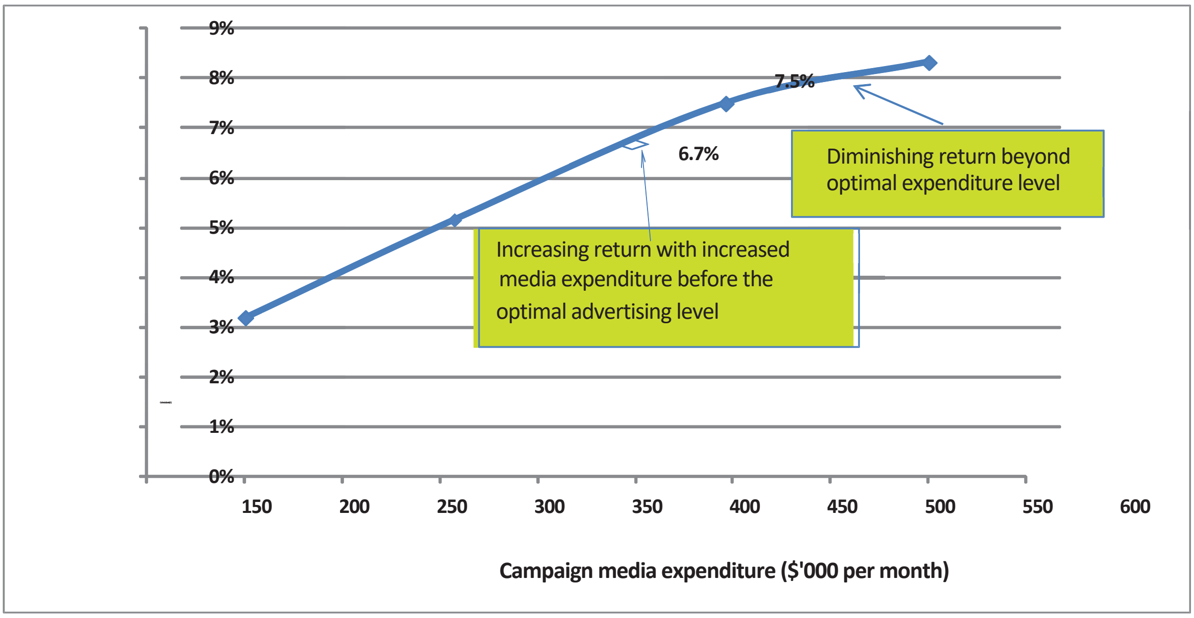
1. **Diminishing return model**: This approach is an application of the classic economic concept of diminishing returns, that as more expenditure in campaign is made, the overall impact or return on the expenditure increases at a declining rate, assuming that all other variables remain fixed. To continue to spend after a certain point (which varies from context to context) is to receive a decreasing return on that input. A diminishing return curve can be established and the expected outcome of the campaign can be estimated. For example, the motorcycle safety campaign utilised this method as no previous history of the benefits of such campaigns existed.

   The method is based on the Monash University Accident Research Centre (MUARC) review of several road safety campaigns developed by the Victorian Transport Accident Commission (TAC) between December 1989 and December 2001. These campaigns related to Random Breath Testing (RBT), speeding, fatigue, motorcycles and other road safety target groups. MUARC found that the road safety media campaigns on speeding reduced serious injury crashes by between 6.2% and 8.7% between 1990 and 1993.

   According to MUARC, there is a significant statistical relationship between advertising expenditure and crash outcome up to an optimal level of expenditure beyond which there are diminishing returns (see Figure 5). This optimal level of expenditure is estimated to be $457,000 per month (2014$) and would achieve an average crash reduction of 7.5%. Assuming a linear relationship between the Victorian expenditure and crash outcome, it was estimated that for the NSW motorcycle campaign the crash reduction rate would be about 6.7% per month pro rata based on an average monthly spend of about $410,000. The Victorian campaign spend was about $457,000 per month in 2014$ (see Figure 8.9).[14] This assumption is tested in the CBA analysis by increasing and reducing the crash rate as well as the retention rate.

[14] Monash University Accident Research Centre (MUARC), (1993) Evaluation of Transport Accident Commission road Safety Television Advertising, Victoria.

Figure 8.9: Advertising Expenditure and Crash Reduction Effect



Source: EPSP based on MUARC research

The full reduction in crashes of 6.7% applies to each month of campaign. However, the safety impacts will decay when there is a break in the campaign period. The issue of "decay" effects of advertising campaigns is discussed under Step 5 below.

2. **Total Audience Rating Points (TARP) model.**

This model is also based on media campaign expenditure and statistical relationship between the campaign expenditure and expected crash reduction established by Monash University, following the equation below.

$$\textit{Casualty Crashes with Advertising Campaign} = \textit{Existing Casualty Crashes} \times \textit{TARPs}^{-0.0077}$$

In the above equation, Existing Casualty Crashes can be obtained from published road safety statistics. The TARPs can be calculated if an advertising campaign budget is known. For example, an advertising campaign budget of $3million can purchase about 3,630 TARPs ($3million /$827[15]). The exponential power (-0.0077) is a factor (calculated from the regression model) presented in the Monash research study and is applied to account for the effects of advertising campaigns. This approach is adapted from Cameron & Newstead (1996)[16]. This model should be used only if there is no other reliable data available.

An appropriate method needs to be chosen for each campaign which is dependent on data availability and data quality. Ideally, a fully controlled before and after analysis should be selected, as it gives the most accurate measure of the campaign effect. However, a fully controlled period is usually difficult to identify thus a partially controlled approach is more often used. Controlled before and after analysis can also be used if a road safety campaign

[15] The average cost of a TARP is $827 (2013$) based on Cameron and Newstead (1996).
[16] Cameron and Newstead (1996), Mass Media Publicity Supporting Police Enforcement and its Economic Value, Paper presented to Public Health Association of Australia 28th Annual Conference Symposium on Mass Media Campaigns in Road Safety.

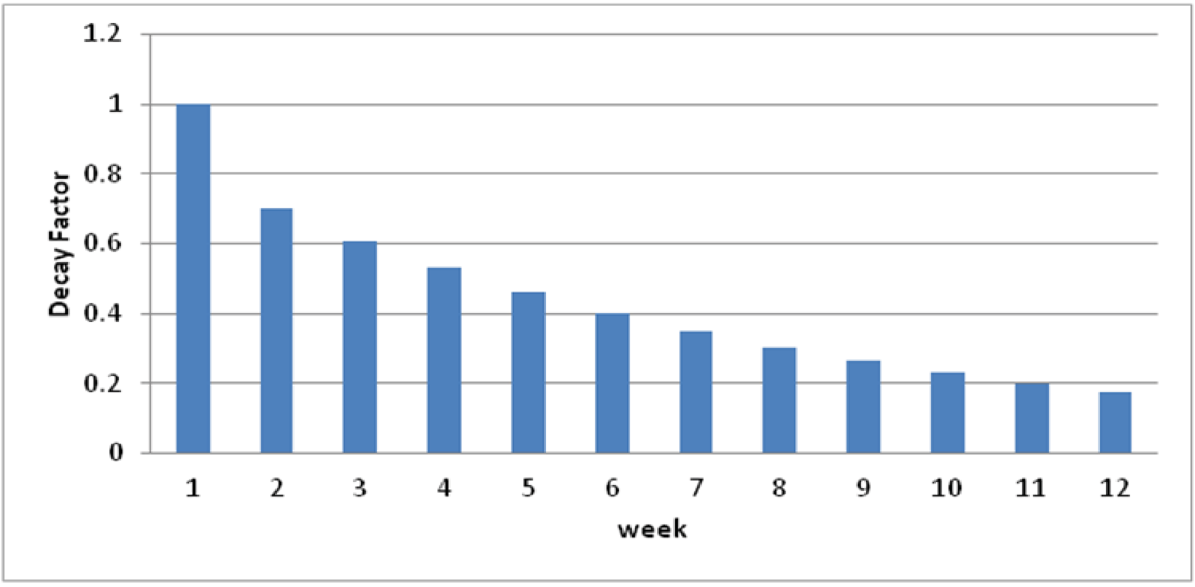
is deployed in specific regions, in that case, other non-campaign regions can be used as a control region.

Step 5 – Estimate safety benefits arising from the advertising campaign and other benefits such as travel time benefits

Once the crash reduction has been estimated for each year (or month) it has to be decayed in line with the expenditure profile of the campaign. The decay (or retention factor) is based on either available data from previous phases of the campaign or previous studies of such types of campaigns. A full crash reduction is expected during the months of the campaign with a decayed rate for the months when there is a break in the campaign or after the campaign ends.

Studies such as Cameron and Newstead (1993) of the Monash University Accident Research Centre (MUARC) noted that advertising effects decay exponentially with time, i.e. a constant retention factor (e.g. 87%/week) represents the proportion of the target audience retaining awareness of the message in the next period, and then the same proportion of them in the next period, and so on. Figure 8.10 illustrates the decay profile of advertising campaign based on MUARC research which found that the decay in the awareness of the road safety message from the advertising campaign follows a negative exponential function which corresponds with a constant retention factor of 87% per week (or 34% per month).17 The decay curve or retention rate may be varied depending on data availability. A lower retention factor implies a faster decay rate, and is a conservative approach in benefit estimation.

Figure 8.10: Illustration of Impact of Advertising Campaign over time

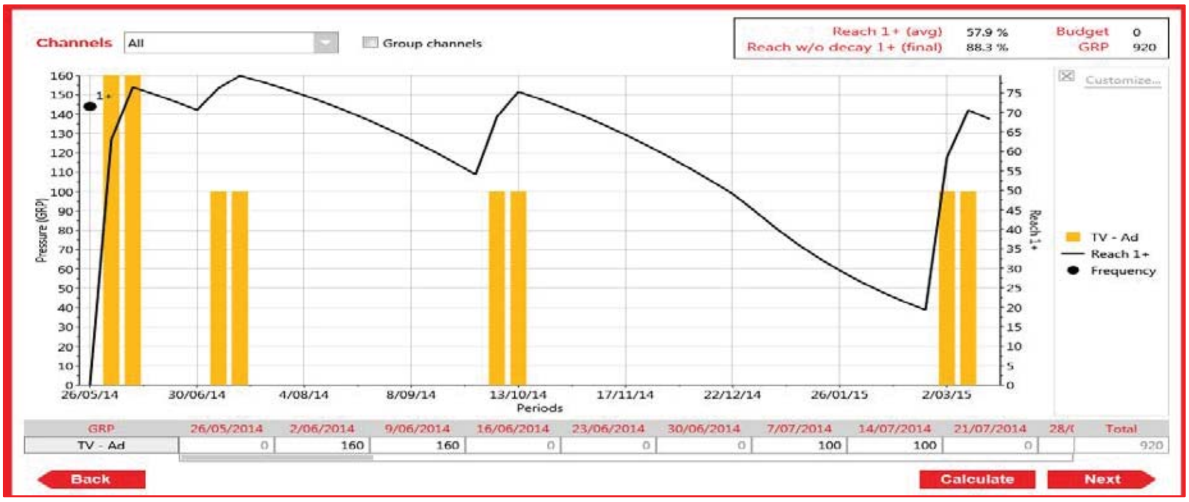


Source: Based on MUARC (1993).

For TfNSW advertising campaign analysis, however, it has been shown that a higher retention rate of 70% per month is acceptable based on tracking survey data (see Figure 8.11). The retention rate is shown as the "Reach" in the graph below. This is assumed to apply to all crashes targeted by the campaign not just casualty crashes as assumed in the MUARC study.

[17] Evaluation of Transport Accident Commission Road Safety Television Advertising, Cameron, M. et al, Monash University Accident Research Centre, September 1993. It is assumed that the decay stops once a long term effect of 5% is reached.

Figure 8.11: Retention Rates for TfNSW "Don't Rush" Safety Campaign



Sensitivity analysis needs to be undertaken on the assumed retention rates to ensure economic results are robust. A conservative retention rate of 34% per month should be considered as one of the sensitivity tests.

For the mobile phone use campaign example the crash reduction effects were estimated using a decay factor of 70% per month. When aggregated over 12 months the annual crash reduction figures can be summarised as shown in Table 8.3(p) below. Table 5 presents the fatalities, injuries and PDO crashes before the advertising campaign, after the advertising campaign, and the reductions attributable to the 2014/15 campaign.

Table 8.3(p): Fatalities, injuries and PDO crashes before and after advertising campaign and expected reductions

Year	Fatal	Injury	PDO crashes
Do nothing (1)			
2013/14	0.8	30.8	32.7
2014/15	0.8	34.3	36.9
2015/16	0.8	37.7	41.6
With advertising campaign (Option) (2)			
2013/14	0.8	30.8	32.7
2014/15	0.6	27.3	29.3
2015/16	0.8	35.5	39.1
Reduction by 2014/15 Campaign (3)			
2013/14	0.00	0.00	0.00
2014/15	0.16	7.00	7.53
2015/16	0.05	2.21	2.43
Total	**0.21**	**9.21**	**9.96**

Notes:
(1) = Base Case projection ('Do Nothing') from Table 2. May not sum to total due to rounding.
(2) = Sum of monthly crash forecast for fatal, injury and PDO in relevant financial year from Table 4
(3) = (2)-(1)

Step 6 - Calculate NPV, BCR and Conduct sensitivity analysis

The CBA is undertaken using a spreadsheet model with the campaign costs and estimated benefits over the analysis period. A discount rate of 7% is used for economic evaluations with sensitivity tests at 4% and 10%. The parameter values for use in estimating crash benefits are based on the Willingness-To-Pay (WTP) approach, and are those recommended in Appendix 4 of these Guidelines. The values are presented in Table 8.3(q). The WTP approach assesses the risks of a fatality, serious injury and minor injury and the amounts drivers are willing to pay to avoid those risks.

Table 8.3(q): Economic parameters for estimating reduction benefit

	Values/person	Average Crash Value
Fatality	$6,635,699	$7,319,335
Injury	$118,388	$151,537
PDO crashes	$9,535	$9,535

Source: Appendix 4 values in 2013/14 dollars.

The economic benefits of reduced crashes or casualties can then be estimated by applying the above parameter values to the estimates of crash reduction by year. Table 8.3(r) shows the costs and benefits for each year of the analysis period for a hypothetical project.

Benefits of travel time savings and reliability

By reducing the incidence of crashes as a result of the advertising campaign, travel time savings are realised by improving general traffic flow as vehicles involved in a crash can limit on-road traffic movement and create blockages for other motorists. Traffic incidents are one of main factors causing traffic delays and travel time variability. By reducing unsafe driver behaviour and the crashes or incidents that happen as a result, traffic flow could be further improved.

The travel time benefit is estimated from avoided travel disruption thus allowing for smoother traffic flow. Assumptions are made regarding travel time delays in urban and rural road conditions due to crashes and the number of vehicles affected. Using the value of travel time per vehicle hour an estimate is derived in relation to potential time savings due to reduced crashes and travel disruption for the analysis period.

Unquantifiable benefits

Any unquantifiable benefits should also be acknowledged even though not estimated due to data limitation

Table 8.3(r): Sample Costs and Benefits (undiscounted)

	Costs $m			Benefits $m				
	Campaign Costs			Road Accident Cost savings			Travel	
	Production Costs	Media cost	TOTAL COSTS	Fatal	Injury	PDO		TOTAL BENEFITS
2013/14	0.408	0	0.408	0	0	0	0	0
2014/15	**0.909**	**2.05**	2.959	13.58	13.85	0.09	0.40	27.93
2015/16	0	0	0	2.35	2.51	0.02	0.07	4.95
Total	**1.317**	**2.05**	**3.367**	**15.93**	**16.36**	**0.11**	**0.47**	**32.88**

CBA RESULTS

A summary of CBA results of the campaign including travel time savings can be presented as shown in Table 8.3(s) below. At the 7% discount rate and for a $1.8 million advertising budget, the publicity campaign can be expected to generate a NPV of $1.13 million and a BCR of 1.68.

Table 8.3(s) Summary of CBA Results-Safety Campaigns

	Discount rate		
	4%[18]	**7%**	**10%**
PV Cost ($m)	$1.73	$1.68	$1.63
PV Benefit ($m)	$2.91	$2.82	$2.72
NPV ($m)	$1.19	$1.13	$1.09
BCR	**1.69**	**1.68**	**1.67**

SENSITIVITY TESTS

Sensitivity tests should be undertaken on key assumptions about crash reduction benefits and decay rates and how they impact on the BCR and NPV.
Examples of sensitivity tests are:

- **Sensitivity test 1**: Base Case crash figures remain at average level over five years.
- **Sensitivity test 2**: The crash reduction rate is reduced to 2%, compared with 6.7% used **in main CBA.**
- **Sensitivity test 3:** The crash reduction rate is reduced to 0.7% which is applying an attribution rate of 10% to the reduction rate of 7%. This is the "switch point" or threshold where NPV = $0 and BCR=1.
- **Sensitivity test 4:** The retention rate in decay profile is reduced to 34% but crash reduction rate is maintained at 6.7%.
- **Sensitivity test 5:** The crash reduction rate is reduced to 2% and the retention rate is also reduced to 34%.
- **Sensitivity test 6:** The crash reduction rate is reduced to 0.7% and the retention rate is also reduced to 34% (worst case scenario).

8.4 Economic Appraisal of Policies and Regulations

The Subordinate Legislation Act 1989 (The Act) requires an agency to prepare a Regulatory Impact Statement (RIS) for new principal statutory rules (regulation, by-law, rule or ordinance). Under Premier's Memorandum 2009-20, agencies are also required to comply with the requirements in the Guide to Better Regulation. A Better Regulation Statement (BRS) must be prepared for all new and amending regulatory proposals (including new Acts or Regulations) which are 'significant' and submitted with the Cabinet or Executive Council Minute. A regulatory proposal may generally be considered 'significant' if it would having a large impact or introduce a major new regulatory initiative. Where a new principal statutory rule is 'significant', the RIS can be submitted in the place of a BRS to avoid duplication. However, note that the outcomes of consultation and justification for the final regulatory proposal must

[18] In 2017 NSW Treasury changed the lower discount rate sensitivity from 4% to 3%.

also be presented with the RIS to meet the better regulation requirements. The Better Regulation Office is available to provide advice on the preparation of a RIS or BRS.

A key component of RIS or BRS is a cost benefit analysis of regulation changes. Thoroughly understanding costs and benefits and likely impacts on different sectors of the community is a key element to assist decision making and apply the better regulation principles. The cost of regulation changes should include:

- Compliance costs of regulator changes relate to capital and production costs and administrative requirements. Examples include costs reporting systems, record-keeping, professional advice, training, equipment and changing of production processes in complying with regulation.
- Economic impacts on resource allocation, productivity, competition, innovation and opportunity cost that would have been received from other options which will not be realised by the preferred option.
- Indirect / market costs. This is the impact that regulation has on market structure, competition patterns and cost of product delays, and including barriers to entry or exit through licensing, restrictions on pricing, quality and location of productions and innovations.
- Social impacts on quality of life, equity, public health and safety and crime reduction.
- Environmental impacts such effects on air quality, noise and greenhouse gas emissions.

The costs and benefits to be following stakeholder groups should be assessed:

- **Businesses:** Businesses may incur compliance costs, administrative costs, licence fees, government charges and change of procedures. The benefits may include an increased efficiency or productivity, reduced accident and injuries and reduced red tape.
- **Consumers:** Lower price and improved safety of products. Sometimes, the cost of regulation compliance can lead to higher price.
- **Government:** The government may incur regulation setup costs, collecting information and record keeping and undertaking regulation enforcement activities. The benefits include licence fee revenue, and improved state economic outcomes.
- **Community:** The community is usually better off from environmental health, safety and reduced anti-social behaviour.

The indirect cost, economic impacts and opportunity cost are the most difficult to estimate. However, some indirect costs such as cost of delays can be estimated. For those intangible aspects of regulation that cannot be quantitatively assessed, a qualitative discussion can be useful.

The Commonwealth Office of Best Practise Regulation is responsible for any regulatory impact analysis for the Australian Commonwealth government. Similarly, a Regulation Impact Statement is required for all decisions made by the Australian government and its agencies that are likely to have a significant regulatory impact on businesses, including amendments to existing regulation.

8.5 Economic Appraisal of ICT Projects

Mandatory requirements for ICT projects are contained in the following:

- NSW Procurement Policy (TPP 04-01). Sets out key principles on government procurement to ensure value for money.

- ICT Capital Investment Process (TPP 06-10). The guidelines apply to all types of ICT investments including new projects, asset replacement and software upgrades.
- NSW Treasury ICT Reinvestment Pool Guidelines (TPP 10-03) and Information and Communications Technology (ICT) Reinvestment Pool Policy & Guidelines Paper (TPP 12-05), which sets out the eligibility criteria for ICT capital funding.
- People First – A New Direction for ICT in NSW (or the latest ICT strategy).

ICT projects include the design, development, implementation, maintenance, support, operation and management of technologies to manipulate and communicate computer based information e.g. software applications, computer hardware and telephony.

General Requirements for ICT Business Cases

The following table outlines the key Treasury requirements that need to be completed based on the project's Estimated Total Cost (ETC), irrespective of the funding source.

Table 8.5(a) ICT Project Treasury Requirements

Estimated Total Cost (ETC), $ Million

	<$5 M	**$5-10 M**	**$10-50 M**	**Over $50 M**
Preliminary Business Case 1	Not required to be submitted	No, unless requested by Treasury	Yes – for projects in years 2-4 of the upcoming forward estimates period	Yes – for projects in the upcoming 5-10 year period
Final Business Case 2	Not required to be submitted	Yes	Yes	Yes
Risk Assessment 3	Not required to be submitted	Done by agency. Results reviewed by Treasury	Done by agency Treasury to formally sign off on risk assessments for proposals by agency as low risk	

1. Preliminary business cases required by 1 July for projects commencing more than 12 months later. Consult with Treasury regarding the year in which to first provide a preliminary business case (for projects in very early planning stages) and the level of updates required in subsequent years.
2. Final business cases including Financial Impact Statement and Economic and Financial Appraisal required to support final project approval. Budget dependent agencies should submit final business cases no later than with the TAM and other budget submission materials.
3. Risk assessment for projects over $5m undertaken using the Gateway project Profile Assessment risk evaluation tool.

Before the preparation of a Business Case, an investment proposal that ensures it is compliant with the most recent NSW Government ICT Strategic Plan and a risk profile assessment using the Gateway Project Profile Assessment Tool (for projects greater than $1M) should be completed. The Preliminary Business Case is used in the Strategic Gateway review to ensure the project's viability before proceeding whilst the Final Business Case is used in the full Business Case Gateway review.

Economic / Financial Appraisal of ICT Projects

An economic/financial appraisal is required to be undertaken for all projects with an estimated total cost greater than $1 million. Full economic and financial appraisals are required to be completed for projects over $10 million however, summaries of economic/financial appraisals are sufficient for projects costing between $1 million and $10 million.

An economic/financial appraisal should consider both the financial and economic costs and benefits of each option. ICT projects are usually evaluated over a 5- year period, or longer based on the asset's economic life.

Project costs include both capital and recurrent costs. Capital costs are asset cost, infrastructure set up, software configuration and design costs. Recurrent costs comprise of operating costs such as the maintenance/vendor management of the asset, software license fees and training expenses.

Benefits from ICT projects may include avoided costs, productivity improvements, customer benefits, reduction in complaint or manual handling costs, reliability and travel time costs savings. The business case should clearly indicate the actual productivity benefits expected to be achieved, say in terms of actual reduction in costs or additional work being completed before including as benefits.

Avoidance of catastrophic failure of the system with possible loss of data and an inability to continue to provide the service to customers under a proposed ICT project is a benefit that may or not be amenable to measurement but should be identified and included in the economic appraisal, either as a consequence or possible cost of doing nothing in the base case or avoided cost in the project option.

A Financial Impact Statement (FIS) is required for proposals for Cabinet and Budget Committee consideration. The FIS outlines the financial impact of the proposal to the budget, the forward estimates and implications for the agency such as whether there is additional staffing.

Funding Source - ICT Reinvestment Pool

One of the funding sources for ICT projects is the ICT Reinvestment Pool managed by NSW Treasury. The ICT Reinvestment Pool is used to fund investments in improving ICT strategic efficiency for capital projects greater than $250,000, with a strong focus on financial savings. These projects are expected to generate large, sustainable financial savings on a whole of government or multi-agency level. The financial savings generated should meet the ongoing operating and maintenance costs of the new asset from existing funding. Agencies are able to retain the realised savings from the implementation of ICT projects funded by the ICT Reinvestment Pool. The ICT Reinvestment Pool does not fund feasibility studies.

Eligible Agencies applying for funding must submit an application to the Secretary NSW Treasury, stating their intent to obtain funding from the ICT Reinvestment Pool and how they will meet the eligibility criteria. If successful in obtaining funding from the ICT Reinvestment Pool, Agencies will be required to report quarterly to Treasury on the progress of projects.

The following table highlights the annual project submission process and timetable for funding application to the ICT Reinvestment Pool:

Table 8.5(b) ICT Reinvestment Pool Process and Schedule

Month	Key Activity
August	Invitation letter sent to Agencies to apply for funding through the submission of: 1. Preliminary Business Cases for capital funding 2. Covering letter to the Secretary NSW Treasury from the Director General stating their intent to obtain funding and how they meet the eligibility criteria.
September	Agency submission of Preliminary and/or Final Business Cases and Treasury assessment of submissions.
October-November	Applications for ICT Reinvestment Pool funding due in the form of a Final Business Case and Treasury evaluation of Business Cases.
January-March	ICT Reinvestment Pool project evaluation by the Evaluation Committee.
March	Budget Committee approval and funding allocated to approved projects.
March-April	Second allocation letter sent to Agencies to confirm funding approval.
June	End of Budget Year (Agency budgets released).

Identification of ICT Benefits

Information and communications technology (IT) remains a central driver of innovation and prosperity and the ICT projects generates a lot of benefits that encompass improvements in work processes, competitiveness and innovations. Most of the benefits of technology come from its consumption, while some come from its production. The table below presents the main ICT investment benefits from usage, and adoption.

Table 8.5(C) ICT Investment Benefits

A. Efficiency savings (monetary benefits)
Time savings
Reduced processing through common standards for data and processes
Time savings for public servants
Reduced error rates, re-work, complaints
Reduced need for multiple collections of data from single customers
More flexible working hours
Information benefits
More accurate, up-to-date and cleaner data and more reliable information
Capacity for greater information sharing across government
Risk benefits
Improved risk management
Improved security and fewer security breaches
Future cost avoidance
Lower costs for future projects through shared infrastructure & valuable knowledge
Reduced demand for service (through better information provision)
Reduced need for future capacity expansion

Encouragement of increased adoption of other e-services
Resource efficiency
Reduced redundancy through integrated systems More effective use of existing infrastructure, and reduced capacity waste
B. Other benefits (non-monetary)
Improved service delivery
Enhanced customer service
Improved service consistency and quality
Improved user satisfaction
Improved communication
Improved reputation and increased user trust and confidence
Integrated view of customers
Increased user involvement, participation, contribution and transparency
Enhancements to information access
Allows more, greater and new data to be collected
Improved security
C. Benefits to users
Monetary benefits
Reduced prices for charged-for services, avoidance of future price increases
Reduced cost of transmitting information - phone, post, paperless interactions, etc.
Reduced travel costs
Reduced associated costs, such as professional advice, software tools, equipment, etc.
Revenue-generating opportunities for citizens, businesses and intermediaries
Time-based non-monetary benefits
Reduced user time (hours saved)
Reduced need for multiple submission of data for different services and events
Reduced travel time
D. Added Value - non-monetary benefits
Quicker response
Reduced application processing time (elapsed time saving) Improved response time to events Improved interactive communication, particularly between government & communities
Improved information
More reliable , up-to-date, live or real time information
Faster and easier access
Transparency (e.g. status of "live" applications)
Enhanced democracy and empowerment
Improved reliability
Reduced error rates
Greater confidence and certainty of transaction
Service consistency and overall reliability
Choice and convenience
Increased choice and ease of access
Greater user convenience (24/7 service delivery) and lesser complaints
Premium service
Extra tools and functionality for users
Improved customer service - Personalised service and service integration

8.6 Measuring de-congestion benefits in economic appraisal

Congestion means travel delays when demand for the available road space approaches or exceeds road capacity. Congestion can also be caused by road works, road closures, bad weather or traffic accidents when road capacity is reduced. The effects of road congestion are typically characterised by:

- Slower speeds and associated delays
- Longer travel times
- Long traffic queue at intersections or other pinch points
- Vehicles travelled as frequently stopping, stationary and starting mode
- Less reliable and predictable travel times

The level of congestion can be measured by two indicators:

- Ratio of travel speed to posted speed limit: This ratio is used to measure road corridor efficiency. Low ratio indicates that the travel speed is lower than speed limit. The lower this ratio is the higher the level of congestion.

- Volume capacity ratio and level of service: Congestion is manifested when the traffic flow approaches the road capacity. Austroads, in its Guide to Traffic Engineering, considers the level of service (LOS) D as the limit of stable traffic flow approaching unstable traffic flow. At the LOS D, drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort is poor, and small increases in traffic volume will generally cause a flow breakdown. Table below shows that relationship between the LOS and V/C Ratio. Generally, road is considered congested when the V/C ratio is 0.85 or above.

Level of Service (LOS)	V/C ratio
A – B	<0.44
C	0.44 to 0.63
D	0.64 to 0.84
E	0.85 to 0.99
F	≥1

In economic appraisals, congestion costs are estimated through various approaches involving direct measurements of congestion effects and congestion externalities.

Direct measurements of road congestion costs in economic appraisals:

- Value of travel time savings (VTTS): Congested delays of private travels and the productivity lost in the additional journey time of business travellers are measured in VTTS in economic appraisal.
- Value of travel time reliability (VTTR): Congestion causes additional travel time variability due to unpredictable travel time. Trip makers usually respond the unreliable travel time by departing early to avoid arriving late. The additional travel time budgeting-in for preventing late arrival is defined as buffer time. The buffer time is a resource cost that is included in the economic appraisal.
- Vehicle operating cost (VOC): The urban and rural VOC models indicate that the VOC is the lowest when the travel speed is around 60km/h – 70 km/h. When congestion occurs, the speed typically drops below 60 km/h. The additional

operating cost is captured in VOC estimate. For example, a medium-sized car travels on urban arterial roads. The VOC is 33.3 cents per km at the speed of 60 km/h which is increased to 54.4 cents per km when the speed is decreased to 30 km/h due to congestion. The congestion caused VOC increase is 63%.

Vehicle stop cost: In signalised and un-signalised intersection traffic modelling, the number of vehicle stops is estimated and an economic cost is attached to a vehicle stop. As at March 2016, the economic cost is 7 cents per vehicle stop for cars covering additional wear and tear and fuel consumption associated with the stop, and 23 cents for light commercial vehicles and 60 cents for heavy commercial vehicles (Appendix 4, Table 16).

While direct congestion costs are measured in VTTS, VTTR and VOC, it is important to recognise that there are significant external costs associated to road congestion. For each trip, the external costs include travel delays it imposed to other road users, its contribution to additional unreliable travel time to other cars and trucks, poorer air quality due to slower speed and more fuel consumption. The external congestion cost is measured by the marginal cost that it imposes on other road users. In Sydney GMR, the marginal external congestion cost is estimated at $0.36 per PCU kilometre travelled (Appendix 4, Table 20). The marginal external congestion cost for other vehicle types is estimated by applying PCU conversion factors (Appendix 4, Table 21). For example, the marginal external congestion cost is $0.36 per VKT for cars and $2.88 per vkt for B-Doubles in Sydney GMR.

8.6.1 Worked example - Light Rail Project

An arterial road link of 10km in length carries heavy traffic in peak hours. The traffic flow in AM peak hour is 1,850 passenger car equivalent (pcu) per hour, but the road capacity is 1,800 pcu per hour. The Volume-to-Capacity (V/C) ratio is 1.03 and the LOS is poor at E, indicating significant congestion and unreliable travel time. The posted speed limit is 60 km/h on the road section but the average travel speed in AM peak hour is only 30 km/h due to heavy traffic.

A parallel light rail is proposed. The transport modelling has estimated that 400 road trips in the AM peak hour will be diverted from the arterial road to the light rail. As a result, the peak hour traffic flow will be reduced by around 22% to 1,450 pcu per hour, increasing the average travel speed to 50 km/h.

As arterial traffic is diverted from the congested arterial road to the light rail, there are significant benefits resulting from relief of road congestion. This worked example demonstrates how the congestion reduction benefits can be estimated. The quantified benefits are also summarised in Table below.

Value of travel time savings (VTTS)
After traffic is diverted to light rail, the remaining traffic (1450 pcu per hour) can travel at a higher speed of 50 km/h. The travel time saving for a single trip is 8 minutes on the 10km road section. The estimated VTTS is $5,570 in the AM peak hour, using value of travel time of $28.81 per vehicle hour as recommended in Appendix 4, Table 9.

Vehicle operating cost (VOC) savings
Before the introduction of light rail, vehicles on arterial roads travel at an average speed of 30 km/h, resulting in VOC of 54.4 cents per vkt. With the light rail and the diverted trips, the travel speed increases to 50 km/h and the VOC accordingly decreases to 37.5 cents per vkt. The reduced levels of road congestion will result in VOC savings of 16.9 cents per vkt, or $2,451 during the AM peak hour.

Value of travel time reliability (VTTR) benefits
With traffic diverted to light rail, travel time becomes more reliable on arterial road: the standard deviation (SD) of travel time is reduced from 4.18 minutes to just 0.14 minutes. This is calculated using the reliability formula recommended in TfNSW / National guidelines:

$$SD_{Travel\ Time} = \text{So} + \frac{S - S_0}{1 + e^{b(V/C\ Ratio - 1)}})$$

The estimated VTTR savings are $1,754 in the AM peak hour.

Congestion externality reduction
The marginal road congestion externality is estimated at $0.36 per pcu kilometre. With 400 road trips diverted to light rail, the congestion externality reduction is estimated at $1,440 in the AM peak hour.

Summary of benefits
In total, the congestion reduction benefit is estimated at $11,214 in the AM peak hour, represented by VTTS (49.7%), VOC savings (21.9%), VTTR savings (15.6%) and congestion externality reduction (12.8%). Applying cost expansion factors of 12.45 (from peak hour to weekday) and 336 (from weekday to year), the total congestion reduction benefits are estimated at $46.9 million per year.

Table Worked example of the road congestion reduction benefit

	Arterial Road in		De-Congestion benefits	% to total benefit
	Base case	Project case		
Project information				
Road selection length (km)	10	10		
Posted speed limit (km/h)	60	60		
Road capacity (pcu/h)	1800	1800		
Traffic volume (pcu per peak hour)	1850	1450		
V/C ratio	1.03	0.81		
Level of Service (LOS)	F	D		
Travel speed (km/h)	30	50		
Value of travel time savings (VTTS)				
Travel time (min)	20	12		
VOT ($/vehicle hour)	$28.81	$28.81		
VOT ($ per peak hour)	$13,925	$8,355		
VTTS ($ per peak hour)			$5,570	49.7%
Vehicle operating cost (VOC) savings				
VOC (Cent/km) *	54.4	37.5		
VOC cost	$7,888	$5,438		
VOC savings			$2,451	21.9%
Travel time reliability savings				
S **	0.89	0.89		
B **	-28.00	-28.00		
S_0 **	0.117	0.117		

Standard Deviation of travel time (min)	4.18	0.14		
Reliability ratio *	0.624	0.624		
VTTR ($ per peak hour)	$1,817	$63		
VTTR savings ($ per peak hour)			$1,754	15.6%
De-Congestion external cost savings				
Trips diverted to Light Rail (pcu per peak hour)		400		
Congestion external cost ($ per vkt)		$0.36		
External cost savings ($ per peak hour)			$1,440	12.8%
Total benefits ($ per peak hour)			**$11,214**	**100.0%**
Annualisation factor *			**4,183**	
Total benefits ($ per year)			**$46,911,619**	

Notes: * denotes economic parameters recommended in Appendix 4; ** denotes values presented in Chapter 7

8.6.2 Worked example – Upgrade of Rail Freight Corridor

The diversion of freight from road to rail as a result of the freight corridor upgrade will lead to a reduction in truck kilometres.

The analysis assumed that the decongestion effect would apply only to the AM and PM periods and the impact would only be realised in the urban sections of the freight corridor.

Assumed Route Distances by Mode for Intermodal Traffic Corridor

	Rail	Road	Tonnage (%)
Sydney – Brisbane	980	970	38%
Melbourne – Brisbane	1,900	1,670	51%
Brisbane – Perth	5,100	5,100	6%
Brisbane – Adelaide	2,730	2,730	5%
Weighted average	**1,783**	**1,664**	

For interstate intermodal traffic the following assumptions on road corridor distance in urban areas were made.

- Melbourne (north): Dynon Port – Craigieburn = 30km
- Sydney (south): Campbelltown – Chullora = 30km
- Sydney (north): Chullora – Hawkesbury = 55km
- Brisbane (south): Ipswich – Acacia Ridge = 40km
- Total = 155km

Thus the average length of road corridor in urban conditions is approximately 10%.
The proportion of the business peak hours compared to the whole day is approximately 20%. Consequently, the decongestion benefits are applied only to this portion of traffic and time of day.

For the purpose of illustration, this reduction due to the project is about 20 million vkt in a year. This reduction will lead to a benefit to the remaining road users by relieving congestion in peak times and speeding up road traffic.

Marginal congestion cost has been estimated per vehicle kilometre by road type and these are presented in the table below.

Assuming the freight trips were diverted from inner arterial roads, the de-congestion benefits in 2016 are estimated as follows:

	Base Case	Project Case
Total road kms	10,470	10,470
Number of heavy vehicles per day	2,000	1,500
Number of VKT	20,940,000	15,705,000
Road distance proportion in urban areas	10%	10%
Affected time - Business peak	21%	21%
Congestion external cost-Articulated trucks-arterial roads ($ /vkt March16 $*	$1.80	$1.80
Number of affected VKT (urban areas during business peak hours)	430,274	322,705
Congestion Cost per day	$774,493	$580,870
De-congestion benefit per day		193,623
Annual De-congestion benefits (expansion factor=336)		**$65,057,425**

* See Table 21 Appendix 4 of Economic Appraisal Guidelines

9. Reporting and Presentation of Economic Appraisal Result

This section provides general principles for reporting and presenting the economic appraisal results to policy makers and other stakeholders.

The forms to be completed by proponents of project or transport initiative are also included in this chapter.

The EA Summary Report Form, presented at the end of this chapter, summarises the key findings and results from the economic appraisal. It presents a summary of the project description, identification of the strategic objectives and how much of those objectives are being addressed by the proposed projects or initiative. Other information presented include feasible options, individual benefits assessed for each option and cost information (to be based on lifecycle costing).

The form also presents information on expected costs and benefits, relative to the base case, for each option and the project periods. The key risks related to costs and benefit realisation should also be identified and assessed as high, nominal or low.

General principles which should be considered when preparing and presenting the Economic Appraisal results are summarised below:

1. **Clarity and transparency** – presentation of economic appraisal results should strive for maximum clarity and transparency of all aspects of assessments. An assessment whose conclusions can withstand close scrutiny of all its facets is more likely to provide information needed to make decisions relating to approval, funding and prioritisation.
2. **Delineation of data and assumptions** – there should be a clear and concise description of all important data sources and references used, as well as key assumptions and their justifications. All information should be available to the extent that these data are not confidential business information or some other form of private data.
3. **Exposition of modelling techniques** – convey at least the basic framework used for modelling demand and project program policy consequences. The presentation should highlight the key elements or drivers that dominate the framework and the results that are produced from it.
4. **Ranges for inputs and results** – at the minimum, uncertainties should be explored through the use of expected values supplemented by upper and lower bounds for important inputs, assumptions and results. If key inputs or assumptions are extremely uncertain, these should be clearly indicated and a discussion on how these uncertainties may affect the conclusions of the analysis should be presented.
5. **Highlighting non-monetised and unquantified effects** – sometimes not all effects may be readily quantified or valued in monetary terms. However, it is still valuable to communicate these effects as well.
6. **Presenting aggregate and disaggregated results** – the analytic framework should be organised in a way to provide information on economic consequences at a disaggregated level presenting the effect on transport consumers, non-users, government and other community groups not captured already in the cost benefit analysis.

An economic evaluation report should cover the following topics:

- An executive summary including the analysis results, decision criteria and recommendations.
- A detailed analysis report covering the project background, objectives, base case definition, options description, cost estimates, benefits, key assumptions, decision criteria, risk factors, results of sensitivity analysis, discussion of qualitative factors, identification of the preferred option and how it compares with the other options (see Economic Appraisal Summary Report Form overleaf).

When presenting the results of a CBA, a DCF analysis for each project option should be presented with a description of each option’s objective. All parameters and assumptions used in the analysis should also be listed, and the results of the sensitivity analysis should be reported. Any qualitative benefits or costs that could not be quantified in economic terms should also be discussed as these factors could also be considered in the decision. The general conclusion of the CBA should provide a ranking of the options and make a recommendation on the preferred option. NSW Treasury Circular (TC12/19) sets out the Submission of Business case requirements in which the economic analysis is a part of a Business Case submission.

Table 9.1 Transport NSW Economic Appraisal Summary Report

A. PROJECT INFORMATION: (Please complete this form for all Project Options)				
Item	**Project Description**			
1	Decision Unit	(e.g. TNSW, Division, RMS, RailCorp, SF, STA)		
2	Project Name			
3	Project Option Name			
4	Project's Funding Program / Sub-program Name			
5	Current Status of Project (most recent achieved milestone)	(e.g. pre-PDP, PDP, EIS, REF, PIP)		
	Qualitative Strategic Initiatives & Motivation for the Project (Problem being addressed)			
6	Improve public transport system			
7	Reliable public transport			
8	Improve Efficiency of Network			
9	Improve Safety & Security			
10	Enhance/maintain Infrastructure			
11	Regional Equity			
12	Improve accessibility			
13	Others			
	Base Case			
14	Base Case Description			
	Project Option Description			
15	Project Option Name / Description			
16	How are the Project Goals being met?			
17	How many other options considered?			
	PROJECT BENEFITS - List and present the PV of benefits for the base case and project option(s)			
	(Over the project period)	**Base Case**	**Option 1**	**Option 2**
18	Avoided Capital Cost			
19	Avoided Recurrent Cost			
20	Asset Sale Proceeds			
21	Incremental net revenue			
22	Travel time savings			
23	Patronage benefits			
24	Operating cost savings (VOC)			
25	Environmental benefits			
26	Safety & Security			
27	Improved Service Reliability			
28	Improved comfort /amenities			
29	Wider Economic Benefits			
30	Others (e.g., Social Inclusion)			
	Project Cost			
31	Capital Cost			
32	Land and Property			
33	Construction Cost			
34	System & Set Up cost			
35	Capital Replacement Cost			
36	Refurbishment / Upgrade cost			
37	Decommissioning Cost			
38	Construction Dis-benefits / Costs			
39	Others (e.g. inventories)			
40	Contingency Cost			
41	Annual Operating Cost			
42	Annual Maintenance Cost			

B. COMPARISON OF OPTIONS - RESULTS							
INCREMENTAL BENEFITS -PREFERRED OPTION relative to the BASE CASE							
	AGENCY & USER BENEFITS	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Annual Avg thereafter**
43	Avoided Capital Cost						
44	Avoided Recurrent Cost						
45	Asset Sale						
46	Net revenue						
47	Travel time savings						

48	Patronage benefits						
49	Operating cost savings						
50	Environmental savings						
51	Safety & Security						
52	Others (quality, comfort,)						
	Wider Economic Benefits (WEB)						
53	Agglomeration						
54	Productivity						
55	Others						

C. PRESENT VALUE INCREMENTAL BENEFITS - PREFERRED OPTION RELATIVE TO BASE CASE

	Discount Rate	**3%**	**7%**	**10%**
56	Avoidable Capital Cost			
57	Avoidable Recurrent Cost			
58	Asset Sale			
59	Net revenue			
60	Travel time savings			
61	Patronage benefits			
62	Operating cost savings			
63	Environmental cost savings			
64	Safety & Security			
65	Others (quality, comfort, etc)			
66	WEBs			

D. CBA SUMMARY INFORMATION - PREFERRED OPTION RELATIVE TO BASE CASE

	Discount Rate	**3%**	**7%**	**10%**
67	NPV			
68	BCR			
69	NPVI			
70	FYRR			

E. PROJECT RISK IDENTIFICATION & ASSESSMENT

	1 - Identify the Key Risk to Total Cost					**Sensitivity Analysis PV Cost**		
		Likelihood[1]	Impact[2]	Assessment[3]		Low	Nominal	High
71	Key Risk 1							
72	Key Risk 2							
73	Key Risk 3							
74	Other							
	TOTAL							
	2 - Identify the Key Risk to Total Benefits					**Sensitivity Analysis PV Benefit**		
75	Key Risk 1							
76	Key Risk 2							
77	Key Risk 3							
78	Other							
	TOTAL							
	3 – Total risk impact on							
79	PV COST							
80	PV BENEFIT							
81	NPV							
82	BCR							

[1] **Likelihood**: Almost Certain, Very Likely, Likely, Unlikely, Very Unlikely, Almost Unprecedented
[2] **Impact:** Insignificant, Minor, Moderate, Major, Severe, Catastrophic
[3] **Qualitative Risk Profile**: Very High, High, Medium, Low

10. Prioritisation of Investment based on Economic Appraisal Results

This section provides the basic framework for the use of economic appraisal results for prioritisation of projects, programs or investment initiatives.

A long-term view of transport infrastructure requires a robust framework for assessing significant infrastructure proposals. A thorough benefit-cost analysis provides information on the relative merits of infrastructure proposals that assist the government to prioritise projects better.

While not the only consideration in addressing the State's and transport's strategic objectives, a robust economic assessment methodology is a useful tool for prioritising investments as well as meeting community needs.

This chapter is scheduled for consultation and review for Version 2.0 of the Guidelines.

The prioritisation process increases the transparency of funding across the portfolio, within the core programs, and also improves communication between stakeholders on the reasons for funding decisions.

The allocation process takes into account the whole of government priorities and TfNSW's objectives of making NSW a better place to live, do business and visit through managing and shaping the future of the whole transport system.

Before a project's funding is approved, it should be able to demonstrate that it will contribute in an efficient and effective manner to TfNSW's objectives, including its social and environmental responsibilities.

The project must also demonstrate that all options have been assessed to the extent practicable against other transport options and alternatives.

Value assessment is used to assess a project's contribution to the strategic objectives of the Government and Transport.

The proposed projects for funding should be prioritised in a consistent way, and grouped into a forward investment program where the initial years of the program are firm, and the latter years are indicative.

Table 10.1 Core Functions, Optimisation Strategy and Methodologies

Categories of Core Functions	Optimisation Strategy	Economic Assessment Methodology	Decision Criteria	Decision Rule
Corporate Services	Minimise cost at agreed service standards	Least Cost Analysis (LCA)	Least Cost	Choose lowest cost option
Customer Service / Legislative / Regulatory	Minimise cost at agreed service standards	LCA	Least Cost	Choose lowest cost option
Maintenance / Operational	Optimisation: Economic, environmental & safety outcomes	Cost-Benefit Analysis	Incremental BCR	IBCR > 1
Growth (Asset Renewal, Expansion, Protection	Optimisation: Economic, environmental & safety outcomes	CBA	BCR, Incremental BCR, FYRR, IRR	BCR > 1

Rankings could be determined across all projects and programs, across modes or within programs. For example, rankings could be determined across all projects relating to roads, bridges, rail, bus and ferries (project centric), or could be determined within each individual mode (program centric).

Prioritisation of proposed investments generally considers three factors:

- Net Strategic Value of proposed investment to the transport once it is delivered
- Measure of the investment's financial and economic viability (i.e. benefit cost ratio or net present value)
- Net risk including delivery risk and strategic risk to TfNSW.

In general, the methodology will involve the following steps:

1. Calculate each investment's net strategic value.
2. Review project appraisal results by validating the calculated decision criteria (e.g. NPV, BCR, IBCR, FYRR, NPVI)
3. Consolidate project data, namely the cost and benefit streams
4. Sort and rank projects and provide the analysis.

10.1 Investment Net Strategic Value

The investment strategic value can be calculated by assigning scores for "contribution to strategic objectives", such as a score between -5 and +5 for each investment project. The strategic objectives are generally considered as equal in importance. However, if it is believed that some strategic objectives should be considered more important than others, these strategic objectives may be weighted, but sensitivity analysis on the weightings should be undertaken. Tools to help decision makers in determining weightings of strategic value, such as paired comparisons, are useful at this stage.

10.2 Calculated Decision Criteria

CBA using discounted cash flow (DCF) will produce the NPV, BCR, NPVI & FYRR for the Base Case and all the alternative options (see Appendix 3 for a DCF example).

Table 10.2: Decision Criteria

SUMMARY OF RESULTS				
	BASE CASE	OPTION 1	OPTION 2	OPTION 3
NPV	$50m	$79m	$150m	$80m
BCR	0.9	1.79	1.0	1.5
NPVI	0.3	0.4	0.2	0.4
FYRR	6%	12%	7%	7%

Based on comparison of BCR, Option 1 represents the best option. However, there are instances when the highest BCR does not represent the best option. While Option 1 has a higher BCR, Project 2 makes a net present value gain of $150m for society. Thus, based on NPV, Project 2 represents the best option.

10.3 Ranking Projects

When ranking projects for program or budgetary funding, the following methodologies can be used:

1. Identify all feasible combinations of projects that fit within the budget and choose the combination with the highest NPV. This works because the combinations of projects are mutually exclusive options
2. Rank the projects by BCR, whereby projects are selected in order of decreasing BCR until the budget runs out.

Both methods give the same results, as demonstrated in the example below:

Table 10.3: Ranking projects

Project	PV of Benefits	PV of Costs	NPV	BCR
1	$200m	$100m	$100m	2.0
2	$140m	$50m	$90m	2.8
3	$120m	$50m	$70m	2.4

With a budget of $100m, two options are possible; either adopt Project 1 at a cost of $100m or adopt Projects 2 & 3 again at a cost of $100m. To make the decision, using method 1, Project 1 has an NPV of $100m but the combined NPV of Projects 2 & 3 is $160m. Therefore Projects 2 & 3 represents more benefits to society within the budget and should be selected.

Using method 2, Project 2 would be chosen first and then Project 3. This will exhaust the budget.[1]

10.4 Constrained Optimisation

The process of portfolio selection is essentially a constrained optimisation problem, specified as:

[1] Example provided by Mark Harvey, BITRE, Commonwealth Department of Infrastructure and Transport.

MAXIMISE: ***TOTAL BENEFITS***

Subject to: ***(Constraints)***
1 - AVAILABLE BUDGET
2 - MANDATORY PROJECTS
3 - MUTUALLY EXCLUSIVE OPTIONS NOT SELECTED
4 - Any other constraints

The portfolio selection process aims to maximise benefits from available funding. The fundamental constraints are summarised below:

- Total spend must not exceed expected available budget for each financial year
- Only one option for each project may be chosen, although multiple options may be submitted
- Constraints ensuring tied funds are spent only are allowed
- Projects already commenced must be included, unless a specific proposal to stop them is submitted
- Projects marked as "Mandatory" must be included.

Other constraints are:

- Current status of the project – a project already committed or under construction may not be stopped unless marginal BCR drops below one after commencement
- Political commitments

For any queries in relation to investment prioritisation please contact the Evaluation and Assurance contact email at EconomicAdvisory@transport.nsw.gov.au.

11. Post Completion Evaluation and Benefit Realisation

This section provides the basic principles for post completion evaluation and benefit realisation. The NSW Government Guidelines for Economic Appraisal requires that projects greater than $10 million be subject to an ex-post evaluation, though all major projects should be subject to some form of review in terms of forecasts versus reality.

The expected benefits are the key decision enabler to decide whether or not to invest in a project, benefit management should be given due consideration.

This chapter is scheduled for consultation and review for Version 2.0 of the guidelines

The key to any evaluation lies in the purpose for which it is undertaken. The purpose could be to add to a body of knowledge or to influence future practice.

Although post completion evaluation is usually carried out during the outcome period, or the period during which the benefits are derived from the investment, there is no hard-and-fast rule that governs when a post completion evaluation is to be undertaken. The following principles provide a guide:

- In order to assess the performance of a new project and assess whether the original project objectives are met, a post completion review is undertaken 12 to 24 months after the commencement of the operating phase, such as a road opening
- A post completion review may be carried out immediately at the end of the investment period to review the implementation process
- For projects of long duration, for which the investment period and its outcome period may overlap significantly, an interim review is possible and recommended
- For select projects, further evaluation should occur over the economic life of the project to determine if there are significant variations in operating expertise
- All transport projects are subject to a safety audit every five years.

Benefits of Conducting a Post Completion Evaluation

Post completion evaluation (PCEv) reviews enable management to review the costs, benefits, design and significant events during the implementation of the chosen option. It also provides findings that can be used to enhance the development and implementation cycle of future projects.

By examining these issues, a post completion review will assist in the development and evaluation of future projects. In short, the review provides an opportunity for learning by experience. Other benefits include:

- Allows an assessment of the decision parameters that were used and the quality of forecasts applied
- Ensures that capital expenditure procedures are understood and followed
- Reviews the appropriateness of sensitivity analysis of the key variables and specifically of the contingency allowances
- Improves management control of projects
- Serves as a basis for the identification of the need for and the implementation of corrective actions. PCE may accelerate the decision to interrupt or significantly re-orient a project through the timely identification of un-forecasted or unalterable deviations in specification, or environmental changes which are not detrimental to the remaining future outcomes of the project

- Identifies the causes of significant deviations. PCE provides an understanding to the causes of over or under performance of the project.

Criteria for Choosing Projects to Evaluate

To guide in the choice of projects to review, the following criteria could be considered:

- **Significance of the project -** this considers the strategic scope of the project, financial scope and risks involved in the project such as risks of failure, risk of liability, risk of new technology/venture and political risk
- **Recurring / Non-recurring projects -** a post completion review of a recurring project represents a key source of information for the decision and control of similar projects in the future
- **Exemplary projects -** projects which have achieved outstanding results should be singled out for review as the review may identify underlying reasons for success, which can be applied into future projects
- **Projects most likely to provide learning -** a cost benefit analysis should be used to decide whether a post completion evaluation should be performed or not, since conducting this may be costly.

Principal Areas of Interest in Post Completion Review

Post completion evaluation can be made from different points of view using various degrees of precision, depending on the aims and objectives of the evaluation and which groups of people will be using the results. The principal areas of interest in conducting such a study are:

- Project formulation
  - Project objective (project outcomes against objectives)
  - Level of appropriateness
  - Design performance
  - Approvals
- Project delivery
  - Risk exposure / risk sharing (actual benefits against predicted benefits)
  - Delivery time
  - Budgetary performance (actual costs against original budget)
  - Project management process (the process by which the project was produced)
  - The project itself (operation and functioning of the facility)

Scope of Post Completion Evaluation

A post completion evaluation should involve:

- A review of all the assumptions that were formulated during the assessment period, and the process that led to their formulation. Special attention should be given to the process that led to the definition of the capital cost used in the decision making process, e.g., cost of capital or discount factor
- Comparison of the actual resources consumed by the project with the forecasts made, with identification of the contributing reasons for any observed deviations

- Comparison of the actual outcome or performance of the project with the forecasts made at the assessment stage
- Re-evaluate the benefits and costs of the selected option to assess whether the anticipated benefits and costs were realised, with an aim to establish reasons for deviations observed and reconsideration of alternative options
- A review of the procedures used to obtain an effective and efficient project control process
- Examine the project design and implementation process to assess the scope for improvement to the option adopted
- A review of conformance with policy

Approaches to Post Completion Evaluation

There are several approaches in undertaking a post completion evaluation which vary in degrees of depth and complexity.

- **Snap Evaluation –** This relies on an evaluation gathering data and making judgements on the facility and its performance without reference to the constraints. This is often termed as "accountability index" or "catalogue of mistakes".
- **Phased Evaluation** – In this approach, the evaluation proceeds with identification of major issues, constraints and objectives of the project design. This is usually done by a team of engineers, architects (other professionals) and economists.
- **Extended Evaluation –** This is more complex and involves a team approach. Part of the evaluation team collaborates with the design engineers from the beginning of the project design phase.
- **Behavioural Evaluation** – This isolates human aspects of the project performance. No reference is made to structure, cost or physical condition but relies heavily on the use of questionnaires, interviews and the more developed techniques such as behaviour mapping, time lapse photography and group discussions. Market research technology plays an important part in the data gathering activity.

Reporting Post Completion Evaluation

A post completion evaluation should clearly indicate the expectations of the project, when the project was initiated and what actually occurred. It provides a summary of the lessons drawn from the decisions, planning and performance audits and also examines the project's operations in relation to the overall strategy of the organisation. The report's main objective is to identify lessons for the future.

The report should provide findings in relation to whether:

- The options have been considered in accordance with each stage of the project
- The sensitivity of the various options to alternate environmental assumptions has been tested
- The project was implemented in accordance with original plans, or what revisions were implemented
- The project has delivered the expected benefits and to what degree
- The extent to which the success or failure of the project can be attributed to other factors such as internal management, project planning or environmental changes.

Benefit Realisation

A benefit is a positive outcome arising from the implementation of an initiative. Traditionally, major capital investment projects have been measured on their success in relation to cost, quality and time of delivery, and not in relation to the benefits or impact that they have delivered. Benefit realisation is emerging as one of the methods to assist organisations in managing the whole lifecycle of investments.

Benefit Realisation Management (BRM) is the process that proactively identifies benefits, plans for their realisation and tracks achievement versus plan. It involves executing, monitoring and measuring the identified benefits to ensure potential benefits expected from the investment are actually realised. It is a continuous process running through the whole project lifecycle.

BRM is undertaken in four phases which are as follows:

1. **Understand** - This involves articulating the vision, objectives and alignment of the project with the strategic drivers. High level benefits are identified and measures defined on how these benefits are to be evaluated. The baseline values of benefits are established from the business case and economic appraisal. A benefit register is established at this stage.
2. **Plan** - The key stakeholders are identified and the following questions are answered: *Who is the Benefit Owner? Who is accountable for delivering the benefits?* This phase involves establishment and agreement on the baseline values of the benefit, the KPI and their measurement methods with the Benefit Owner and key business stakeholders.
3. **Manage -** This phase involves establishing a benefit tracking regime and reporting format and mechanism. The actual values of benefit measures are collected, collated and recorded in the benefit register. BRM review sessions were held with Benefit Owners and key stakeholders.
4. **Evaluate and Report** - The project success or failure is evaluated by reporting to the Benefit Owner and other stakeholders the actual benefits achieved versus targets. Shortfalls in benefits may represent non-compliance or non-alignment with strategic objectives of government. It is important to ascertain that if shortfalls are occurring to see what is causing the non-achievement of full benefits and whether necessary enablers are in place and working properly. This phase will document the benefit outcome and identify learnings from project activities to inform further strategic decisions and priorities. The updated benefit register is summarised in a dashboard and a report is prepared for the Benefit Owner/ Executive.

The use of BRM practices drives more benefits from a funded investment, validates the success of a completed investment, generates performance information and provides lessons learnt. This will in turn benefit the shaping of future investments and support better decision making.

Refer to NSW Benefit Realisation Management Framework for more detailed guidance and application to transport programs and projects.

LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
ABS	Australian Bureau of Statistics
AGM	Average Gross Mass
AIP	Accident Investigation and Prevention
ARA	Australasian Railway Association
ARRB	Australian Road Research Board
ARTC	Australian Rail Track Corporation
AST	Appraisal Summary Technique
ATC	Australian Transport Council
AWE	Average Weekly Earnings
BCR	Benefit Cost Ratio
BFS	Bureau of Freight Statistics
BITRE	Bureau of Infrastructure Transport and Regional Economics
BRS	Better Regulation Statement
BTE	Bureau of Transport Economics
BTS	Bureau of Transport Statistics
CBA	Cost Benefit Analysis
CBD	Central Business District
CCTV	Closed Circuit Television
CEA	Cost Effectiveness Analysis
CGE	Computable General Equilibrium
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
Co2-e	Carbon Dioxide Equivalent
CPI	Consumer Price Index
CVM	Contingent Valuation Method
dB	Decibels
DCA	Disaggregated Crash Type
DCF	Discounted Cash Flow
Dft	United Kingdom Department for Transport
DoIT	Commonwealth Department of Infrastructure and Transport
DOT	Department of Transport
ED	Economic Development
EIA	Environmental Impact Assessment
EPA	US Environmental Protection Authority
ESA	Equivalent Standard Axles
ETC	Estimated Total Cost
EVRI	Environmental Valuation Reference Inventory
FIC	Finance and Investment Committee
FIRR	Financial Internal Rate of Return
FIS	Financial Impact Statement
FMM	Freight Movement Model
FreightSim	Freight Simulation Model
FY	Financial Year
FYRR	First Year Rate of Return
GAM	Goal Achievement Matrix
GC	Generalised Cost
GDP	Gross Domestic Product
GGE	Greenhouse Gas Emission
GMR	Greater Metropolitan Region
GRIT	Generalised Regional Input Output

GTK	Gross Tonne Kilometres
HC	Human Capital
HC	Hydrocarbons
HLM	Harbourlink Model
HOV	High Occupancy Vehicle
HTS	Household Travel Survey
IA	Infrastructure Australia
IBCR	Incremental Benefit Cost Ratio
ICT	Information and Communication Technology
INSW	Infrastructure NSW
I-O	Input Output
IPART	Independent Pricing and Regulatory Tribunal
IPMF	Investment Portfolio Management Framework
IRR	Internal Rate of Return
ITLS	Institute of Transport and Logistics Studies
ITS	Intelligent Transport Systems
IVT	In Vehicle Time
JTW	Journey to Work
LCA	Least Cost Analysis
LCC	Life Cycle Costs
LCV	Light Commercial Vehicle
LGA	Local Government Area
LOS	Level Of Service
MBCR	Marginal Cost Benefit Ratio
MBSC	Metropolitan Bus System Contract
MCA	Multi Criteria Analysis
MPM	Major Periodic Maintenance
MVKT	Million Vehicle Kilometres Travelled
N2O	Nitrous oxide
NAASRA	National Association of Australian State Road Authorities
NATA	New Approach to Appraisal
NIMPAC	NAASRA Improved Model for Project Assessment and Costing
NO_x	Nitrogen oxides
NPV	Net Present Value
NPVI	Net Present Value per dollar of capital investment
NRAM	Noise Reduction Assessment Methods
NSFC	North Sydney Freight Corridor
NSW	New South Wales
NTC	National Transport Commission
NTK	Net Tonne Kilometres
NWRL	North West Rail Link
NZTA EEA	New Zealand Transport Agency Economic Evaluation Manual
O&M	Operating & Maintenance Cost
OD	Origin and Destination
OIA	Objective Impact Assessment
OMBSC	Outer Metropolitan Bus System Contract
PAYGO	Pay As You Go
PCE	Passenger Car Equivalency
PCU	Passenger Car Equivalent Unit
PCEv	Post Completion Evaluation
PERS	Pedestrian Environment Review System
PET	Pensioner Excursion Ticket
PM10	Particulate matter of 10 microns or smaller

PPP	Producer Price Index
PV	Present Value
PVB	Present Value of Benefits
PVC	Present Value of Costs
REF	Review of Environmental Factors
REVS	Rural Evaluation System
RGA	Road Geometry Analyst
RIS	Regulation Impact Statement
RM	Routine Maintenance
RMS	Road & Maritime Services
ROH	Rule of Half
RTA	Road Traffic Authority
RUC	Road User Cost
RUE	Road User Effects
SC	Stated Choice
SCATES	Computer Aided Traffic Engineering System
SCATS	Sydney Coordinated Adaptive Traffic System
SCOT	Standing Committee on Transport
SEU	Social Exclusion Unit
SFM	Strategic Freight Model
SGEM	Sydney General Economic Model
SIS	State Infrastructure Strategy
SMT	Strategic Merit Test
SMVU	Survey of Motor Vehicle use
SO2	Sulfur dioxide
STA	State Transport Authority
STM	Sydney Strategic Travel Model
STPR	Social Time Preference Rate
TAG	UK Department for Transport, Transport Analysis Guidance
TAM	Total Asset Management
TCorp	NSW Treasury Corporation
TEDS	Transport and Environment Database System
TERM	Transport Enterprise Risk Management
TEV	Total Economic Value
TfNSW	Transport for NSW
TPM	Transition Probability Matrixes
TRARR	Traffic on Rural Roads
TREDIS	Transportation Economic Development Impact System
TRESIS	Transport Environmental Strategy Impact Simulator
VCR	Volume Capacity Ratio
VKT	Vehicle Kilometres Travelled
VMS	Variable Message Signs
VOC	Vehicle Operating Cost
VSL	Value of Statistical Life
VSLY	Value of statistical life year
VTPI	Victorian Transport Policy Institute
VTT	Value of Travel Time
VTTS	Value of Travel Time Savings
WACC	Weighted Average Cost of Capital
WEBs	Wider Economic Benefits
WEI	Wider Economic Impacts
WTA	Willingness to Accept
WTP	Willingness to Pay

GLOSSARY OF TERMS

@Risk – A simulation add-on for Microsoft Excel. It performs risk analysis using Monte Carlo simulation to show the possible outcomes. In economic appraisals, it has been used for risk assessment and sensitivity tests.

Appraisal Summary Technique (AST) – A technique broadly used in the assessment of the economic, environmental and social impacts of a project. It involves creating an appraisal summary table containing the description of objectives, sub-objectives, impacts and ratings or scores. Objectives are broadly classified into economic, social and environment. Sub-objectives are detailed breakdowns of objectives that assist in revealing an extensive range of impacts. The project proponent is required to enter the objectives and an assessment staff or team determines the impact through ratings or scores. Impacts are described qualitatively and quantitatively. For each impact a score is provided. The scoring could be a grade, a monetary value or general points on a scale.

Agglomeration economies – An economic benefit recognised in Wider Economic Benefits (WEB) of infrastructure investment. It refers to the additional productivity benefits arising from proximity and clustering explained by economies of scale, access to more customers, access to more suppliers, knowledge spillovers and access to workforce enabling better job matching.

Base case – The base case reflects the realistic circumstances in the absence of the project case and is generally defined as the existing condition, or the existing service standard, and its continuation over the life of the evaluation period. It is generally the 'do-nothing' option or the continuation of the status quo. It is not a 'spend nothing' option but is based on continuation of current levels of service or policy.

Base year – The year to which all values are discounted when determining a present value. It is usually the year of analysis.

Benefit Cost Ratio (BCR) – Calculated as the discounted benefits over the life of a project divided the discounted capital costs plus discounted operating and maintenance costs. The ratio needs to be 1 or above for the project to proceed.

Benefit realisation – A process of monitoring progress towards the planned outcomes. It usually involves 4 phases: (1) Understand the outcomes targeted by the investment. This phase is all about establishing the strategic intent and identifying the outcomes required to achieve this intent. (2) Plan the benefit realisation including additional details such as the owner, the target to be achieved and the units with which to measure progress. It also includes the necessary arrangements needed to be in place to realise the benefits. The outputs of the Plan phase form the basis for the benefits section of the program business case. (3) Realising the benefits then is achieved by monitoring progress towards the planned outcomes. Deviations from plan can be picked up early with the appropriate corrective action taken. Throughout this process the business case should be updated and maintained as there will inevitably be differences between what was initially proposed and what is attainable as the program progresses. (4) Reporting of actual versus planned is provided to facilitate the accountability of performance of the program.

Better Regulation Statement (BRS) – A Better Regulation Statement is required for significant new and amending regulatory proposals and must be approved by the NSW Better Regulation Office before a proposal is considered by Cabinet or the Executive Council. A Better Regulation Statement should be a succinct document which justifies a regulatory proposal. It must demonstrate that the better regulation principles have been applied when developing the regulatory proposal. The purpose of a Better Regulation Statement is to provide Portfolio Ministers, the Premier and Cabinet, with sufficient information to enable them to make an informed decision about whether to approve the proposal. It also provides information to business and the community about decision making, ensuring transparency and accountability in the regulatory development process. A core part of BRS is an economic analysis of costs and benefits of regulation changes.

Capital costs – Include construction, planning and design, engineering and environmental investigations and project management costs, unless these are already considered as "sunk" cost.

Concept cost estimate – A concept estimate is prepared during the project's concept and development stages, and finalised following the determination of the Environmental Impact Assessment and the finalisation of the project development. The RTA (now RMS) Project Estimating Manual presents and discusses concepts estimates and provides appropriate estimate method to use for cost-benefit analysis of road projects. It is based on the project schedule and assumed funding allocations as required by the project schedule. For rail projects, RailCorp has followed the Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction published by the Commonwealth Department of Infrastructure and Transport.

Conjoint analysis – A conjoint analysis seeks willingness to pay values by asking people directly, rather than inferring values from observations of people's behaviour. Conjoint analysis reveals how people make complex judgments. The techniques assume that complex decisions, including route choice decisions, are based not on a single factor or criterion, but on several factors 'considered jointly'. This method reveals people's preferences in a realistic manner and enables assessment of the weight or value people give to various factors that underlie their decisions.

Constant price – A price from which the effects of general inflation have been removed.

Consumer surplus – The difference between the amount the consumer is willing to pay for a particular good or service (rather than go without it) and the amount the consumer actually pays. The consumer surplus concept is central to the economic theory underlying the estimation of benefits.

Contingent valuation method (CVM) – The CVM uses a direct approach, i.e., basically asking people what they are willing to pay for a benefit and/or what they are willing to receive by way of compensation to tolerate a cost or a loss. The process of asking may either be through a direct questionnaire/survey, or by experimental techniques in which subjects respond to various stimuli in laboratory' conditions. The technique is so named because the value it estimates is contingent upon the hypothetical situation described to the respondent.

Cost benefit analysis (CBA) – A structured technique for assessing the economic efficiency of resource allocation, by quantifying in money terms the costs and benefits of a range of alternative project proposals. The benefits and costs are defined in terms of society as a whole. The analysis involves deriving decision criteria such as benefit cost ratio (BCR), net present value (NPV), first year rate of return (FYRR), internal rate of return (IRR) and net present value per dollar of investment (NPVI).

Cost effectiveness analysis (CEA) – The CEA is similar to CBA but benefits are excluded, either because they cannot be valued, or the benefits from all options under consideration are the same.

Contingency – Allowances for possible cost increases and the uncertainty of cost estimates. These allowances shall be based on the phase of development of the activity and the level of accuracy of the estimate in that phase. The early phases of the project development are associated with a higher level of risks and uncertainty, thus a higher level of contingency allowance is allocated.

dB(A) – A-weighted decibels that is used to express the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, the decibel values of sounds at low frequencies are reduced, compared with unweighted decibels, in which no correction is made for audio frequency.

Discount rate – It measures the rate at which one wishes to sacrifice future consumption for present consumption. It is the rate at which costs and benefits in future years are discounted to express them in present values in the base year. The inflation free rate currently being used is 7%.

Diverted travel – Traffic which switches from one route to another as a result of the project, or trips that switches from one mode to another as a result of transport investment.

EMME – An interactive-graphic multi-modal transportation planning model that contains a decision support system. Transport modelling involves the determination of equilibrium between the demand and supply sides of vehicles and travellers on the transportation facilities.

Employment density – The number of employment per square kilometre used to define the degree of agglomeration or clustering in Wider Economic Impact assessments. A better measure of agglomeration is **effective employment density** defined as total employment in the locality plus employment in surrounding areas weighted by their proximity. The proximity is a function of the generalised travel cost. The effective employment density increases if a transport project reduces the generalised travel cost even if the total employments in different zones remain unchanged.

Evaluation period – The time frame over which the costs and benefits of a project are compared (sometimes referred to as the project life). It encompasses the initial period of the capital investment and the subsequent period over which the benefits of the project accrue. In many cases 20 years is adequate; 30 years is the maximum period usually used for road evaluation.

Expansion factors – Refer to factors used for converting traffic volume during morning or afternoon peak hours into a daily traffic volume.

Externality – This relates to the external effects of a project which is not accounted for in market transactions and that is therefore not directly reflected in the financial cash flow of a project. The environmental impact of a project is a typical example of such an externality. Economic analysis attempts to value such externality and internalise this into project benefits and costs to improve efficiency of the use of the limited resource and to contribute to the enhancement of environmental sustainability.

First year rate of return (FYRR) – The first year rate of return (expressed as a percentage) is a measure of the benefits achieved in the first full year of a scheme's operation divided by the capital costs incurred to achieve this. The first year rate of return is typically used to determine the best start date for a scheme.

Fixed trip matrix / Fixed matrix technique – Refers to a situation where the number of induced trips is considered as insignificant thus the number of trips in the base case and the project option is assumed the same. Fixed trip matrix techniques ignore the impacts that there are more trips or induced demand in trip generation, that people travel to different locations and that people change modes in a single trip.

Generalised Regional Input Output Technique (GRIT) – This is generalised regional input output (GRIT) technique which derives regional input-output tables from the national input-output table using location quotients and superior data at various stages in the construction of the tables. The Australian Bureau of Statistics publishes the national Input–Output (I–O) tables as a part of the Australian national accounts, complementing the quarterly and annual series of national income, expenditure and product aggregates.

Generalised Cost (GC) – The generalised cost is the sum of time (travel, waiting, transfer time) and financial costs (fare, vehicle operating costs, tolls) incurred during travelling.

Goal Achievement Matrix (GAM) – A tool used in the analysis of impacts that are not readily able to be quantified in monetary terms (such as social objectives). GAM is based on estimating which option best achieves a set of predetermined goals of a project. Weights are assigned to the goals, so that each option can be evaluated in terms of the goals achieved.

Greenhouse Gas Emission (GGE) – Gases (e.g. carbon diode, methane) that contribute toward the greenhouse effect which represents a negative externality. Greenhouse gases are emitted from cars, freight and public transport.

Hedonic price – The price of goods determined by its characteristics and is usually determined by regression analysis. For example, the hedonic pricing approach will capture the relationship between the price of the property and characteristics such as the level of air pollution, neighbourhood and access to amenities.

Human Capital (HC) approach – A method which captures the ex-post sum of various identifiable costs. This approach can be used to determine accident costs. The ex post value of accidents is based on the value that has been lost such as, such as loss of work income, medical expenses, long term care, insurance cost, vehicle repair, property damage.

Induced travel – Additional demand for travel that occurs as a result of a decrease in generalised cost of travel.

Incremental Cost Benefit Analysis (ICBA) – The cost benefit analysis should be based on costs and benefits of the options incremental to the base case. The most effective way of evaluating a project is to include all the absolute costs and benefits associated with the options, and then compare the difference in costs and benefits of the project options to the base case.

Input-Output (IO) Table – A table which shows the input and output structure of industries, supply and use of products in the economy and relationships between industries.

Internal rate of return (IRR) – The discount rate at which the present value of benefits equals the present value of costs. An internal rate of return greater than the discount rate indicates an economically worthwhile project.

Life Cycle Cost (LCC) – Whole of life-cycle costing which analyses the total value of road costs (construction and maintenance) and road user costs (vehicle operating costs, road user time and safety cost) as well as society cost over the asset life.

Logsum – An accurate measure of consumer surplus measured from the logarithm of the sum of utilities from all transport users. The logsum approach estimated consumer surplus with greater accuracy as it is based on actual demand curves, while the 'Rule of half' approach assumes the linearity of the demand curve.

Market price – The price of goods and services when they are freely bought and sold in a given market.

Monte Carlo Simulation – A simulation process which draws random samples from specified probability distributions to display a range of outcomes and the probabilities they will occur. It is commonly used in risk analysis.

Multi-Criteria Analysis – An evaluation tool used for decision making between a range of projects or options, which can't be easily quantifiable. MCA can be used to describe the impacts of a project using criteria in order to determine a relative ranking of projects based on a score.

NAASRA –The National Association of Australian State Road Authorities, now known as Austroads.

National Building Blackspot Program – Federal government program which provides funding for road and safety improvements in locations where crashes occur.

Net Present Value (NPV) – The difference between the present value of benefits and the present value of costs. A positive net present value indicates that the project has economic merit.

Net Present Value per dollar of capital Investment (NPVI) – The overall economic return of a project in relation to its requirement for initial capital expenditure. Defined as the NPV divided by present value of the investment costs where the capital costs are those incurred to initially complete the project. The project with the highest NPVI is chosen first when there is a constraint on capital.

Network effects – The impact on the wider corridor or area as a result of a transport improvement.

NIMPAC – NAASRA Improved Model for Project Assessment and Costing. This is a road planning model developed by NAASRA. The model carries out evaluation by considering the state of the road section, standard road designs and maintenance and user costs.

Noise Reduction Assessment Methods (NRAM) – A procedure to assess the types of noise controls needed for an area of land adjacent to a road which include strategic environmental assessments, changes to existing roads and review noise estimated in Environmental Impact Statements.

Nominal price – Price which includes the effect of inflation.

NRM (NAASRA Roughness Meter) – A unit of measure to describe road pavement roughness.

Objective Impact Assessment (OIA) – A process aimed at testing the degree of impact of projects on the objectives of government to examine strategic fit of projects.

Opportunity cost – The cost of an alternative that is foregone when another option is chosen.

P50 – Represents the project cost with sufficient risk provisions to provide a 50 per cent level of confidence in the outcome, that is, that there is a 50 per cent likelihood that the project cost will not be exceeded.

P90 - Represents the project cost with sufficient risk provisions to provide a 90 per cent level of confidence in the outcome, that is, that there is a 90 per cent likelihood that the project cost will not be exceeded.

Passenger Car Equivalent (PCE) – The impact varying traffic modes have relative to a passenger car (base value of 1).

Post Completion Evaluation (PCE) – Method to evaluate the costs, benefits, design and significant events during the implementation of the preferred option which will assist in the development and evaluation of future projects.

Present Value (PV) – The value of a stream of future cash flow which has been discounted back to today's value in order to take into account the time value of money.

Price Year – A reference year for which the value of all costs and benefits are expressed in terms of.

Regulatory Impact Statement (RIS) – A document which is required to be prepared under the Subordinate Legislation Act 1989 for all new statutory rules in NSW. The RIS sets out the purpose for the regulation, assesses alternatives and outlines the costs and benefits of the regulation.

Residual value – The residual value is a measure of the capacity of the asset to continue earning benefits after the evaluation period. The residual value is based on the economic life or useful life of the asset.

Resource cost – Financial costs that exclude taxes, GST and subsidies. Resource costs are used in economic evaluations.

REVS – The Rural Evaluation System is a program used by Roads & Maritime Services for the economic evaluation of rural road improvement proposals.

Risk Assessment – A procedure to identify risk factors, estimate the likelihood of risk occurrence and determine the consequence of risk occurrence.

Risk Matrix – A matrix used in risk assessment to provide a score to evaluate the consequence and likelihood of a type of risk occurring.

Road user effects (RUE) – Unit values used in project evaluation that impact the road user such as vehicle operating cost, travel time, crash costs and environment costs.

Rule of half (ROH) – Used to estimate the consumer surplus benefit. Assumes linearity in the demand curve.

Sensitivity test – A procedure used to assess the possible impact of uncertainty and shows how changes in the values of various factors or changes to assumptions affect the overall cost or benefit of a given investment project.

Social exclusion – Describes the situation of existence of barriers which make it difficult or impossible for people to participate fully in society.

Stated Preference (SP) approach – Conducted usually through surveys and questionnaires asking people what they are willing to pay for a benefit and/or what they are willing to receive by way of compensation to tolerate a cost or a loss.

Strategic cost estimate – Cost estimates incurred during the main phases of the project which may include Project Development, Investigation & Design, Construction & Implementation and Finalisation.

Strategic merit test – A qualitative project appraisal tool used to check if the proposed project aligns with the economic, environmental and social objectives, policies and strategies of the government. This typically consists of a series of questions which try to identify the contribution of the proposed project to the government's objectives, policies and strategies.

Sunk cost – Costs that are already incurred and hence, have no salvage or realisable value.

Sydney Strategic Travel Model (STM) – A multi-modal strategic model maintained by Bureau of Transport Statistics, used to analyse network-wide impacts of mode choice and to provide future year growth factors for all transport modes. The STM projects travel patterns in Sydney Newcastle and Wollongong under different land use, transport and pricing scenarios. The model produces the estimates of travel to and from each travel zone, from and to every other travel zone, as well as travel within zones. It is best used to examine the impacts of significant proposed changes to land use or transport system.

Transit Oriented Development – Refers to a planning concept which facilitates mixed use, commercial and residential development near public transport.

Transport Enterprise Risk Management (TERM) – A risk framework which determines the risk exposure by scoring the likelihood and consequences of identified risks.

Transport Social Exclusion Index – A tool used to compare and identify social exclusion in different locations and demographic groups. A number of factors are determined that represent aspects of accessibility (such as mobility need, land use accessibility, physical and communication accessibility, automobile access, mobility options and financial wealth) and a rating score is given.

TRARR– Traffic on Rural Roads is a micro-simulation model of traffic flow on two-lane roads, which was originally developed by the Australian Road Research Board (ARRB). TRARR can be used investigate the effects of changes in road and traffic characteristics such as investigate overtaking lane projects.

Travel zone – Is the geographical area and/or boundary used to identify origin and destination trips.

TREDIS – A flexible and modular framework for conducting economic impact and benefit cost analysis of transportation projects, programs and policies. It is a hybrid model in a sense that it calculates conventional benefits such as value of travel time savings, and vehicle operating cost savings, accident cost reductions, but also regional impacts such as job growth, personal income growth, business output and Gross Domestic Product (GDP) growth.

TRESIS-SGEM – An integrated model system combining the Transport Environmental Strategy Impact Simulator (TRESIS) and Sydney General Economic Model (SGEM). TRESIS models the interrelationship between transport and location choices of individuals and households while SGEM, a spatial computable general equilibrium model models a number of economy wide impacts of specific transport polices and strategies. It is used for assessing Wider Economic Impacts (WEIs).

Total Economic Value (TEV) – A measure of the benefits of preserving the environment by not developing the area. It is used to assess the damage impacted on the environment due to the construction of a project.

Upstream / Downstream Effects – Refers to the indirect costs of transport including energy generation, vehicle production and maintenance and infrastructure construction and maintenance.

Value of statistical life (VSL) – The value society is willing to pay to reduce the risk of death.

Value of statistical life year (VSLY) – The value society is willing to pay to reduce the risk of premature death, expressed in terms of savings a statistical life year.

Value of travel time savings (VTTS) – The benefits from reduced travel time costs which include travel time, waiting time, access and egress time.

Variable trip matrix method – This technique is different from the fixed trip matrix technique in that the effects of induced demand, trip and mode changes are considered in traffic modelling thus demand in the project option matrix is generally higher than that in the base case matrix for a given forecast year.

Vehicle operating cost (VOC) – The costs incurred in operating a vehicle. This can include costs associated with fuel, oil, tyre, repair & maintenance.

Volume Capacity Ratio (VCR) – An indicator that represents the amount of traffic congestion. It is calculated as the volume of traffic passing at a particular point divided by the lane capacity. The lower the VCR the better the quality of traffic.

Weighted Average Cost of Capital (WACC) – The rate of return that investors would require in order to supply debt and equity capital for investment in a similar asset. It also reflects the opportunity cost of capital, that is, the return that could have been earned in the market.

Wider Economic Impacts (WEI) / Wider Economic Benefits (WEB) – Impacts of transport investments on agglomeration economies, increased competition as a result of better transport system, increased output in imperfectly-competitive markets and economic welfare benefits arising from an improved labour supply.

Willingness to pay (WTP) – An ex-ante measure of the amount that individuals are willing to pay for a good, service or benefit.

APPENDIX 1

Australian Economic Appraisal Guidelines

In Australia a number of appraisal guidelines exist across jurisdictions, each varying in scope and approach and, in some cases, aligned to differing funding mechanisms. In this section we present all relevant known guidelines in Australia and illustrate the relationship between the guidelines and funding mechanisms that are relevant to the NSW context.

Presented in the table below is an outline of relevant known appraisal guidelines in Australia.

Table 1: Overview of current Australian economic appraisal guidelines

Jurisdiction	Relevant Guidelines
Commonwealth / national	Australian Transport Assessment and Planning (ATAP Guidelines).
	Infrastructure Australia, Assessment Framework: For initiatives and projects to be included in the Infrastructure Priority List, March 2018
	Handbook of Cost Benefit Analysis, January 2006, Department of Finance and Administration
NSW Government	Guide to Cost Benefit Analysis, Policy and Guidelines Paper, TPP 17-03, NSW Treasury, March 2017
	Guidelines for Capital business Cases, Policy and Guidelines Paper, TPP 08-05, NSW Treasury, December 08
	Commercial Policy Framework: Guidelines for Financial Appraisal, Policy and Guidelines Paper, TPP 07-04, NSW Treasury, July 07
Queensland Government	Queensland Government-Cost benefit Analysis Manual; Department of Infrastructure and Planning – Project Assurance Framework Guidelines
Victorian Government	Victoria Department of Transport – Guidelines for Cost Benefit Analysis
South Australian Government	South Australian Department of Treasury and Finance – Guidelines for the Evaluation of Public Sector Initiatives
Western Australia Government	Western Australian Department of Treasury and Finance – Project Evaluation Guidelines

The following points emerge from the above table:

- While state agency guidelines such as the NSW Treasury Guidelines feature prominently in state government project appraisals, there are new significant volumes of guidance and literature emerging from the Commonwealth. For instance, the former Department of Finance Handbook of Cost Benefit Analysis was for a long time the main reference from the Commonwealth government. The development of the Australian Transport Assessment and Planning Guidelines in 2016 and the Infrastructure Australia Guidelines in 2012[1] and updated this year[2], are now the primary guidance documents.
- The primary guidelines at the state level are the publications by the NSW Treasury. The Guide to Cost Benefit Analysis, (TPP 17-03, NSW Treasury) provide a framework for undertaking financial and economic appraisals across all public sector agencies.

[1] Infrastructure Australia's Reform and Investment Framework, Guidelines for making submissions to Infrastructure Australia's Infrastructure priority list using the Reform and Investment Framework, May 2012.

[2] Infrastructure Australia, Assessment Framework: For initiatives and projects to be included in the Infrastructure Priority List, March 2018

- Research indicates that there is still an absence of appraisal guidance in some states and territories. This suggests that the development of appraisal guidance has not been consistent throughout state governments in Australia.
- It is also worth noting the difference between a set of "guidelines" and a volume of "manual". Whilst both these types of documents are of an educational/guidance nature, it is generally accepted that "guidelines" provide higher level strategic advice on how an appraisal should be contextualised and structured, whilst "manuals" tend to be more instructive, providing detailed parameter values and worked examples (e.g. the inclusion of algorithms in traffic models and mathematical formulae).

ECONOMIC ANALYSIS GUIDELINES / MANUALS FOR ECONOMIC APPRAISALS

1. Guide to Cost Benefit Analysis, Policy and Guidelines Paper, TPP 17-03, NSW Treasury, March 2017.
2. Guidelines for Capital business Cases, Policy and Guidelines Paper, TPP 08-05, NSW Treasury, December 08.
3. Commercial Policy Framework: Guidelines for Financial Appraisal, Policy and Guidelines Paper, TPP 07-04, NSW Treasury, July 07.
4. Australian Transport Assessment and Planning (ATAP) Guidelines.
5. Infrastructure Australia – Assessment Framework: For initiatives and projects to be included in the Infrastructure Priority List, March 2018.
6. Commonwealth Department of Finance and Administration – Handbook of Cost Benefit Analysis.
7. Queensland Government Department of Infrastructure and Planning – Project Assurance Framework Guidelines.
8. Victoria Department of Transport – Guidelines for Cost Benefit Analysis.
9. New Zealand Transport Agency (NZTA) –Economic Evaluation Manual (EEM).
10. New Zealand Government Agglomeration Elasticities in New Zealand (by D Mare and D Graham).
11. United Kingdom Department for Transport (DfT) – Transport Analysis Guidance.
12. Victorian Transport Policy Institute (VPTI) – Transport Cost Benefit Analysis: Techniques Estimates and Implications.
13. Commonwealth Productivity Commission – Valuing the Future: The Social Discount Rate in Cost-Benefit Analysis.
14. Austroads – Guide to Project Evaluation Part 1 – Part 8.
15. Transportation Research Board - Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners.
16. U.S Department of Transportation Federal Transit Administration - Guidance for Major Capital Investments (New Starts and Small Starts)

APPENDIX 2

Review of discount rates for use in economic evaluation of transport investments

Currently New South Wales (NSW) Treasury's guidelines for economic appraisal recommend applying a central real discount rate of 7 per cent. This 'benchmark' rate ensures consistency across projects appraisals.

The theory of discounting is to translate future costs and benefits to a common time unit, in order to compare costs and benefits that accrue at different times and express them as an equivalent amount in today's dollars.

Discount rates can either reflect the perspective of producers (businesses and individuals investing in debt and/or equity) or consumers (individuals consuming and/or saving), or some combination of both.

The main issue in choice of discount rate is whether it should reflect the marginal return on alternative use of capital or the marginal rate at which consumers are willing to forego present consumption (save) for future consumption. In a competitive market and in the absence of taxation, these two rates would be equal. However, taxation of the return on capital means that the marginal return on capital usually exceeds the marginal rate of return on private savings.

Producer or consumer rate

PwC suggests that a producer rate methodology be applied in estimating discount rates for NSW Government transport investments, given that the producer rate accounts for foregone output due to crowded out private sector investment (as well as the benefits from reinvesting project benefits in the private sector) and the supply curve for savings as a function of the interest rate is inelastic so most capital invested in the public sector would be sourced from foregone private sector investment rather than consumption.

Furthermore there is little reliable Australian/NSW data available to estimate a consumer rate, requiring use of overseas data as proxies.

There are a number of international and Australian examples that apply a producer methodology to estimate discount rates. The Productivity Commission 2010 paper prepared by a visiting researcher, Bureau of Transport and Regional Economics 2005 paper, New Zealand Treasury and the Jenkins and Kuo (Queen's University, Canada) paper in 2007 are examples.

In 2003 the UK Treasury changed its discount rate approach from a producer rate of 6.0 to a consumer rate of 3.5 per cent, based on a social time preference rate (STPR). This appears to reflect a policy decision to give more weight to longer term benefits in projects with intergenerational impacts.

NSW-specific rate

PwC has estimated NSW-specific producer rates based on a weighted average cost of capital (WACC) approach. This is considered a more realistic approach to measure the ‘opportunity cost’ of public investment, given it could displace private sector investment and the private sector invests in a combination of debt and equity (other producer rate methodologies consider either debt or equity, but not both concurrently).

The WACC methodology was applied by New Zealand Treasury when reducing its discount rate from 10 to 8 per cent in 2008. A Productivity Commission 2010 paper prepared by Mark Harrison also supports a producer rate. It measures a ‘rate of return to capital in the market sector’, considering investment in Australia's stock of produced assets.

The PwC core analysis derives a NSW-specific discount rate of 7.1 per cent, based on the 30-year historical average NSW Treasury Corporation (TCorp) 10-year bond rate, 30-year historical average Sydney inflation, a benchmark debt: equity ratio from Independent Pricing and Regulatory Tribunal of NSW (IPART) regulatory applications, and an assumption of mid-range systematic risk based on Australian infrastructure company market data for the last 30 years. Market data for Australian infrastructure companies is used as a proxy for NSW Department of Transport specific risk given that there is no accepted measure of government risk in this sector and these companies are expected to undertake similar investments to the Department. This value is in between the theoretical extremes of no risk premium for public investment and the view that public investments should be evaluated on the same basis as private risk.

If the last 10-years were considered to better reflect expectations regarding future bond rates, CPI and market returns, the discount rate would be 4.6 per cent.

If a low risk premium is applied based on Professor John Quiggin (University of Queensland) estimates using Consumption CAPM, the discount rate is 3.7 per cent or 5.3 per cent (assuming the 10 year and 30 year historical averages respectively). If the level of private sector risk averaged across the Australian market is applied, the discount rate is 5.4 per cent or 8.5 per cent (the 10 year and 30 year historical averages respectively)

A NSW-specific social time preference rate (STPR) is derived as 5.0 per cent, which is higher than the UK rate as there has been higher historic growth in NSW gross state income per person (noting, however, that there are no Australian empirical estimates for most of the underlying parameters making it challenging to rely on this).

Conclusion

Given the potential challenges applying a differential discount rate to transport projects over the broader NSW portfolio, and in light of the above findings, and considering the importance of consistency in the absence of overwhelming consensus otherwise, there are merits continuing to apply the current 7 per cent rate.

However, any of the other rates above (ranging from 3.7 to 8.5 per cent) could be theoretically supported given the range of differing views and lack of clear consensus in discount rate theory and rationale.

SUMMARY OF DISCOUNT RATE ESTIMATES

	Core estimate	Lower sensitivity	Upper sensitivity
Producer rates			
RFMRR	5.6%	3.3%	5.6%
CAPM	9.3%	3.3%	12.9%
MRC	8.9%	6.9%	11.7%
WACC	7.1%	3.7%	8.5%
Consumer rates			
RFMRR	5.6%	3.3%	5.6%
STPR	5.0%	1.6%	14.2%

Range: Minimum 5.0% Maximum 9.3%

ESTIMATION OF NSW SPECIFIC DISCOUNT RATES (2010-11)

APPROACH	DISCOUNT RATE APPLYING CURRENT NSW / AUSTRALIAN DATA PRE-TAX, REAL RATE		KEY ASSUMPTIONS	REPORTED / OVERSEAS DATA
PRODUCER RATES	(i) Return from investing in debt (risk free market rate of return)	5.6%	– 30-year historical NSW 10-year bond rate – 30-year historical Sydney CPI – 10-year debt margin for AAA rated companies	3.3%-5.6%
	(ii) Return from investing in equity to Australian infrastructure companies (capital asset pricing model)	9.3%	– As above for (i) except no debt margin, and: – Market risk premium of 5.9 per cent nominal (post-tax) for the entire market between 1979 and 2008 (i.e. 30 years) – Company tax rate of 30% – Equity beta for Australian infrastructure companies (0.55) – Risk premium of 3.3% for Australian infrastructure companies (0.55*5.9%)	3.3%-12.9%
	(iii) Return from investing in a combination of debt and equity to Australian infrastructure companies (weighted average cost of capital)	7.1%	– As above for (i) and (ii), and: – Average debt:equity ratio of 60%:40% based on NSW IPART benchmark assumption for Australian and NSW market	3.7%-8.5%
	(iv) Marginal return to private capital in Australia (Productivity Commission visiting researcher proposed approach)	8.9%	– Average annual rate of return on capital from 1965 to 2007 based on national accounts data	6.9%-11.7%

APPROACH	DISCOUNT RATE APPLYING CURRENT NSW / AUSTRALIAN DATA PRE-TAX, REAL RATE		KEY ASSUMPTIONS	REPORTED / OVERSEAS DATA
CONSUMER RATES	(v) Market rate of interest at which consumers lends and borrows (risk free market rate of return)	5.6%	– As above for (i)	3.3%-5.6%
	(vi) Marginal social rate of time preference	5.0%	– Pure time preference rate of 1.0% based on average annual NSW death rate between 1999-2009 and the median estimate of the time preference due to myopia from international empirical literature – Growth in NSW real gross state income per person between 1992 to 2008 – Median estimate of the marginal utility of consumption from international empirical literature	1.6%-14.1%

APPENDIX 3

Cost Benefit Analysis - Discounted Cash Flow Analysis (DCF)

PRO FORMA

Last Update June 2018

Evaluation and Assurance, Finance and Investment Division

For any feedback or comments please send an e-mail to: EconomicAdvisory@transport.nsw.gov.au

PROJECT NAME – DISCOUNTED CASH FLOW ANALYSIS – OPTION 1

TIME		COSTS $000			BENEFITS $000								NET BENEFIT (COST)
t	Year	Capital Cost	Operating & Maintenance Costs	TOTAL COSTS	Travel Time Savings	VOC Savings	Safety Benefits	Environmental Benefits	Amenity Benefits	Incremental Revenue	Resid ual Value	TOTAL BENEFITS	
0	Base Year	25,000		**25,000**									**-25,000**
1	Year 1	30,000		**30,000**									**-30,000**
2	Year 2	100,000		**100,000**									**-100,000**
3	Year 3	50,000		**50,000**									**-50,000**
4	Year 4	10,000		**10,000**									**-10,000**
5	Year 5		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
6	Year 6		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
7	Year 7		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
8	Year 8		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
9	Year 9		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
10	Year 10		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
11	Year 11		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
12	Year 12		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
13	Year 13		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
14	Year 14		17,000	**17,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**15,100**
15	Year 15		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
16	Year 16		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
17	Year 17		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
18	Year 18		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
19	Year 19		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
20	Year 20		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
21	Year 21		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
22	Year 22		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
23	Year 23		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
24	Year 24		17,000	**17,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**15,100**
25	Year 25		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**

26	Year 26		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
27	Year 27		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
28	Year 28		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
29	Year 29		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800		**32,100**	**30,100**
30	Year 30		2,000	**2,000**	15,000	8,800	5,000	1,500	1,000	800	38,475	**70,575**	**68,575**
TOTAL		**215,000**	**82,000**	**297,000**	**390,000**	**228,800**	**130,000**	**39,000**	**26,000**	**20,800**	**38,475**	**873,075**	**576,075**
Proportion of total benefits (%)					**45%**	**26%**	**15%**	**4%**	**3%**	**2%**	**4%**	**100%**	

Discount Rate	Discounted Cash Flows ($'000)											
	Capital Cost	Operating & Maintenance Costs	TOTAL COSTS	Travel Time Savings	VOC Savings	Safety Benefits	Environmental Benefits	Amenity Benefits	Incremental Revenue	Residual Value	TOTAL BENEFITS	Net Present Value
NPV at 7%	188,825	26,818	**215,643**	135,327	79,392	45,109	13,533	9,022	7,217	5,054	**294,655**	**79,012**
NPV at 3%	203,028	49,062	**252,090**	238,250	139,773	79,417	23,825	15,883	12,707	15,851	**525,706**	**273,616**
NPV at 10%	179,313	17,987	**197,300**	93,856	55,062	31,285	9,386	6,257	5,006	2,205	**203,056**	**5,756**

SUMMARY OF RESULTS	
Present Value Benefits @ 7% = **294,655** Present Value Costs @ 7% = **215,643**	BCR1 = **1.37** BCR 2 = **1.42**
NPV @ 7% = **79,012** PV Capital = **188,825**	NPVI = **0.42**
PVB (Y1) = **22,887** PVC = **188,825**	FYRR = **12%**

Discounted cash flow analysis should be undertaken for the Base Case and all the alternative options.

The incremental costs of options relative to the base case should be used in the analysis. The discounted cashflow analysis of Option 1 used in the pro-forma example shows that capital costs distributed across the construction period, the operating and maintenance costs including major periodic maintenance every 10 years during the project period, and the specific benefits quantified and monetised in the cost benefit study. The costs and benefit values for use in the discounted cashflow are calculated in separate modules (see embedded CBA models for appropriate calculations for relevant project type). Download the DCF pro forma here or contact the Evaluation and Assurance, Finance and Investment for a copy of the excel model.

Summary Analysis for Option 1

The discounted cashflow analysis indicates that Option 1 is economically viable with positive NPV of $79m and Benefit Cost Ratio (BCR) of 1.37. Cost is more than covered by the economic benefits from carrying out this option. Net Present Value of Initial Investment (NPVI) is 0.42. This will need to be compared with the NPV per dollar investment of other options. The Option with the highest NPVI provides the highest return on the incremental expenditure. The FYRR of 12% is higher than the discount rate of 7%, which indicates that the project can be expected to continue to yield benefits throughout the evaluation period (Note: if FYRR < Discount Rate, the implementation should be deferred until FYRR ≥ the Discount Rate). This also indicates that the project under this option can be implemented and need not be deferred.

Discounted cash flow analysis should be undertaken for the Base Case and all the alternative options and the results presented in the summary table as shown below:

SUMMARY OF RESULTS			
CRITERIA	**OPTION 1**	**OPTION 2**	**OPTION 3**
NPV	$79m	-$29	$57
BCR	1.37	0.91	1.24
NPVI	0.42	-0.10	0.28
FYRR	12%	8%	11%

Analysis of Results:
Based on comparison of BCR, Option 1 represents the best option. However, there are instances when the highest BCR is not the best option as demonstrated by the example below:

Project	PV of Benefits	PV of Costs	NPV	BCR
1	200	100	100	2.00
2	350	200	150	1.75

While Option 1 has a higher BCR, Option 2 is a better project and should be chosen as the preferred option because society makes a net gain of $150 not just $100. In this approach, it may be appropriate to make a further judgment between competing options on the basis of the scale of any non-quantitative costs or benefits.

APPENDIX 5

Consultancy Briefing
Economic Appraisal services
Project name

Contents

1. Introduction

1.1 Document purpose

(The brief to the consultants conveys the expectations and objectives to the potential consultant. The brief seeks solutions a Consultant can propose or provide in terms of conducting economic appraisal for a project, how much it will cost and how long it will take.

This pro-forma brief can cover all types of projects and can range from a small document to a large one. A brief for a small project may require the basic components of this document which can also be conveyed via an email whereas a brief for a large project, may take the form of an invitation to tender (ITT). It should be as long as it needs to be to convey the specific requirements.)

The purpose of this Consultancy Brief is to provide an overview of the (Project Name) and the economic appraisal services that (Transport for NSW (TfNSW) or Roads and Maritime Services (RMS) or Sydney Trains) requires to be included in the Project Business Case.

This Consultancy Brief provides a starting point for a Request for Proposal (RFP) / Expression of Interest (EOI) for economic appraisal services.

The document sets out:

- Project description: Project background, scope and overview.
- Scope of economic appraisal services: Tasks, deliverables, obligations and personnel requirements.
- Response to the Consultancy Brief: How a prospective service provide can response a RFO/EOI.
- Management of services: General process and obligations.

1.2 Key dates and details

Event	Anticipated dates
Issue of RFP	xx xxx 2016
Closing Time	xx xxx 2016 6:00PM Sydney time
Expected execution of Work Order	xx xxx 2016
RFP Distribution	RFP documentation including any updates is available from the contact officer.
Lodgement Method	Offers should be lodged by email with the contact officer at: xxx.xxx@transport.nsw.gov.au
Contact Officer	For all matters relating to this RFP, the Contact Officer will be: Name Position Address Contact details

1.3 *The Principal*

The Principal in the service agreement which governs the consultancy service is (Name of Project Manager, Division, Agency) who is responsible for the development of the Project Business Case.

Provide in this section the proponent's details:

Profile: Trading name, ABN, ACN, Full name, Address, Registered office, Business website

1.4 *Audience*

This Consultancy Brief provides guidance for the Service Providers intending to tender for the role of economic appraisal services in support of the (Project).

1.5 *Documents control*

The control, distribution and update of this Consultancy Brief is the responsibility of the Project Manager. Changes or updates to this document will be controlled through the Project Manager.

2. Project description

This section should provide the project overview, background, scope and objectives. The information should be concise but sufficient for prospective consultants / service providers to appreciate the project and related economic appraisal tasks.

2.1 *Project background*

Provide the strategic context such as the project's alignment with the State Plan 2021, the State Infrastructure Plan, Future Transport 2056 and other Transport strategic documents.

Other information necessary for understanding the background of the project should also be provided.

2.2 *Scope*

Provide project scope and the scope of consultancy work.

2.3 *Objectives*

Provide the high level project objectives or tasks.

2.4 *Related and dependent studies*

Provide details of any related and dependent studies.

3. Economic appraisal services

3.1 *Guidelines*

The economic appraisal should be undertaken in accordance with the relevant national and NSW guidelines:

- Transport for NSW, "*Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*" V1.8, , Appendix 4 - Economic Parameter Values and Valuation Methodologies updated to June 2018.
- Transport and Infrastructure Council, "Australian Transport Assessment and Planning", (previously called National Guidelines for Transport System Management (NGTSM)) with the latest release on June 2018.
- NSW Treasury, "NSW Government Guide to Cost-Benefit Analysis", OFM tpp17-03, March 2017.

These guidelines and the economic parameters recommended for estimating costs and benefits are broadly consistent. Where these guidelines are inconsistent the precedence should be given to the relevant TfNSW Economic Appraisal Guidelines, since they have been developed and calibrated specifically for the transport context in NSW.

Where the economic appraisal is part of Business Case development, relevant Business Case policy, guidelines and templates should also be adhered to. Refer to Business Case Guidelines /Template.

3.2 Purpose

The purpose for this brief is to seek professional services in economic appraisal for the development of the Strategic/Final Business Case for (Project).

3.3 Scope of Economic Appraisal services

Depending on the project need, the economic appraisal services could be one or all of the following:

- Strategic Merit Test
- Rapid Economic Appraisal
- Economic Appraisal
- Financial Appraisal

The required economic appraisal service should include the identification and measurement of benefits that are expected to be achieved through the development and implementation of the (PROJECT).

Typical transport benefits include:

- Value of Travel Time Savings (VTTS)
- Travel of Travel Time Reliability (VTTS)
- Vehicle Operating Cost (VOC) Savings
- Road crash reduction and benefit
- Environmental benefit
- Public transport amenity benefit
- Reliability benefit, if applicable
- Public transport option value, if applicable
- Wider Economic Benefits (WEBs), if applicable

Specific requirements for certain benefits:

- Any real escalation of VTTS are used for sensitivity test only
- WEBs are used for sensitivity test only
- Public transport Option Value, if estimated, is used for sensitivity test only

3.4 Transport modelling

The required economic appraisal service includes the development and running of a travel / traffic model that will generate the outputs at specific level of detail: travel zones, by origin-destination and assignment to routes for measuring the transport benefits, including reliability. The choice of modelling level depends on the type of project being evaluated.

The Consultant should specify the following information:

- Model to be used: STM, PTPM, WRTM
- Modelling years: For example, 2021 and 2031
- Modelling period: peak hours, interpeak, weekdays (minimum requirement is 1 hour am peak & 1 hour pm peak)
- Traffic vehicle breakdowns: Car, LCV and HCV
- Travel purpose: Private and business trips
- Public transport patronage

3.5 CAPEX and OPEX

The Project costs are provided below:

- CAPEX by year (Provide P50 or P90 cost depending on stage of Business Case)
- OPEX per annum - Detailed operating / maintenance cost
- Schedule of Major Periodical Maintenance and expected cost to reflect a whole of life cost profile
- Any resource cost correction expected (e.g., removing cost escalation, removing tax and transfer components)
- Expected cost variation (if any to allow the consultant to design meaningful sensitivity tests)

3.6 Methodology and Assumptions

The consultancy proposal should clearly outline the methodology to be used in the conduct of the economic appraisal, the parameters and the assumptions to be used in the appraisal.

3.7 Decision Criteria & Sensitivity Tests

The following indicators are required to be calculated and presented in the economic appraisal report:

- Benefit Cost Ratio (BCR)

There are two ways to calculate the BCR. The Consultancy economic appraisal report should provide the calculations for BCR1 and BCR2.

$$BCR1 = \frac{PV\ of\ Benefits}{PV\ of\ Capital\ Cost \pm PV\ of\ change\ in\ Recurrent\ Costs}$$

$$BCR2 = \frac{PV(Benefits \pm PV\ of\ change\ in\ Recurrent\ Costs)}{PV(Capital\ Cost)}$$

- Net Present Value (NPV)
- Net Present Value per dollar of Capital Investment (NPVI)
- Internal Rate of Return (IRR)

The economic appraisal report should provide a breakdown of estimated economic benefits and the assumptions used in estimating these benefits.

The economic appraisal should include sensitivity test scenarios relating to meaningful changes in specific variables, such as capex, opex, benefit stream, etc.

3.8 *Timeframe and deliverables*

The Economic Appraisal proposal should clearly enumerate the expected deliverables and timeframes.

Typical economic appraisal deliverables include:

- Strategic Merit Test report
- Rapid economic appraisal report
- Economic appraisal report
- Financial appraisal report
- Associated Excel models: TfNSW recognises consultant's intellectual property of associated models. However, the access of fully linked and workable model is essential for reviewers to check, verify and validate the estimated costs and benefits. The consultant is obliged to provide the Excel model to the Principal.

The economic appraisal report should include a summary table of economic appraisal results (See Appendix 1) for the summary template.

Other project deliverables include:

- Workshop or presentation held by the consultant to the Principal and relevant stakeholders
- Database and survey collection data

Use a Gantt chart to specify the deliverables and expected timeframe and milestones. An example is provided below.

Project delivery and timeline

	Task Name	Responsible	Duration	Sep-16				Oct-16			
1	Provide input data	Principal	1 wk								
2	Draft economic appraisal report	Consultant	4 wk								
3	Review of the draft report	Principal	1 wk								
4	Final report	Consultant	2 wk								

3.9 *Price*

Provide the price for the conduct of the economic appraisal study and reporting, i.e the total price and the breakdown of the total price, including the hourly rates for each resource category and the hours per week to be provided by each resource.

Where assumptions have been made in relation to the costs and pricing, these will need to be stated in this section.

4. Response to this Consultancy Brief

Prospective Service Providers must submit a bid to complete the Services described in this Consultancy Brief within the timeframe required.

4.1 Response to this Consultancy Brief

The interested Service Provider should provide the following information:

- A detailed yet succinct response to each of the selection criteria (see Section 5.1 below), including an outline of proposed methodology, relevant experience and capacity to undertake the task.
- An outline of the project plan, which includes timelines for outputs and deliverables.
- A breakdown of the proposed budget and a fee schedule and an itemised list of project related expenses (GST should be as a separate item in the budget). Key personnel and their daily or hourly rates should also be presented.
- Names of all persons proposed to work on the project, describe their proposed role and level of involvement, and provide information that demonstrates their capacity to undertake their proposed role.
- Detail other resources required to undertake the task.
- A declaration of any possible disclosures or conflict of interest that may affect the consultant's independence during this contract.
- Demonstrate financial capacity to undertake the task and any risks that might impact the task.
- Adhere to Code of Conduct, Ethics & Probity, Work, Health & Safety and other management systems.
- Names and contact details of two referees.
- Other matters which should be taken into account in the evaluation of the RFO/EOI.

4.2 Personnel requirements

- A thorough understanding of, and experience in, economic and financial analysis techniques applied to transport proposals at the regional, network and/or corridor levels.
- A thorough understanding, and experience in delivering the economic and financial components of a business case.
- Strategic thinking and problem solving skills and experience in applying these to large scale multi-disciplinary programs and projects.
- Success in working with multi-disciplinary teams.
- Availability to carry out the Services for the required time commitment.

5. Management of services

5.1 Selection of the preferred service provider

The selection of the successful consultant will be made on the basis of merit. The selection of the preferred service provider will be based on the following criteria:

- Demonstrated knowledge and experience in the industry and/or the task.
- Demonstrated understanding of the tasks specified in the project brief and the scope and magnitude of work required in the timeframes.

- The suitability of the methodology to the project's objectives.
- Proven experience and track record in undertaking economic appraisal and/or tasks stated in the project brief.
- Demonstrated high level project management skills including a capacity to meet project deadlines.
- Personnel with the required skills, professionalism, experience and availability.
- Confidence and ability to meet all deliverables and outcomes.
- Total professional service fees and value for money.

5.2 Document submission

All documents described in this Consultancy Brief that are to be provided to the Principal must be submitted in soft copy formats.

All reports, schedules or plans submitted by the Service Provider to the Principal are to include a title, date, author (individual and company) and company contact details.

The Service Provider must ensure that all documents submitted are checked and approved prior to delivery to the Principal.

5.3 Document quality

The Service Provider must submit all documents progressively to the Principal in accordance with the timeframes contained in this Consultancy Brief.

All draft and final documents produced as part of the Services must demonstrate a high quality of drafting. This is an essential requirement of the Services. All draft and final documents issued to the Principal should be at a standard such that they do not require substantial rework as a result of poor document design, drafting and editing, or because of the lack of appropriate senior review by the Service Provider.

5.4 Consultant's Obligations and Requirements

- The consultant will be required to adhere to the "Professional Service Agreement" with Transport for NSW / RMS which includes confidentiality, privacy and disclosure, conflict of interest and insurance.
- Achieve the deliverables within the agreed timeframes and within the agreed budget.
- Provide highly skilled and collaborative input to deliver the Services.
- Manage risks, issues, assumptions, dependencies and ensure they are properly identified, resolved or mitigated.
- Manage change control and ensure proposed change requests (i.e. to time, cost, quality or scope) are properly identified and appropriately controlled.
- Monitor and assure quality outputs and deliverables.
- Provide expert economic analysis and Business Case input services.
- Provide assistance and input to project management and Business Case development.

- Assist in the development of a Business Case that meets the assurance process undertaken by TfNSW.
- Provide specialist analysis, advice and input to program management tasks.
- Provide generally high quality services and documentation.

Economic Appraisal Summary Report APPENDIX 1

PROJECT INFORMATION: (Please complete this form for all Projects)

Item				
	PROJECT DESCRIPTION			
1	Decision Unit	(e.g., TNSW, Division, RMS, RailCorp, SF, STA)		
2	Project Name			
3	Project Option Name			
4	Project's Funding Program/Subprogram Name			
5	Current Status of Project (most recent achieved milestone: (pre-PDP, PDP, EIS, REF, PIP)			
	QUALIATATIVE STRATEGIC INITIATIVES & MOTIVATION FOR THE PROJECT (PROBLEM BEING ADDRESSED)			
6	Improve public transport system			
7	Reliable public transport			
8	Improve Efficiency of Network			
9	Improve Safety & Security			
10	Enhance/maintain Infrastructure			
11	Regional Equity			
12	Improve accessibility			
13	Others			
	BASE CASE			
14	Base Case Description			
	PROJECT OPTION DESCRIPTION			
15	Project Option Name / Description			
16	How are the Project Goals being met?			
17	How many other options considered?			
	PROJECT BENEFITS - List and present the PV of benefits for the base case and project option(s)			
	(Over the project period)	Base Case	Option 1	Option 2
18	Avoidable Capital Cost			
19	Avoidable Recurrent Cost			
20	Asset Sale Proceeds			
21	Incremental net revenue			
22	Travel time savings			
23	Patronage benefits			
24	Operating cost savings (VOC)			
25	Environmental benefits			
26	Safety & Security			
27	Improved Service Reliability			
28	Improved comfort /amenities			
29	Wider Economic Benefits			
30	Others (e.g., Social Inclusion)			
	PROJECT COST			
31	**Capital Cost**			
32	Land and Property			
33	Construction Cost			
34	System & Set Up cost			
35	Capital Replacement Cost			
36	Refurbishment / Upgrade cost			
37	Decommissioning Cost			
38	Construction Dis-benefits / Costs			
39	Others, e.g. inventories			
40	Contingency Cost			
41	**Annual Operating Cost**			
42	**Annual Maintenance Cost**			

B. COMPARISON OF OPTIONS - RESULTS

INCREMENTAL BENEFITS -PREFERRED OPTION RELATIVE TO THE BASE CASE

	AGENCY & USER BENEFITS	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Annual Ave. thereafter**
43	Avoidable Capital Cost						
44	Avoidable Rec. Cost						
45	Asset Sale						

46	Net revenue						
47	Travel time savings						
48	Patronage benefits						
49	Operating cost savings						
50	Environmental savings						
51	Safety & Security						
52	Others (quality, comfort,)						
	Wider Economic Benefits (WEB)						
53	Agglomeration						
54	Productivity						
55	Others						

C. PRESENT VALUE INCREMENTAL BENEFITS - PREFERRED OPTION RELATIVE TO BASE CASE

		@7% Discount Rate	**@3% Discount Rate**	**@10% Discount Rate**
56	Avoidable Capital Cost			
57	Avoidable Recurrent Cost			
58	Asset Sale			
59	Net revenue			
60	Travel time savings			
61	Patronage benefits			
62	Operating cost savings			
63	Environmental cost savings			
64	Safety & Security			
65	Others (quality, comfort, etc)			
66	WEB			

D. CBA SUMMARY INFORMATION-PREFERRED OPTION (RELATIVE TO BASE CASE)

		@7%	**@3%**	**@10%**
67	**NPV**			
68	**BCR**			
69	**NPVI**			
70	**FYRR**			

E. PROJECT RISK IDENTIFICATION & ASSESSMENT

	1 - Identify the Key Risk to Total Cost					**Sensitivity Analysis PV Cost**		
		Likelihood[1]	**Impact[2]**	**Assessment[3]**		**Low**	**Nominal**	**High**
71	Key Risk 1							
72	Key Risk 2							
73	Key Risk 3							
74	Others							
	TOTAL							
	2- Identify the Key Risk to Total Benefits					**Sensitivity Analysis PV Benefit**		
75	Key Risk 1							
76	Key Risk 2							
77	Key Risk 3							
78	Others							
	TOTAL							

	3 - TOTAL RISK IMPACT ON:			
79	PV COST			
80	PV BENEFIT			
81	NPV			
82	BCR			

APPENDIX 6

Checklist for the conduct of economic appraisal

Introduction

This checklist is to help analysts, consultants, project managers and funding units to determine the completeness of a project's economic evaluation. It also includes a checklist pro-forma which can be prepared and signed off by the analyst and the project manager to confirm that all aspects of the evaluation have been completed.
Specifically, the checklist is to:

- Confirm that all sections of the economic evaluation have been completed and none have been overlooked by mistake.
- Confirm that all sections are presented in sufficient detail to allow the project's consideration for planning, programming, and funding.
- Highlight any issues that should be considered before submitting the project for inclusion in the road program.
- Direct reviewers to the appropriate sections of the evaluation where the assumptions are discussed.

Reviewing Evaluations

In seeking to verify the completeness of a project evaluation, the following checklist provides a guide as to what the reviewer should be looking for within the documentation.

- Does the evaluation address the project's stated objective or the problem it is designed to solve?
- Is the base case and alternative options identified?
- Is the traffic or transport model used in the evaluation identified?
- Are the data sets appropriately described?
- Are all relevant costs and benefits identified and quantified or where appropriate?
- Has the appropriate evaluation technique(s) been applied?
- Does the evaluation use the latest economic parameter values?
- Are the benefit and cost streams discounted at 3%, 7%, 10%?
- Does the evaluation address uncertainty and risk? (Sensitivity analysis).

Additional Issues

When reviewing an economic evaluation:

- Ensure that any assumptions made in the evaluation can be considered relevant to project and recorded in the report.
- Take the time to review the spreadsheet summaries that determine the Benefit Cost Ratio (BCR) and other evaluation results. See Appendix 3 for the Discounted Cash Flow (DCF) Pro Forma for the CBA. It is important to do the DCF for each option and to check the data entries and calculations to ensure that no errors have occurred.

Pro-forma Checklist for Economic Evaluations of Projects

It is appropriate to record that both the analyst preparing the evaluation and the project manager has reviewed the thoroughness of a project's economic evaluation and report on whether they find it satisfactory. The pro-forma below is a checklist which is completed by indicating whether the information provided in the economic evaluation report is satisfactory, unsatisfactory or not required.

Comments should be provided, particularly if some information content(s) are unsatisfactory. The completed checklist should be attached to the economic analysis report.

A general recommendation should be made about whether the project should proceed as it stands or whether further works/specifications are required.

The checklist is to be signed by both the analyst and the project manager.

NAME OF THE PROJECT: ______________________________________
DIVISION / BRANCH: ____
PROJECT MANAGER: ____
LOCATION OF PROJECT: ______________________________________
PROJECT AMOUNT: ____

PROCEDURE	Information Provided S=Satisfactory U= Unsatisfactory N=Not Required	COMMENTS
1. Purpose Of CBA Project objective and the objective of the evaluation clearly specified.		
2. Compliance with Treasury and TFNSW and other funding agency guidelines		
3. Key Inputs to the Evaluation a. **Parameters used** Appropriate parameters are used in the analysis either by staff or by external consultants - Travel time calculations - VOC calculations - Accident costs calculations - Amenity values - Reliability estimation -Environmental Benefits -Others (specify) b. **Assumptions,** e.g.. - population /traffic growth - other projects (to be) completed - cordon area - others c. **Traffic Data Generated**		

4. Approach/Methodology a. Base Case Developed. b. Alternative Options Identified c. All relevant project costs identified & quantified. - Capital Cost - Operating and Maintenance d. Benefit Calculations - all possible project benefits identified and quantified. 1) Quantifiable Passenger Benefits User Costs Savings Avoided Cost. VOC Cost Saving. Travel Time Savings. Others		
2) Non-quantifiable Qualitative factors identified and possibly valued in the analysis: - Environmental factors - Road safety Others (Specify) e. Time Stream of Costs and Benefits f. Discounting Calculations/ Discount Rate g. Incremental Analysis undertaken		
5. Transport Model Validation		
6. Decision criteria (please tick) CBA - NPV - NPVI - BCR - IRR - FYRR		
CEA - PV - PVI - FYRR		
7. Risk and Sensitivity Analysis		
8. Results a. Accuracy of results b. Impact of results (compared to the base case results		
Comments by Analyst completing the Checklist Name: Signature: ________________ Date Recommendation:		
Comments by the Project Manager: Name Signature:________________ Date Recommendation:		

APPENDIX 7

Summary of environmental externality parameters & methodology

The environmental externality parameters have been indexed from the Guide to Project Evaluation, Part 4 Austroads (2008) and the National Guidelines for Transport system Management in Australia, part 3 (ATC 2006a). The methodologies involved in these valuations are summarised in the table below.

Environmental Externality	Sources	Methodology
Air Pollution	Austroads 2003d Infras/IWW (2000)	Austroads (2003d) uses values from the Infras/IWW study, a European study valuing environmental externalities in 17 European countries using a control/ avoidance cost approach. This method reflects the cost of prevention or mitigation. The study uses estimates of externality costs from the Transport and Environment Database System (TEDS) which provides forecasts volumes and emissions for the 17 EU countries. Human health costs, building damages and crop losses were included. Results from the study were then calibrated to Australian conditions which adjust for Purchasing Power Parity (PPP), vehicle occupancy rate and population density (as Australia has a more dispersed population than Europe). The results from Infras/IWW study are presented in Euro/1000vkt.
	ATC 2006b Watkiss 2002 Cosgrove 2003 Pratt 2002 ExternE 1999	ATC calculates air pollution values using \$/tonne health costs of air pollutants from Watkiss (2002). The health costs are derived by assessing the increase in air pollution from vehicle emissions using air quality dispersion models. The output of these models is linked to population and the impact of the number of people exposed to increases in emissions is then assessed. These impacts are quantified using exposure or dose response functions which link pollution concentrations and impacts (e.g. number of respiratory cases per level of pollution). Finally, the value of mortality is calculated through the Willingness To Pay (WTP) methodology. Emission factors from Cosgrove (2003) were derived from modelling the transport subsectors, using vehicle fleet models, which is then aggregated (bottom up approach). (ABS Survey of Motor Vehicle Use data). Once these factors are obtained, the methodology is outlined by Pratt (2002) where emission factors or conversion rates (g/vkm) are used to derive the air pollution cost. The health costs (\$/tonne) is multiplied by the emission factors (g/vkm) to arrive at the air pollution cost (cents/vkm).

		Watkiss (2002) reports $/tonne estimates using results from the ExternE (1999) study (a European study which provides economic evaluation of a range of climate change impacts). These are adjusted for Australian population densities (by GIS data) as well as using the population weighted average to obtain national values for urban locations. The Watkiss (2002)/ExternE (1999) study uses a damage cost approach which measures the damage or opportunity costs for the society that is suffering from environmental impacts. Pollutants relevant to Australia include CO, NO_x, PM_{10} and total hydrocarbons. As recommended by ATC, rural values are 1% of the urban value.
Greenhouse Gases	Austroads 2003d ExternE 1999	Values for greenhouse gases are sourced from ExternE (1999) which provides damage cost estimates and are similarly calculated as above using a $/tonne CO_2 damage cost, converted to cents/vkm. The ExternE (1999) study provides damage cost estimates ($/tonne) using the WTP approach. If not equity weighted this would show that poorer countries have lower WTP implying that environmental damage on poorer nations is less important as the same damage imposed on richer nations since WTP is a function of income and is different for countries and individuals.
Noise	Austroads 2003d Infras/IWW 2000	The noise parameter value is taken from the Infras/IWW (2000) study. Noise costs are estimated as the sum of the WTP for noise reduction (defined as a silent space above 55db) and the valuation of health effects of noise exposure (i.e. disturbance and stress). The results of Infras/IWW (2000) suggest that 60% of the total noise costs is associated with WTP for noise reduction and 40% from health effects. Values were adjusted for Australia using vehicle occupancy rate, population weighted density and PPP.
Water Pollution	ATC 2006b Pratt 2002	ATC estimates water pollution based on mitigation costs (control costs) which is based on estimating the social cost of installing mitigation devices (e.g. sedimentation tanks, treatment of storm water runoff) on a per vehicle kilometre basis (presented in cents/vkm). These mitigation costs are from a New Zealand Land Transport Pricing study. No adjustment for Australian conditions is made as mitigation methods in New Zealand are similar to Australia.
	Austroads 2003d	Austroads also considers WTP in estimating the water pollution parameter value. Using the WTP methodology, water pollution represents 15% of the air pollution for passenger cars.

Nature &Landscape	Austroads 2003d Infras/IWW 2000	Values are taken from the Infras/IWW(2000) study and are adjusted based on the vehicle occupancy rate. The values estimated by the study are based on the costs of repair and compensation, which is the cost that is necessary to improve existing infrastructure to a state that is environmentally acceptable (defined as the environmental state in 1950). The area of land impacted by road transport is determined (i.e. length of road, tracks) and then is multiplied by unit cost factors ($/m^2) for repair and compensation costs. The repair cost consists of 4 unit costs: unsealing, ecosystem, soil/water and other (such as barrier and visual impacts).
Urban Separation	Austroads 2003d Infras/IWW 2000	Values are taken from Infras/IWW (2000) study and are adjusted based on vehicle occupancy rate. The Infras/IWW (2000) study assesses constraints to the mobility of pedestrians to value urban separation effects (using a unit cost of time lost per person per hour). To calculate the urban separation effects, the network data (km of urban roads) as well as data on crossings per day and time losses per crossing is collected, then multiplied by the unit cost and aggregated to urban population.
Upstream and downstream	Austroads 2003d Infras/IWW 2000	Values are taken from Infras/IWW (2000) study and are adjusted based on vehicle occupancy rate. The study applied percentage factors to the air pollution and greenhouse gas costs to produce estimates to derive the upstream and downstream costs. For a particular identified process (i.e. vehicle production), the relevant emissions were identified and the cost factors (percentage of total air and greenhouse gas costs) were calculated.

References

- ATC (2006a), National guidelines for transport system management in Australia, part 3: appraisal of initiatives, Australian Transport Council.
- ATC (2006b), National guidelines for transport system management in Australia, part 5: background material, Australian Transport Council.
- Austroads (2003d) Valuing Environmental and other externalities APR-229, Austroads.
- Cosgrove, D.C (2003) Urban Pollutant Emissions from Motor Vehicles: Australian Tends to 2020, BTRE consultancy report for Environment Australia.
- European Commission (1999) ExternE: Externalities of Energy volume 8 Global Warming, European Commission.
- Infras/IWW (2000), External Costs of Transport – Accidents, Environmental and Congestion Costs in Western Europe, Zurich/Karlsruhe.
- Pratt, C (2002) Estimation and valuation of environmental and social externalities for the transport sector, 25th Australasian Transport Research Forum.
- Watkiss, P (2002) Fuel Taxation Inquiry: The air pollution costs of transport in Australia. A report for the Commonwealth of Australia.

APPENDIX 8

Appraisal Summary Table

INSTRUCTIONS: Provide a score if the Project / Program or Option meets the criteria under each Expected Outcomes

NAME OF PROJECT: PROGRAM:

PROJECT SPONSOR: **PROJECT MANAGER:**

EXPECTED OUTCOMES	**SCORED QUALITATIVE ASSESSMENT**						
		MAX. SCORE	**BASE CASE AND OPTIONS**				
	CRITERIA		**BASE CASE**	**1**	**2**	**3**	**4**
1 – Better perception of Government	The Project/Program facilitates / enables internal process improvements rendering BETTER government service Increases Integrity Seen to be more transparent Regulation and compliance with best practice and legislation						
	Maximum Possible Score	**4**					
2 – Delivers specific values ***A. Government Improvement***	The Project/Program directly affects work practices and creates direct benefits which are as follows. • More Effective Outcome (e.g., direct improvements in core administrative functions) • Improve the quality of Government service • Provides new / better Information • Enhance organisational capability • Enables improved decision making and accountability assignment • Enables infeasible but desirable activity Prevent or reduce undesirable events or outcomes • Contributes to improvement of internal infrastructure resulting in improved service capability						
	Maximum Score	**7**					
B. Financial Benefits	• More Efficient Process (Internal efficiency) • Resource savings for the public						
	Maximum Score	**2**					
C. Social Values	• Contributes to improved transport services to the public (e.g. improved accessibility & affordability) • Contributes to improved services to the disabled and disadvantaged • Contributes to improved transport service reliability due to better monitoring and reporting • Greater convenience to the citizen (can pay online, no travel required)						

EXPECTED OUTCOMES	CRITERIA	MAX. SCORE	BASE CASE	1	2	3	4
		SCORED QUALITATIVE ASSESSMENT					
			BASE CASE AND OPTIONS				
C. Social Value (Con't)	● Increased satisfaction with quality of service, ● Increased social status ● Stronger relationships among agencies communities						
	Maximum Score	**7**					
D. Customer Value	● Increased participation ● Promote fairness ● Promote transparency						
	Maximum Score	**3**					
E. Environment Value	● Promote increased safety ● Promote increased security ● Supports environmental targets and reduction in CO2 emissions						
	Maximum Score	**3**					
3. Aligns or promotes Agency key objectives	● Improve performance across NSW Rail, Bus and Ferry network ● Coordinate the provision of more reliable and secure transport services ● Provide equitable and accessible transport services to meet community demand						
	Maximum Score	**3**					
3. Resource Option	***Funding / resource alternatives*** ● No funding / resource alternatives ● Potential for sharing of internal resources ● Potential for external funding (government grants) ● Already included in the budget						
	Maximum Score	**4**					
4. Readiness & Deliverability	● Governance structure & project/program management in place						
	Maximum Score	**1**					
	TOTAL SCORE	**34**	**0**	**0**	**0**	**0**	**0**
Additional Comments	***<Provide any additional comments that could serve as supporting information for the intangibles>***						

Total Point Score=34 MAXIMUM POINT AVAILABLE =5.45	**Discounted Total Project Cost NPV@7%**	**BENEFIT COST SCORE [1]**				
	$155,000,000	**0.22**	**0.00**	**0.00**	**0.00**	**0.00**
	B-C SCORE (Qualitative Assessment)	**0.22**				
	HYBRID BCR [2]					

[1] **Benefit Score is = Project Points ÷Project Cost, in $m**

[2] **Hybrid BCR can be calculated by adding the B-C Qualitative Assessment Score to the BCR derived from the usual quantitative cost benefit analysis study.**

APPENDIX 9

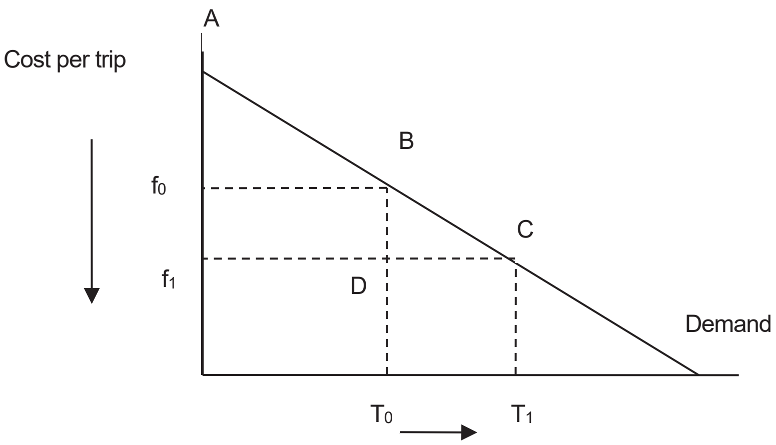
Technical Appendix- Consumer Surplus and LogSum Measure

1. CONSUMER SURPLUS

Consumer Surplus is a measure of benefits defined as the difference between what the customer is willing to pay and the actual amount paid. This is represented in the diagram below.

Figure 1 Consumer Surplus from induced trips

At cost f_0, the consumer surplus is the triangle



ABf_0. When there is a decrease in trip cost (f_1), the additional consumer surplus is f_0BCf_1. The rectangle f_0BDf_1 represents the savings to existing trips while triangle BDC is the benefit from the induced trips.

The consumer surplus can be calculated using the fare elasticity, which is readily available. RailCorp has derived a methodology for estimating the consumer surplus by integrating the demand function which is in the form of a negative exponential and a function of the fare:

$$CS = \int_{f_0}^{f_1} Q(f)df$$

where:
$Q(f)$= demand function given by: $Q(f) = \alpha e^{-\lambda f}$
CS = consumer surplus
f = average fare
λ,α = constants

Using the point elasticity formula for negative exponential, the consumer surplus simplifies to:

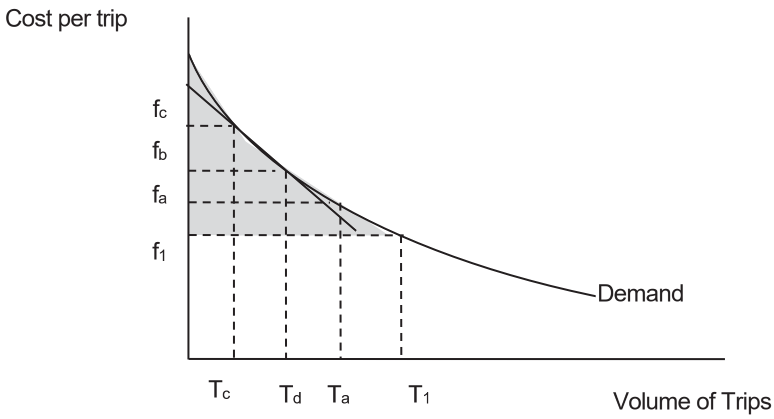
$$CS = \frac{f_1 \, x \, Q}{\varepsilon} = \frac{f_1(T_1 - T_0)}{\varepsilon}$$

where:
CS = consumer surplus
f = average fare
Q = number of induced trips (T_1-T_0)
ε = fare (price) elasticity

Numerical Integration

In some cases, using the "Rule of Half" to estimate consumer surplus from induced trips may not be accurate such in the case of large changes to price. Numerical Integration is a method developed as an alternative to approximate the Rule of Half in the economic appraisal of new modes. Numerical Integration involves defining a set of trapeziums to approximate the change in consumer surplus[1]. This method involves using additional/intermediate points on the demand curve and applying the rule of half to each pair of adjacent points, resulting in a more accurate approximation of consumer surplus. This would be best calculated using economic analysis software.

Figure 2



2. Use of Logsum measure of consumer surplus benefits

The benefits of transport projects and initiatives are measured in terms of consumer surplus. The current practice is usually through the use of the "Rule of Half".

The left side of Figure 3 shows that, when a new transport mode is introduced with the travel cost *C* and number of trips of *T*, the consumer surplus benefits are shown in the shaded triangular area because some travellers are willing to pay more than the cost *C*. The right side of Figure 3 shows that, when a transport improvement lowers the travel cost from C_0 to C_1, the number of trips increases from T_0 to T_1. The benefits for existing trips are the reduced travel costs as shown in shaded rectangular area. The consumer surplus benefits for induced trips are shown in shaded triangular area. The rule of half (ROH) approach is used to measure the consumer surplus benefits in conventional economic appraisals. These benefits can be further separated into different categories typically including travel time savings, vehicle operating cost savings and accident cost savings etc.

Figure 3 Consumer surplus benefits of transport projects

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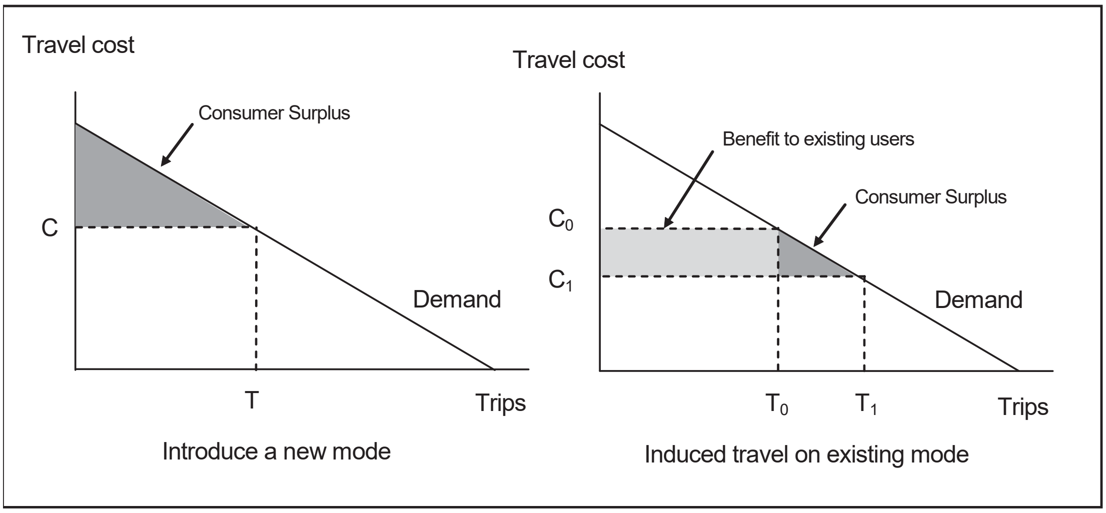
[1] Nellthorpe, John & Hyman, Jeff (2001). Alternatives to the Rule of Half in Matrix-Based Appraisal. Institute of Transport Studies, UK



When transport demand and mode choice are modelled in logit models based on random utility maximisation (RUM), the above consumer surplus benefits could be obtained in the demand modelling. These benefits are mathematically expressed as:

$$E(CS_n) = \frac{1}{\propto n}[ln\left(\sum_{j=1}^{JA} e^{VA}{}_{nj}\right) - [ln\left(\sum_{j=1}^{JB} e^{VB}{}_{nj}\right)$$

where,

n – Individuals

CS – Consumer surplus

CS_n – Consumer surplus of individual n

$E(CS_n)$ – Expected consumer surplus benefits for all individuals n under the condition before and after transport improvement

α_n – Marginal utility in income, $1/\alpha_n$ acts as the factor that converts the utility into dollar term

B – Represent the condition before transport improvement, usually referred as the base case

A – Represent the condition after transport improvement, usually referred as the project case

j – Transport mode alternative. Before transport improvement, $j = 1,2, \ldots\ldots, JB$, representing that there are JB transport alternatives. After transport improvement, $j = 1,2, \ldots\ldots, JA$, representing that there are JA transport alternatives

V – Utility, VB_{nj} represents the utility derived from alternative j by individual n before transport improvement. VA_{nj} represents the utility derived from alternative j by individual n after transport improvement

$ln(\sum_{j=1}^{JA} e^{VB}{}_{nj})$ represents total utilities derived by all individuals n from all transport mode alternatives JB before transport improvement.

$ln(\sum_{j=1}^{JA} e^{VA}{}_{nj})$ represents total utilities derived by all individuals n from all transport mode alternatives JA after transport improvement.

The equation shows that consumer surplus is measured from the logarithm of the sum of utilities derived from all transport users from all available transport models. As such, the consumer surplus benefits are referred as "logsum" which is also known as *inclusive values*.

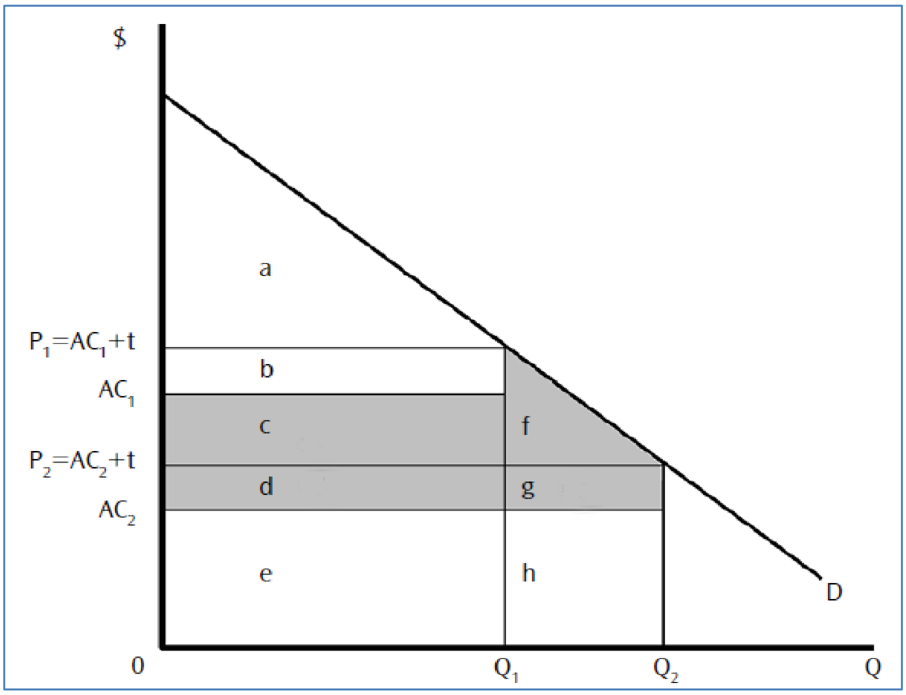
Theoretically, the logsum approach is more accurate because it is based on actual demand curves, while the ROH approach assumes the linearity of the demand curve as shown in Figure 1. However, the logsum approach has not been used often in actual economic appraisals. This is because the logsum is essentially the sum of utilities which has no unit, while in conventional economic appraisal, benefits are directly estimated in dollar term. To convert the utility into dollar term, analyst must estimate the marginal utility of income, which varies from the project specific surveys and there is no formal guide how it should be derived. In addition, logsum is estimated as the total utilities. Although it is possible to separate the utilities for different attributes (e.g., fare, travel time or comfort), it is not easy to estimate conventional transport benefits in terms of value of travel time savings, vehicle operating cost savings, accident cost savings and transport externality benefits. Finally, in some projects, transport demands are not estimated from utility models in which logsum can be calculated.

The TfNSW recommends that consumer surplus benefits continue to be estimated using the ROH approach. For certain projects where the logsum from the utility models can be readily estimated and the marginal utility with respect of income is available, the logsum approach can be used in economic appraisal with appropriate cross-check with benefits estimated from ROH approach.

3. Resource Cost Correction on Public Transport Project Model (PTPM)

Resource cost correction is based on consumer surplus theory as illustrated in the figure below:

Figure 4 Consumer surplus at the perceived behavioural cost and the social resource cost



Source: ATC 2006 National guidelines of transport system management, Volume 5, P55

In this figure, subscript 1 denotes the base case and subscript 2 denotes a transport project case, thus:

P1 – perceived behavioural cost at the base case
P2 - perceived behavioural cost at the project case
AC1 – social generalised cost at the base case
AC2 - social generalised cost at the project case

Q1 – number of trips or demand at the base case
Q2 – number of trips or demand at the project case

The perceived consumer surplus

The perceived consumer surplus can be estimated as:

$$Perceived\ Consumer\ Surplus = (P1 - P2)x\frac{(Q1 + Q2)}{2}$$

It is assumed that the perceived consumer surplus has been estimated in PTPM logsum output, as the PTPM is based on behavioural values. This output can be expressed as a generalised in-vehicle travel time, or other types of utilities.

Please note that the rule of half is only applied to the induced trips (Q2-Q1) at the perceived cost, shown in "area f".

Resource cost correction steps

The estimation of the consumer surplus at social resource cost is a process which can be referred to as the resource cost correction. This can be done in the following 5 steps:

1. Convert the perceived cost into resource cost (ie, P1 is converted to AC1, P2 is converted to AC2), by changing the behavioural parameters to resource parameters (for VTTS, VOC etc.), removing tax components in perceived cost, and removing transfer components from perceived cost (e.g., toll, public transport fare).

2. Extract the user surplus from PTPM

$$A = (P1 - P2)x\ \frac{(Q1 + Q2)}{2}$$

3. Calculate the increase in the perceived cost

$$B = Q2P2 - Q1xP1$$

4. Calculate the increase in the resource cost

$$C = Q2\ x\ AC2 - Q1\ x\ AC1$$

5. The user benefits after the resource cost correction is calculated as

$$D = A + B - C$$

Please note that the resource cost can be either higher or lower than the perceived cost. The above resource cost correction can be used in both situations. Unperceived cost can also be included in this framework but it is recommended that the unperceived resource cost is separately presented following the common practice.

APPENDIX 10

Probabilistic Cost Benefit Analysis

This appendix demonstrates probabilistic cost benefit analysis through the use of Monte Carlo simulation approach. Using the software @risk, a Monte Carlo simulation can be undertaken where probabilistic distributions of the benefits and cost of the project were generated rather than single numbers. These were then used to generate the probabilistic distribution of the Benefit Cost Ratio (BCR), the NPV and other decision criteria.

The following are specific steps to follow in applying Monte Carlo risk analysis to conduct probabilistic cost benefit analysis.

1. Determine the associated cost drivers and risks. These variables reflect potential risks and uncertainties that would impact on the evaluation criteria BCR and NPV. All possible risks to a project should be identified and quantified to be able to adequately capture the uncertainty associated with the projects. These variables are usually based on professional judgement. The candidates of risk variables may include cost estimate, transport demand elasticity, travel time reliability, economic life of certain asset or road crash reduction rate etc.
2. Specify plausible ranges of values and statistical distributions to all risk items. Statistical distributions can be discrete (e.g., Poisson, Binomial) or continuous (e.g., Normal, Logistic, Weibull). The @RISK provides 71 mostly used statistical distributions. In practice, it is important to determine which distribution a variable may follow as the different specification will change the simulation result. If there are observations or historical data, the Distribution Fitting function in @Risk can be used to discover the most appropriate distributions. As a rule of thumb, the number of observations should be 30 as a minimal for use of the Distribution Fitting. If there are insufficient observations, professional judgement and guided assumption can be used to decide the statistical distribution.
3. Account for correlation between risk elements. When modelling associated cost drivers and risks, it is important to consider the impact of inter-relationships between risk items to generate accurate and sensible output. Failure to suitably account for correlation between project risks can result in artificially tight project cost distributions and an incorrect assessment of true project risk.
4. Generate a probability distribution using Monte Carlo simulation methods. The most common technique in combining the individual elements and their distributions is by using Monte Carlo simulation. Monte Carlo simulation is a computerised mathematical technique that facilitates accounting for risks in quantitative analysis and decision making, A number of easy to use proprietary tools exist for implementing this to incorporate risk in project evaluation. The most widely used ones are @Risk and Oracle's Crystal Ball. The Evaluation and Benefits Branch, Finance and Investment uses @Risk and is able to provide assistance to projects by way of undertaking the Monte Carlo simulation modelling for these projects.
5. Add simulation outputs. During a Monte Carlo simulation, values are sampled at random from the input probability distributions of the risk items. These results are combined to obtain an outcome for each iteration. This process is repeated hundreds or thousands of times, and the result is a probability distribution of possible outcomes. The resultant probability distribution of possible outcomes indicates not only what could happen, but also the likelihood of it happening. In the CBA, the mostly used simulation output is NPV and BCR. The simulation will calculate the mean, median and percentile values of the BCR and NPV. It will also be able to generate the distribution of the outputs including the probability of $BCR \geq 1$ or $NPV \geq 0$ that provide additional information on economic viability for decision making.

6. Simulation settings: specify the number of simulations and number of iterations. The @RISK allows the maximal number of simulation of 100 and the maximal number of iterations of 10,000. The selection of the settings is to balance the accuracy and simulation time. A normal simulation can be done within 1-2 minutes with an average modern computer thus the maximal number of iterations can be used in most situations.
7. Check the simulation results. The outputs from a simulation include the probability density, cumulative ascending and tornado charts. For each simulated output variable, it generates the minimum, maximum, mean, median, standard deviation, skewness, kurtosis and percentiles. The simulated output can also be readily fitted into a distribution. If the simulated results are strange, the user should check and revise the input specifications, and redo the simulation.

The following section presents a worked example of cost benefit analysis of life jacket use campaign illustrating the use of @Risk simulation.

Over the last 10 years, there were on average 17 fatalities annually on New South Wales' waterways, of which a large proportion was as a result of drownings which could have been prevented by wearing a lifejacket. The most common characteristic of the majority of the fatalities on waterways is the failure to wear a lifejacket. A lifejacket safety campaign was proposed to promote lifejacket wearing and to reduce drowning fatalities.

The target groups for the campaign are males aged 35-54. The campaign is aimed at reaching this demographic as they are the most over-represented group in recreational boating fatalities in New South Wales. The total cost of the campaign is estimated at $1,400,000 over the 2015/16 financial year starting from September 2015. Of this, $1,100,000 is for the media cost covering the advertisements across channels such as television, print, radio, out of home and online/digital. The remaining $300,000 is for administration, production costs and agency fees.

Identify @Risk input variables

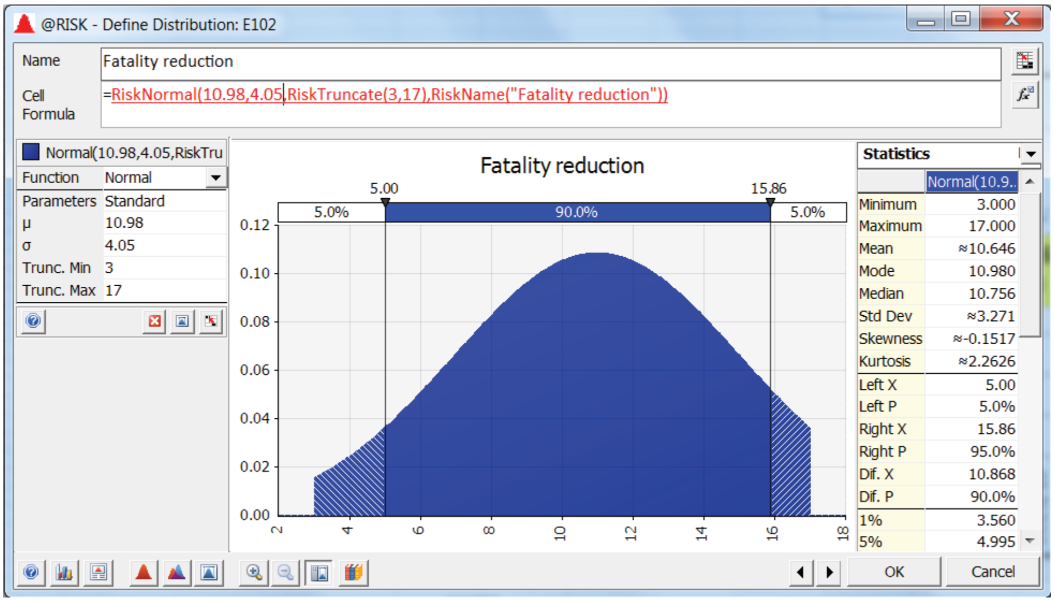
@Risk Input Variable 1: Fatality reduction

Statistical modelling shows that the preventable fatalities are 11.79 per annum without the campaign reduced to 10.98 with the campaign (see table below). The estimated preventable fatality reduction is subject to certain level of statistical confidence, which is set as the first input variable.

Table 10.1 Forecasting preventable fatalities in the base case and option

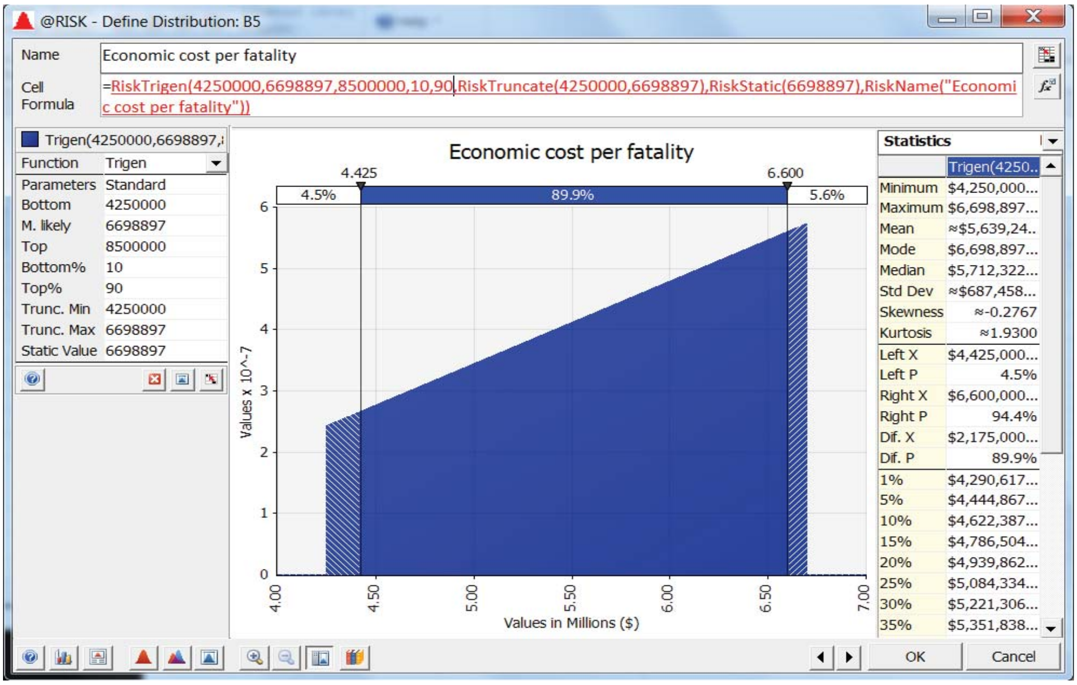
Financial Year	Preventable fatalities Base case: NO campaign	Preventable fatalities, Option: With the campaign
2003/04	5	5
2004/05	5	5
2005/06	6	6
2006/07	8	8
2007/08	8	8
2008/09	9	9
2009/10	15	15
2010/11	6	6
2011/12	12	12
2012/13		17
2013/14		3
2014/15		10
2015/16 (forecast)	11.79	10.98 **@Risk Input Variable 1**

The historical preventable fatality data from 2003/04 to 2014/15 roughly follow a normal distribution, with the standard deviation of 4.05, minimum value of 3 and maximum value of 17. As such, the @Risk input variable is specified as the normal distribution, STD 4.05 and truncated for the range of 3 to 17. This specification is shown in the chart below.



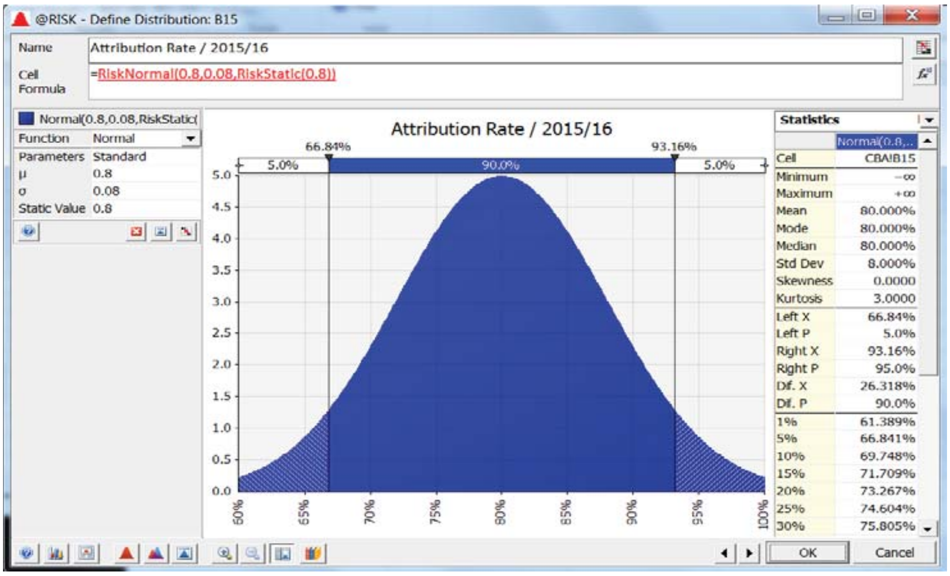
@Risk Input Variable 2: Economic cost per fatality

The economic cost per drowning fatality is estimated based on the Willingness-To-Pay (WTP) approach. The TfNSW economic appraisal guidelines estimated the value at $6,698,897 as at 2014/15. The Commonwealth Better Regulation Office estimated the economic cost of a statistical life at $4,250,000. While the WTP value is used in the core CBA, it is reasonably assumed that the economic cost per drowning fatality is in the range of $4,250,000 to $6,698,897. In the @Risk, this is specified as shown in Figure below.



@Risk Input Variable 3: Attribution rate

A statistical analysis was undertaken to estimate the fatality reduction attributable to the campaign. However, it was difficult to isolate the effect of the campaign and other factors. For example, fast rescue response could also reduce the drowning fatality. It was assumed that at least 80% drowning fatality could be attributed to the lifejacket wearing. This input variable is specified as a normal distribution as shown in the chart below:



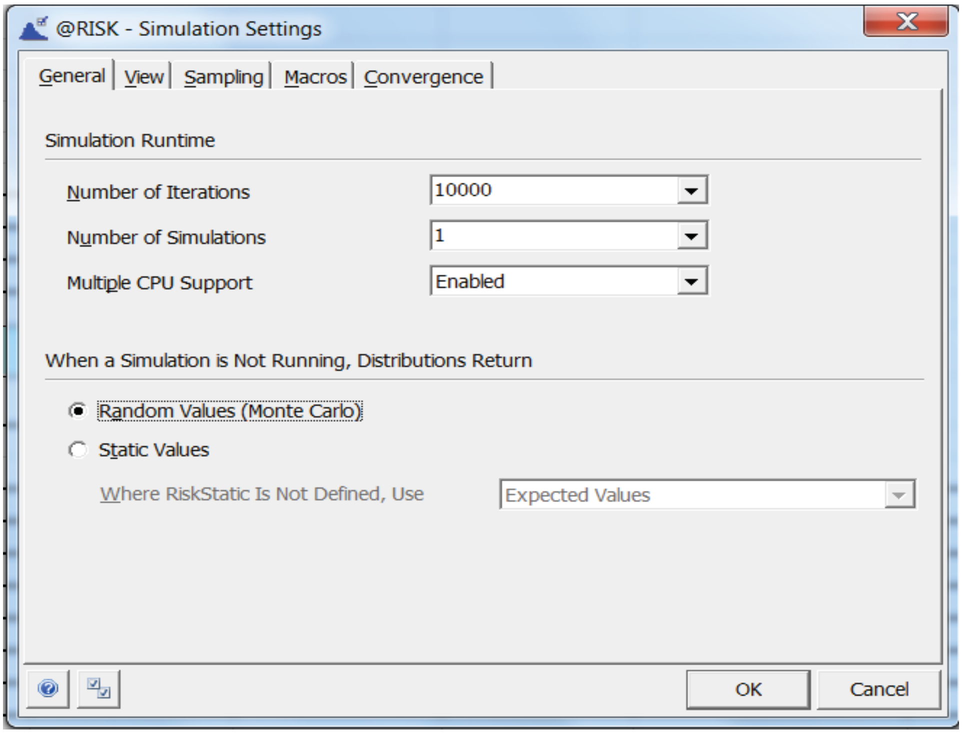
<u>**Run @Risk Simulation for identified risk elements**</u>

The CBA will generate point estimates of PV Cost, PV Benefit, NPV and BCR as shown in Table below. The purpose of @Risk analysis is to investigate how three input variables affect the outputs in terms of NPV and BCR.

Table 10.2 CBA Summary Results

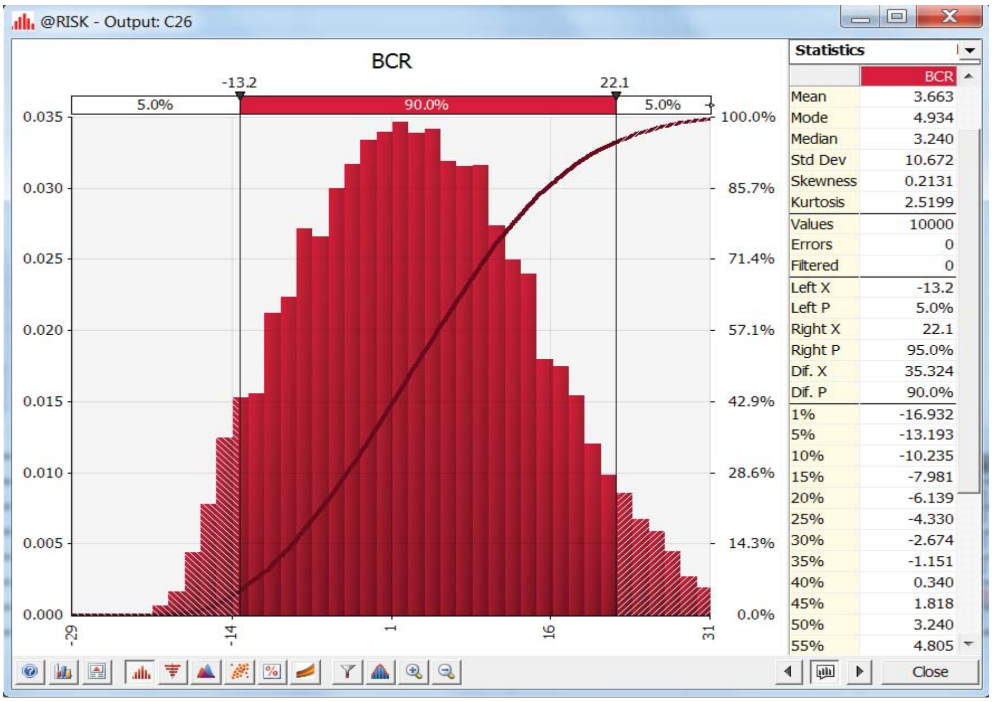
	Discount rate 7%
PV Cost ($m)	$1.40
PV Benefit ($m)	$6.13
NPV ($m)	**@Risk Output 1**
BCR	**@Risk Output 2**

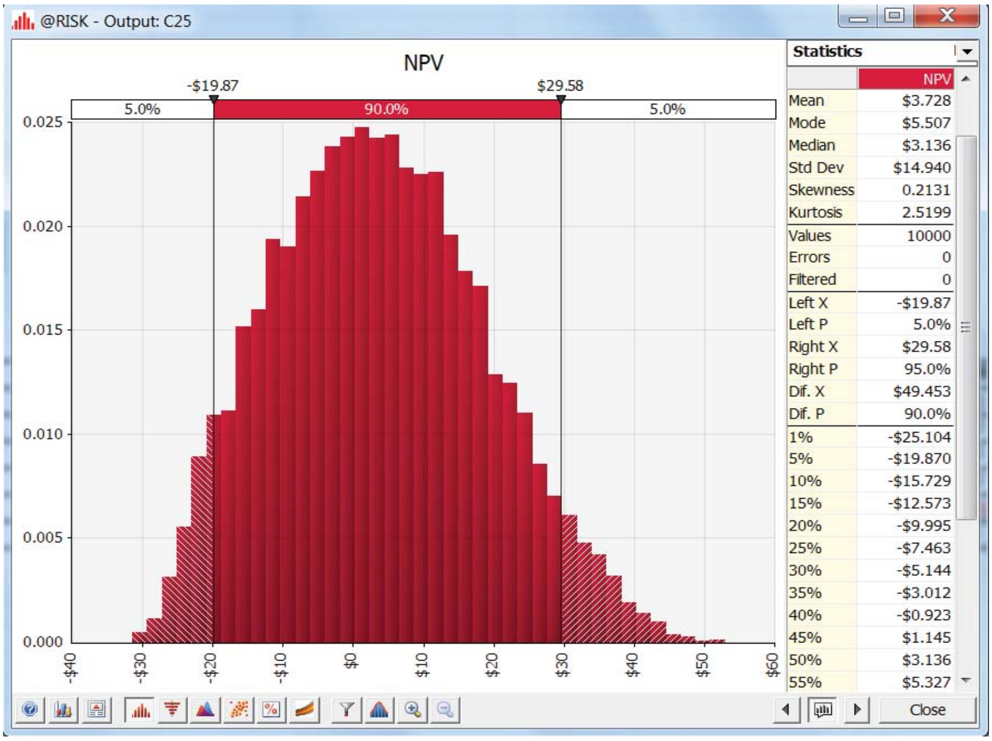
In the Simulation Settings, specify the number of iterations and number of simulations (Figure below). When a simulation is running, @Risk randomly draw values from the specified input variables. A typical simulation will run 1-2 minutes depending on model complexity, number of input variables and simulation specification.



Check the simulation outputs

The simulation result (Figure below) shows that the mean BCR is 3.66 and the median BCR is 3.24. The mean and median diverge a bit because the distribution is left-tilted. The probability of BCR ≤ 1 is 39% and BCR ≥ 1 is 61%, suggesting a certain risk that BCR will be less than 1 although the core BCR is 3.66. The NPV follows the same pattern, with the mean of $3.72m and median $3.14m. At 90% confidence level, the NPV ranges from -$19.87m to $29.58m. The same as BCR, the probability than NPV ≤ $0m is 39%.





The @Risk analysis provides a richness of possible outcome to assist decision making. In the worked example, the point estimates give a BCR of 3.66 and NPV of $3.72m, indicating the proposed campaign is economically viable. However, there is a 39% probability that the campaign will not be economically viable.

APPENDIX 11

Social Inclusion Index

Social inclusion refers to people's ability to participate adequately in society, including education, employment, public service, social and recreational activities. Social exclusion describes the existence of barriers which make it difficult or impossible for people to participate fully in society.

The Government's vision of a socially inclusive society is one in which all Australians feel valued and they all have the opportunity to participate fully in society. Achieving this vision means that all Australians will have the resources, opportunities and capability to:

- **Learn** by participating in education and training;
- **Work** by participating in employment, in voluntary work and in family and caring;
- **Engage** by connecting with people and using their local community's resources; and
- **Have a voice** so they can influence decisions that affect them.

Social inclusion recognizes that many are excluded from the opportunities they need to create the life they want, and can become trapped in spirals of disadvantage caused by family circumstances, low expectations, community poverty, a lack of suitable and affordable housing, illness or discrimination – often leading to leaving school early, long-term unemployment and chronic ill-health. Some people are at greater risk of multiple disadvantages, such as jobless families, Aboriginal and Torres Strait Islander people, people with disability and mental illness, vulnerable new migrants and refugees, those with low incomes and people experiencing homelessness. The costs of this social disadvantage are high – to individuals, communities and the nation.

Thus, it is the Government's objective to reduce the incidence of social exclusion. Key indicators that measure key issues affecting social inclusion include:

- Material/economic;
- Health and disability;
- Education and skills;
- Social resources;
- Community and institutional resources; and
- Housing and personal safety.

The UK government's Social Exclusion Unit (SEU) undertook pioneering research on particular forms of social exclusion and its link to transport[1]. The Imperial College's review of transport aspects of social inclusion led to a recommendation to modify the New Approach to Appraisal (NATA), the UK Government's guidelines on cost-benefit analysis and environmental impact assessment[2]. In the USA, the social exclusion issues are incorporated in "environmental justice" and "just transportations"[3]. In Canada, social exclusion has been regarded as a transport planning and transport equity issue[4]. In Australia, research has been undertaken on social exclusion for specific groups (e.g., children)[5] or specific region[6]. Social exclusion has not been

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[1] Social Exclusion Unit, 2003, making the connections, final report on transport and social exclusion.
[2] Social inclusion: transport aspects, Imperial College, 2006
[3] Overview of the American experience with modelling transport equity, appendix in 'social inclusion: transport aspects", Imperial College, 2006
[4] Social inclusion as a transport planning issue in Canada, Victoria Transport Policy Institute, 2003
[5] Investigating the relationship between travel patterns and social exclusion of children in Sydney, Anatoli Lightfoot and Leanne Johnson, ATRF 2011

accommodated in formal evaluation and planning process in Australia. Current research used five dimensions to indicate a person's risk of being socially excluded:

- Low household income - Household income and number of trips per day are both significant influences on the risk of being socially excluded. The higher a respondent's household income and the more trips are made per day, the less the risk of being socially excluded.
- Employment status – High risk for unemployed or people not participating education, training or voluntary work.
- Political activity – High risk for people having not contributed to / participated in a government political party, campaign or action group to improve social / environmental conditions, to a local community committee / group in the past 12 months
- Social support – High risk for people not able to get help if you need it from close or extended family, friends or neighbours
- Participation – High risk for people having not attended a library, sport, hobby or arts event in the past month

Research indicates links between mobility, accessibility and the prospects of a person being socially excluded. The mobility is negatively correlated with the likelihood of social exclusion among adults: higher trip making implies less risk of social exclusion. Inadequate transport sometimes contributes to social exclusion, particularly for people who live in an automobile dependent community and are physically disabled, low income or unable to own and drive a personal automobile. It is likely that improved public transport service levels might reduce the risks of social exclusion in these areas.

Seven dimensions of transport-related exclusion are:

- Physical exclusion – based on physical, cognitive and linguistic barriers. Some people lack the mental and physical capabilities to use the available means of mobility.
- Geographical exclusion – based on shortcomings in spatial coverage of transport provision.
- Exclusion from facilities – based on location and/or nature of the facilities themselves.
- Economic exclusion – based on cost of transport services.
- Time-based exclusion – based on scheduling conflicts and incompatibilities between the schedules of transport services and temporal.
- Fear-based exclusion – based on concerns regarding personal safety and security associated with the use of transport services.
- Space exclusion – based on inappropriate design of transport interchanges and related public spaces.

Social exclusion index

Current transport planning and evaluation mainly focus on capital costs, travel time, vehicle operating costs and crash rates. More comprehensive evaluation frameworks are needed to better incorporate social exclusion. Lower-income households located in automobile-dependent areas face particular hardship from unaffordable transport and risk of social exclusion. According to ABS, 15% of household incomes are spent in transport. Rural residents spend more on transport than urban residents in absolute terms and as a portion of income.

It is often helpful to have a quantified index for comparing social exclusion in different locations and demographic groups. Such an index can help evaluate potential solutions. It would be a useful tool for assessing how resources to improve social inclusion are most effectively invested.

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[6] Transport and social disadvantage in Western Sydney, University of Western Sydney, 2006

A potential Transport Social Exclusion Index is described in the table below[7]. It uses six factors that represent various aspects of accessibility, rated from 0 to 5 using various indicators, giving a maximum rating of 30. An individual or group that rates low on this scale could be considered to face significant problems from social exclusion.

Table 10.1 Transport social exclusion index

Factor	Definition	Indicators	Rating
Mobility Need	Number of "essential" trips outside the home a person must make	From 5, subtract one point each for: • enrolled in school • employed outside the home • is a primary caregiver (responsible for children or disabled adults) • has special medical requirements (such as dialysis) • has other responsibilities that require frequent travel	
Land Use Accessibility	Average travel distance to common destinations, based on land use clustering and mix, and roadway network connectivity	One point for each different type of public services within 0.8 kilometre of residences • food store, other retail shops • post office / newsagency • school • park	
Physical and Communication Ability	An individual's physical and communications ability	One point for being able to • walk one kilometre • bicycle 3 kilometres • speak and read the local language • has residential telephone • has residential internet service	
Automobile Access	An individual's ability to use an automobile	One point for • having a drivers license • having a vehicle rental within suburb • living in a household that owns at least one motor vehicle • owning a personal car • having a major paved highway within 5 kilometres of home	

[7] Adapted from "Social inclusion as a transport planning issue in Canada", Victoria Transport Policy Institute, 2003

Factor	Definition	Indicators	Rating
Mobility Options	Number of non-automobile mobility options available to an individual for local travel	• Three points for accessing a train station • Two points for access a bus stop or transitway station	
Financial Wealth	Ability to pay for transport services.	One point for each income quintile # • Lowest quintile <$436 per week • Second quintile $436 - $634 per week • Third quintile $635 - $$853 per week • Fourth quintile $854- $1174 per week • Highest quintile >$1174 per week	
Total			

This index rates each factor from 0 (worst) to 5 (best), resulting in a total rating from 0 to 30. An individual or a group that rates low (0-10) could be considered facing significant problem of social exclusion. A rate between 10 and 20 could indicate certain social exclusion concerns. A rate between 20 and 30 could indicate no social exclusion issues

- based on ABS Household Income and Income Distribution in 2010/11 dollars

Valuation of additional trips

People make trips for different purposes including social, recreational, shopping, commuting, business or educational. More trips mean the less risk of social exclusion. Stanley et al (2010)[8] has undertaken an empirical study to measure people's willingness to pay for increased mobility. The study conducted face-to-face interviews across Melbourne in 2009 with 443 adults. It was designed as a follow on survey from an existing Melbourne household travel survey, to extend data scope without extending the time for administering the survey. The survey sampling has covered different geographic areas (inner and outer metropolitan areas), different accessibilities (people living in areas within walking distance to public transport and outside such distance), different age distributions, income groups and risks of social exclusion. The data collected from the survey was used to specify an econometric model (known as Generalised Ordered Logit Model). From the model, it was estimated that an individual is willing to pay $19.30 for an additional trip to engage more activities and overcome social exclusion.

How does the willingness to pay of $19.30 per additional trip compare with the economic benefits used in conventional economic evaluation. To illustrate, we assume a typical half hour trip by public transport. Its generalised travel cost has two components: value of travel time and fare cost. The value of travel time is $8.45 per trip (half of value of travel time of $16.89/h, see Appendix 4, Table 1). The average public transport fare is estimated as $2.08 per trip (based on Appendix 4, Table 52). The total generalised travel cost would be $10.53 for the trip. As the person is willing to pay $19.30 for the trip, the consumer surplus is $8.77 for the trip. The willingness to pay and its consumer surplus are particularly relevant to the assessment of new public transport services.

[8] Social exclusion and the value of mobility, John Stanley et al, Journal of Transport Economics and Policy, Volume 45, Part 2, 201;

APPENDIX 12

Wider Economic Benefits[1]

An in-house wider economic benefit model has been developed in Evaluation and Benefits Branch, Finance and Investment which uses the outputs from the Sydney Strategic Travel Model (STM). The following STM outputs are used as inputs for the WEBs Model:

- Travel demand between origin-destination travel zones by transport modes (rail, bus and car) in 2021 and 2031.
- In-vehicle travel time between origin-destination travel zones by transport mode.
- Auxiliary (access and egress) time between origin-destination travel zones by mode.
- Waiting time between origin-destination travel zones by transport mode.
- Boarding numbers of rail and bus between origin-destination travel zones, for calculating number of transfers.
- Public transport fare between origin-destination travel zones by transport mode.
- Road toll amount between origin-destination travel zones for car driving.
- Distance travelled between origin-destination travel zones by transport mode.

These outputs are loaded to a macroeconomic model to estimate the impacts of transport investments on welfare and gross domestic products. The welfare impacts refer to agglomeration economies, benefits of the increased competition caused by the increased market catchment due to better transport infrastructure, increased output and welfare benefits arising from improved labour supply. The GDP impacts refer to the productivity of increased workforce, people choosing to work longer hours, people moving to higher paid and more productive jobs and business travel time savings.

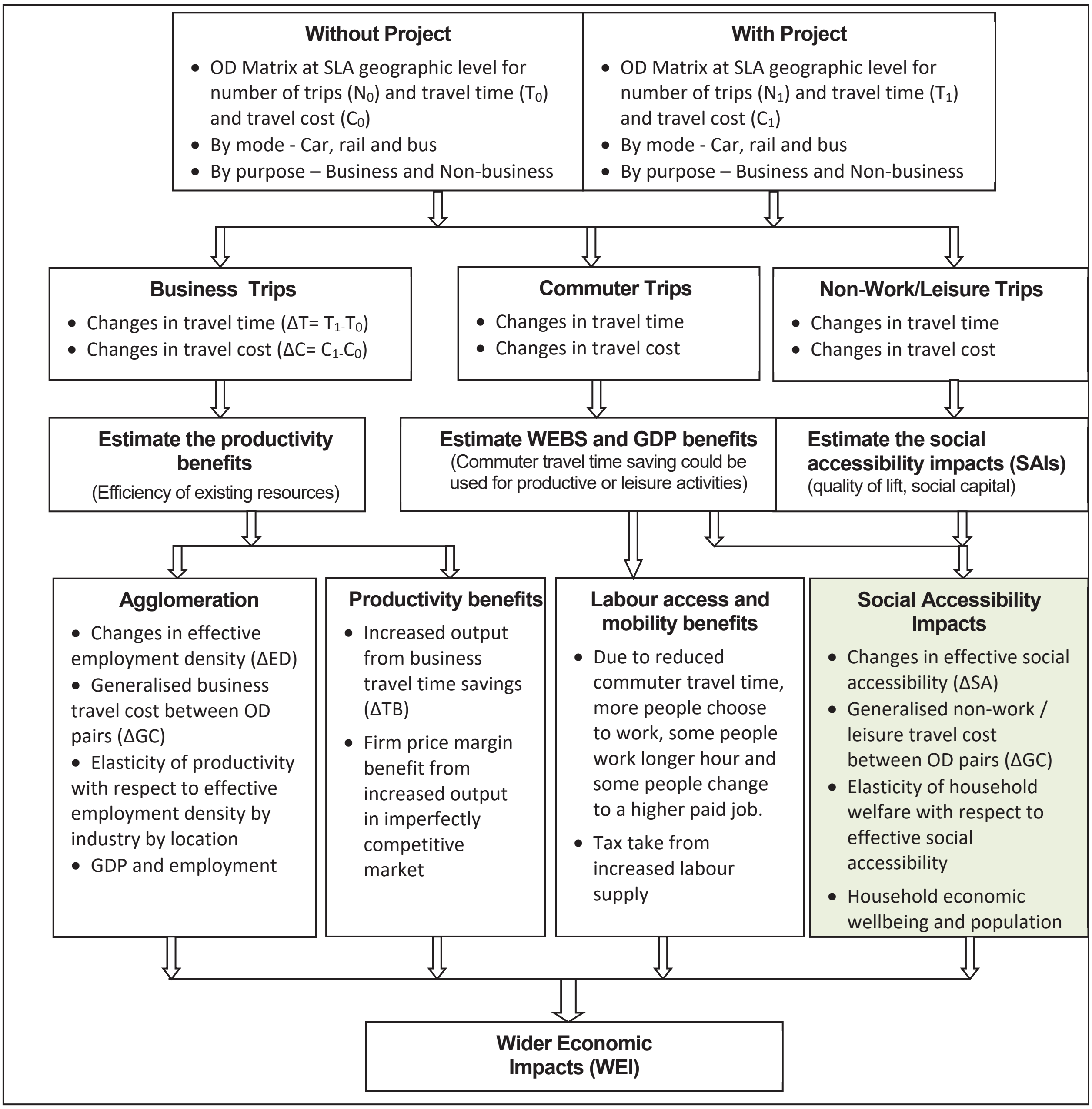
The TfNSW WEBs model framework is shown in Figure 11.1 below. The model primarily uses the modelling outputs of the Sydney Strategic Travel Model (STM) developed by NSW Bureau of Statistics & Analytics (BSA) for OD matrix analysis. WEB modelling requires an assessment of Origin-Destination (OD) traffic matrices with and without an infrastructure project.

The STM model output includes the 2-hour peak period travel in a 2690 origin by 2690 destination travel zone matrix for Sydney Greater Metropolitan Area which have been aggregated into 80 Statistical Local Areas (SLA) to reduce computing burden, without loss of analytical accuracy.

The macroeconomic model comprises of an economic database and the algorithms for estimating employment density, effective employment density, agglomeration benefits and other wider economic benefits. The economic database provides SLA level employment, average productivity, values of travel time, vehicle occupancy and spatial information of SLA land areas, resident density and employment density. The productivity elasticities are treated as exogenous variables in TfNSW WEBs model. This means that elasticities have to be estimated or sourced from other studies. In TfNSW WEBs model, the elasticities for Sydney estimated by the Institute of Transport and Logistics Studies have been built in. The elasticities of UK and New Zealand have also been included for testing sensitivities. These elasticities will be revised based on the outcome of the work currently being undertaken by the Commonwealth Department of Infrastructure and Regional Development and their resulting guidelines for WEBs estimation.

[1] The treatment of WEBs is currently under review and should not be included in an Economic Appraisal without contacting the TfNSW Evaluation and Assurance team.

Figure 11.1 TfNSW WEBs Framework: Assessing WEBs of Transport Projects



Wider Economic Benefits can be presented by industry and by location. The model has been applied for assessing the wider economic benefits of North West Rail Link. The WEBs represent 7.9% mark-up over conventional economic benefits as shown in the table below.

Table 11.1 Wider Economic Benefits Summary[2]

Cost / Benefit Item	Welfare Benefits (NPV $M)	GDP Impacts (NPV $M)
Project costs (A)	**$7,100**	
Conventional economic benefits(A)		
Value of business travel time savings	$805	
Other conventional benefits	$5,595	
Total Conventional Economic Benefits	**$6,400**	
Wider Economic Benefits (B)		
Welfare Impacts		
WB1: Agglomeration economies	$321.2 (63.4%)	
WB2: Increased output in imperfectly competitive markets	$80.5 (15.9%)	
WB3: Benefits arising from improved labour supply	$105.0(20.7%)	
GDP Impacts		
GB1: More people choose to work		$80.0
GB2: Some people choose to work longer hours		$0
GB3: Move to higher productive jobs		$271.5
GB4: Agglomeration economies		$321.2
GB5: Imperfect competition		$80.5
GB6: Business time savings and reliability		$805.0
Total Wider Economic Benefits	**$506.7**	**$1,558.2**
WEI as % of conventional economic benefits	**7.9%**	

(A) Assume project costs and conventional economic benefits
(B) Transport for NSW's estimate

[2] Legaspi J., et al., Estimating the wider economic benefits of transport investments: The case of the Sydney North West Rail Link project, Case Stud. Transp. Policy (2015), http://dx.doi.org/10.1016/j.cstp.2015.02.002