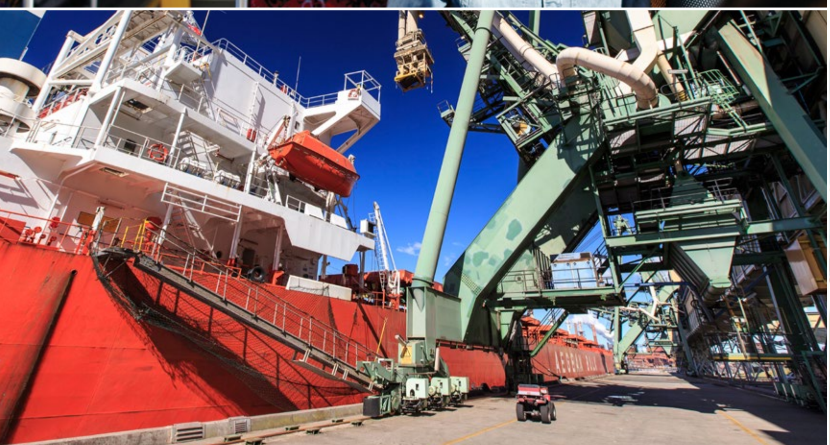
NSW GOVERNMENT | Transport for NSW

Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives

Transport Economic Appraisal Guidelines



March 2016

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Transport Economic Appraisal Guidelines

Evaluation and Benefits, Finance and Investment
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Transport for NSW

FOREWORD

The 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. 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 contribute to improved resource allocation by ensuring that the strategic alignment and value for money assessment have been consistently determined across the Transport cluster.

The 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 them 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 demonstrations and customised case studies on the application of economic appraisal methods and models to particular projects, programs or activities in the work areas.

The *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 is at the leading edge of robust, transparent decision making and driving value for money.

We welcome your feedback on this document. Please send any comments to Julieta.Legaspi@transport.nsw.gov.au or Economic.Appraisal@transport.nsw.gov.au

Tim Reardon
Secretary

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PRINCIPLES AND GUIDELINES: ECONOMIC APPRAISAL OF TRANSPORT INVESTMENTS AND INITIATIVES

1. Introduction

The Transport Legislation Amendment Bill 2011, which amends the Transport Administration Act 1988 and other transport legislation to establish new arrangements for the administration of the NSW transport sector. The new integrated transport authority – Transport for NSW – is now responsible for the coordinated delivery of transport services. Transport planning and service delivery are now consolidated across the transport cluster into the one authority.

Funding decisions are now vested on the integrated authority and thus will require a consistent framework for assessment of project and program proposals and funding requirements.

Other changes affecting the NSW transport sector include:

- The need for an integrated approach in addressing the expected growth in freight and passenger transport task;
- A focus on the relationship between transport infrastructure and economic productivity and land use;
- The need to appraise new modes; and
- Emerging approaches in forecasting transport demand.

1.1 Objective of this document

The objective of this document is to put together the underlying principles and guidelines to inform the economic appraisal of transport projects and initiatives. It promotes a standard appraisal framework to be applied to proposed projects, programs and initiatives within the NSW transport portfolio. A consistent set of economic parameters and values are also provided for use in economic appraisal across the transport sector.

The document provides clear exposition of concepts, a logical set of analytical steps, illustrative calculations, practical advice for dealing with data limitations and references to reports and tools that can assist practitioners in estimating the benefits and costs of transport investment projects.

The development of a standard appraisal approach across the NSW transport sector will ensure multi-modal (i.e. cross agency and network) impacts are not only considered but are also captured and quantified in the appraisal process. This multi-modal portfolio approach is likely to increase the comparability of project appraisals and hence, optimise the efficiency of State-funded capital investment.

The objective of providing overarching guidelines to transport portfolio is to improve the resource allocation to projects by ensuring that the strategic alignment 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 as a dollar of investment in the rail network.

This document also presents various remaining economic appraisal issues in relevant sections, which although may not be totally resolved within the guidelines, are presented clearly and concisely. The varying interpretation and approaches adopted by various entities in relation to the issues and possible resolutions are included in the discussions.

1.2 Various existing economic analysis guidelines

A thorough review and assessment of existing guidelines for economic appraisal of projects has been undertaken for the purpose of identifying conventional and leading edge methods that best measure and value the costs and benefits of transport projects. (See Appendix 1 for a list and summary features of these guidelines and manuals).

Presently there are two nationally agreed frameworks for conducting cost benefit analysis of transport projects. These are:

1. National Guidelines for Transport System Management in Australia produced for the Australia Transport Council (ATC) by the Guidelines Assessment Methodology Working Group and endorsed by the Standing Committee on Transport (SCOT).

2. Austroads “A Guide to Project Evaluation” prepared by ARRB.

The ATC guidelines have greater coverage of the strategic process and methods. The focus is on urban and non-urban land transport – road, rail and intermodal. The key feature of this guideline is that it 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)

The Austroads Guide on the other hand is more focused on evaluation of road investment. It includes a well-developed road user effects (RUE) unit values widely used for economic evaluation of both urban and non-urban road investment projects.

Within NSW, the NSW Treasury Economic and Financial Appraisal Guidelines provides a framework for undertaking financial and/or economic appraisals across all public sector agencies. Some agencies have also published its own industry specific appraisal manuals (such as NSW Health Infrastructure’s *Guidelines for the Economic Appraisal of Capital Projects*).

The more specific transport guidelines include the RTA Economic Analysis Manual which provides guidelines for road solutions while the RailCorp Guide to Evaluation of Capital Projects focuses on rail solutions.

Other forms of transport, such as bus, ferry and freight, do not currently have mode specific guidance on economic appraisal. While the NSW Treasury guidelines provide the overarching framework for investment appraisals in the NSW public sector, the absence of a single set of transport appraisal guidelines across agencies and modes has meant that TNSW has not had the opportunity to guide a common and readily comparative approval process for transport evaluations and business cases.

These guidelines include general descriptions and generic methods of economic appraisal and these are synthesised in this NSW Transport Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives.

This document builds on the current existing guidelines for assessing the economic merits of the projects. It provides a set of practical guidelines to assist economic appraisal of investment and initiatives within the transport portfolio. This covers the discounted cash flow techniques of cost benefit analysis and cost effectiveness analysis all of which may be used at different times to evaluate projects.

Cost benefit analysis (CBA) is covered in more detail because it is the preferred approach when considering the range of costs and benefits attributable to a project. CBA is a support tool to assist decision-makers, recognising that there are always benefits which cannot be economically valued. It can be applied at all stages of the project life cycle and 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 guidelines are aimed at three user groups. The guidelines are mainly aimed at project managers, staff and consultants. The annexes to the guidelines and the embedded models provide more detailed information and guidance for those actually conducting analyses. To aid consistency, there is a need for a common database of "standard values" to be used in CBA of transport investment and initiatives across the portfolio.

A Summary of the Principles and Guidelines will be a companion document to the material which will be useful in providing senior managers and policy makers an overview of the principles, the methodologies and processes involved in the CBA.

Ways of assessing the wider impact of transport including case study are also presented in this document.

Economic parameter values for quantifying benefits and costs are listed in Chapter 2 and discussed in detail in Appendix 4.

1.3 Economic Appraisal within the Investment Decision Framework

The investment decision framework is a cross portfolio framework that applies to Transport for NSW and the operating entities. The framework ensures a strategic overview and alignment of the program and project objectives with the State Plans, the Transport Master Plan and the corporate plans. The focus is on capital growth and maintenance.

The investment framework does not in and of itself make investment decisions – rather, it provides the data, process, governance and tools as an integrated capability that enables these decisions to be made.

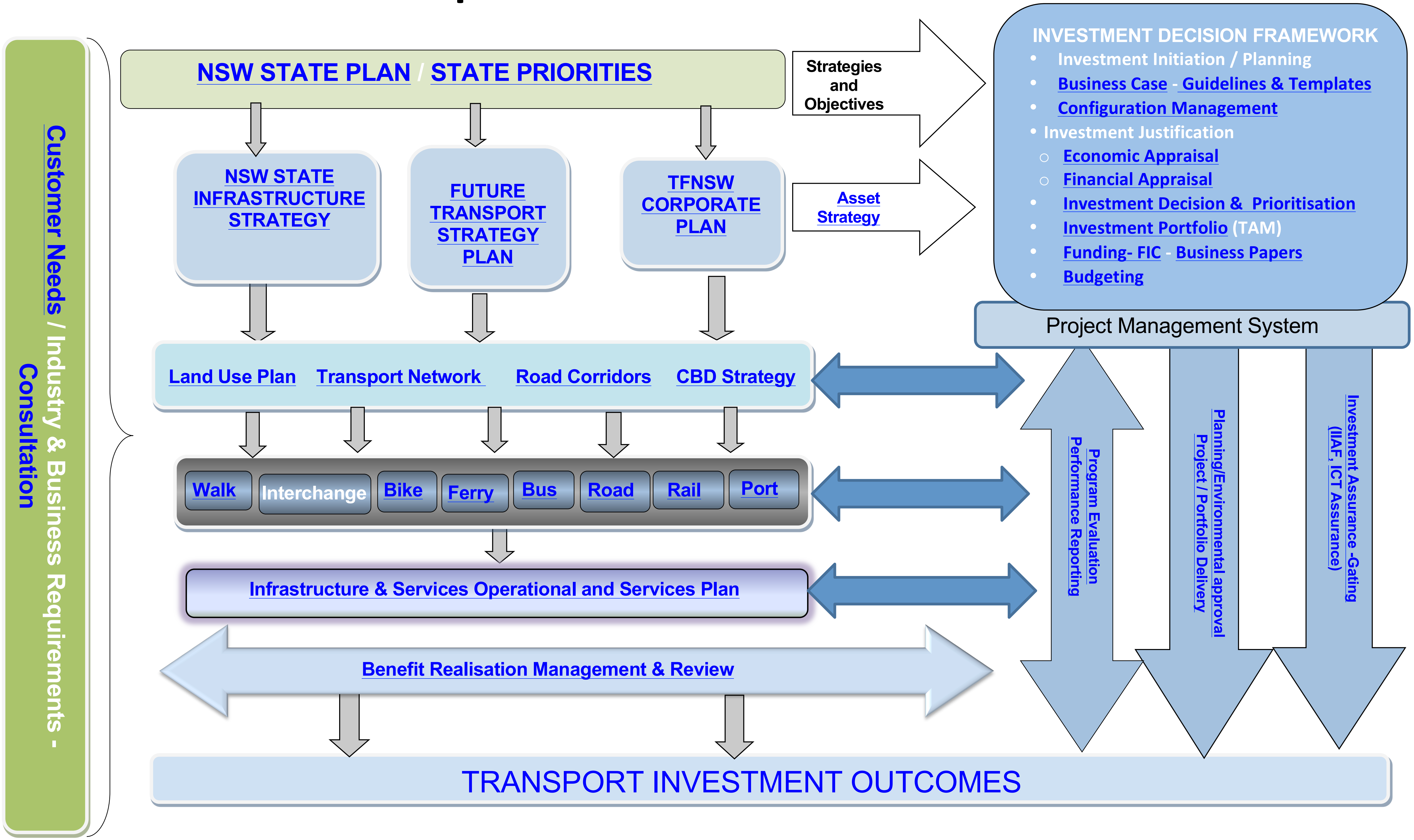
Economic appraisal assists investment decision making through the use of robust tools such as cost benefit analysis which informs decisions on investment proposals that will constitute the investment pipeline.

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 (Tpp08-05), Business Case Guidelines other than Capital, NSW Premier's Department, 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.

Detailed descriptions of the processes involved in the investment decision are included in materials provided in the specified links to the items (control + click to open links).

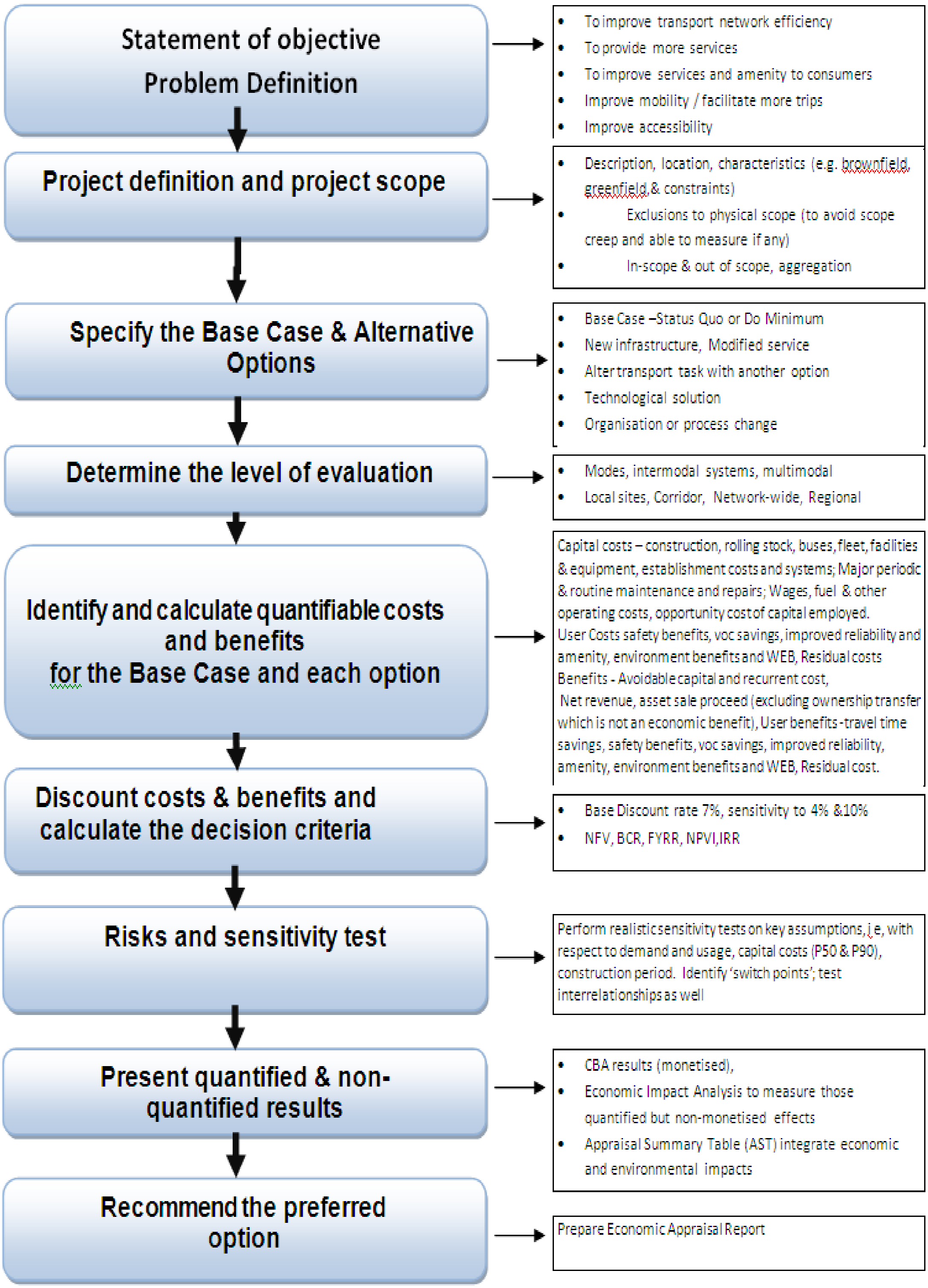
Transport Investment Framework



1.4 Process of economic appraisals

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

Figure 1.2 - Cost Benefit Analysis Process



1.5 Funding and assessment framework of Government agencies

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

- **Infrastructure Australia** - focuses on projects of national significance costing over $100m. The projects are assessed under the *Reform and Investment Framework*[1].
- **Commonwealth Department of Infrastructure and Transport (DoIT)** - the Federal Department of Infrastructure and Transport provides funding to road and transport projects under National Building, Major Cities, Building Australia and Liveable Cities programs.
- **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 the infrastructure Investor Assurance Framework (IIAF).
- **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[2].
- **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.

[1] For details, see the Reform and Investment Framework, Infrastructure Australia, 2012

[2] 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)	Australian Department of Infrastructure and Transport (DoIT)	Infrastructure NSW (INSW)	NSW Government Department of Premier and Cabinet, NSW Treasury Department of Finance Services and Innovation	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 Risk-High Profile (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 • Information and Communication Technology (ICT) projects	• 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 Infrastructure Australia templates for the stages: • Goal Definition • Problem Identification • Problem Assessment • Problem Analysis • Option Generation • Option Assessment • Solution Evaluation	• 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 to 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

Attributes	Infrastructure Australia (IA)	Australian Department of Infrastructure & Transport (Infrastructure &Regional Development)	Infrastructure NSW (INSW)	NSW Government Department of Premier and Cabinet, NSW Treasury Department of Finance Services and Innovation	Transport for NSW (TfNSW)
Strategic priorities	Infrastructure Australia has 7 Strategic Priorities: • Expanding Australia's productive capacity; • Increasing Australia's productivity; • Diversifying Australia's economic capabilities; • Building on Australia's global competitive advantages; • Developing Australia's cities and regions; • Reducing greenhouse emissions; • Improving social equity and quality of life in our cities and regions.	• Nation Building—Economic Stimulus Plan: Many of the programs are being administered by the Commonwealth Department of Infrastructure and Transport • Nation Building – Black Spot Funding	• 20-year State Infrastructure Strategy (SIS)	• NSW State Plan NSW 2021	• NSW Transport Master Plan Long Term Master Plan • • NSW Ports and Freight Strategy NSW Freight and Port Strategy • Corporate Plan: Connections Towards 2017 • Results and Service Plan • Total Asset Management
Assessment guidelines	• Infrastructure Australia's Reform and Investment Framework 2012 • Better Infrastructure Decision Making Submission Coversheet and Templates Building Australia Fund Evaluation Criteria	National guidelines for Transport System Management Project appraisal for land transport	Issued Contingency Guidebook Infrastructure Investor Assurance Framework (IIAF), June 2016	• Treasury Economic Appraisal Guidelines • NSW Government Guidelines for Financial Appraisal • Treasury Capital Business Case Guidelines • Treasury_Circular 16-09_Infrastructure_Investor_Assurance_Framework_IIAF **Department of Finance Service and Innovation** issued DFSI Secretary Circular and the ICT Assurance Framework	• Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives • 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 of 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.

2.1 Introduction

2.1.1 Scope and Level of Economic 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 prove that the project will generate benefits for the users of the assets or the projects and the community at large and the cost of implementing these are covered by these benefits, hence the net present values are positive. 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 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 (people/business) 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 form 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, 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 cost benefit analysis (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 low discount rate for project evaluation can make future generations worse off.

The New South Wales (NSW) Treasury in Guidelines for Economic Appraisal recommends a central real discount rate of 7 per cent, with sensitivity for 4% and 10%.

There is an absence of overwhelming consensus on the right discount rate to use for economic appraisal. Appendix 2 –provides a summary of the Review of Discount Rate for use in Economic Appraisal of Transport Initiatives. 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)3 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 Project 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. 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' economic life is 15. Computer hardware and intelligent transport system initiatives will have shorter lives. (Table 77 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 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

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

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.

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; wage levels have shown a trend to increase in real terms (i.e. above general price inflation rates) in past years.

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. The NSW Government Guidelines propose that CEA should be used in the areas of education, health, welfare, the environment, and law and order and that CBA should be used in all other areas. However when the benefits are similar or a particular objective is required, CEA may be applicable to transport projects.

A cost-effectiveness analysis 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 cost-benefit analysis. 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, and continues to be widely used throughout the world. 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 evaluations are 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 consider private sector funding. For large or significant projects full or partial private sector funding may be a possibility.

2.3 Major Steps in Cost Benefit Analysis

1. 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. 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 or investment 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 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. Examples include measures of increasing road capacity and passenger capacity of public transport of existing transport network.
- To provide more services.
- To improve services and amenity to costumers.

- Improve mobility / facilitate more trips. Examples include providing public transport in outer urban low density areas and measures making disability people using public transport system.
- 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 and business groups.
Defining measurable operational performance against benchmarks also assist in providing the basis for the post completion review.

2. 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, or
- Contraction or amplification of existing facilities, or
- Replacement of existing facilities,
- Upgrading or improvement of 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 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 if the project can be undertaken in stages. This may assist funding by spreading the project over time and reduce project risk by giving flexibility to cancel a project if the assessed benefits are not being derived.

3. Specify the Base Case and alternative options

A cost benefit evaluation focuses on how a project will change the base case. Hence the correct specification of the base case is important. Base Case is usually defined as business as usual or no policy change case. When evaluating a new link in a network, 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 to 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.

4. 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 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 successful identification of options or optioneering:

- 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 technique option, best practicable means option, and so on.

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.

5. 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.

6. 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 calculation of 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.

- 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:

- Minimises 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. 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 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 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.

- **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 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.

- 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

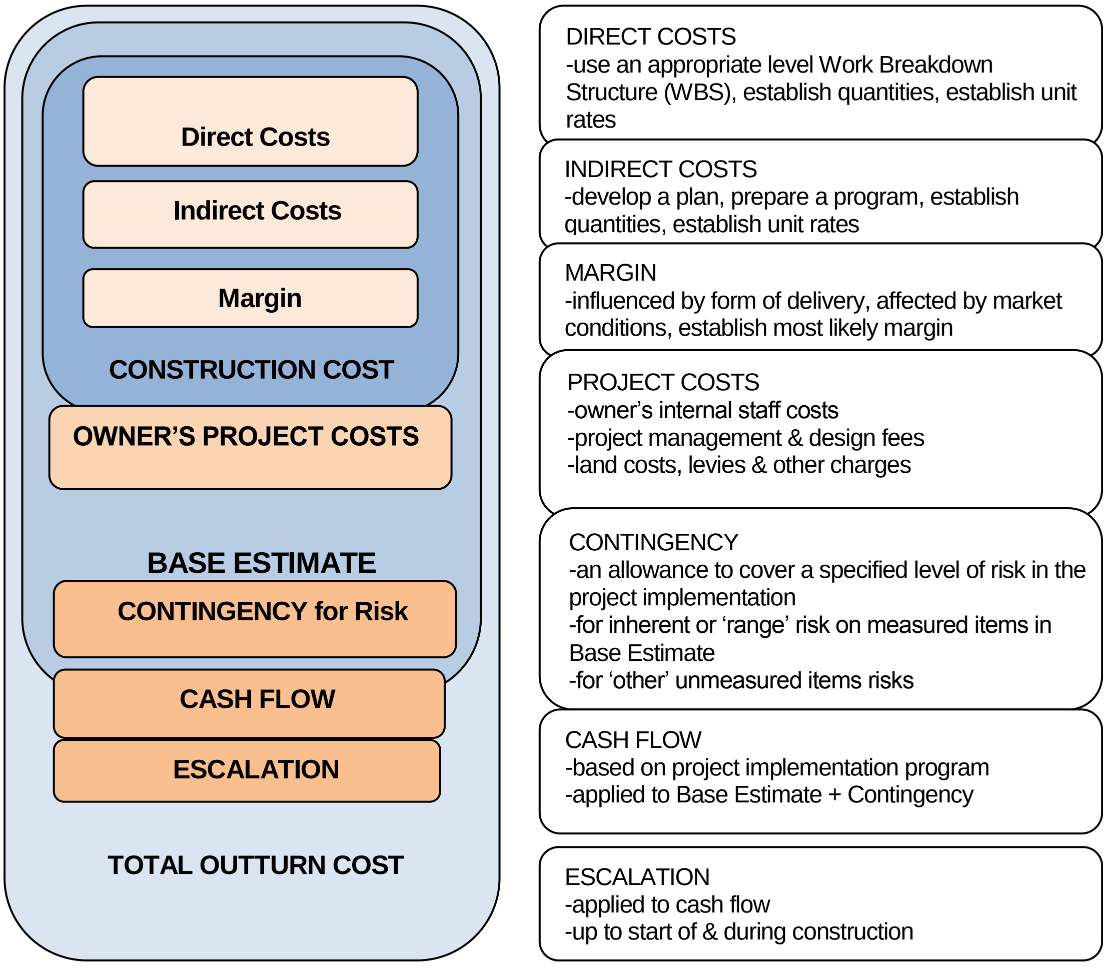
- listed in direct and indirect cost items to cover events such as abnormal weather, contaminated grounds, etc.
- Cash flow applied to the base estimate plus contingency based on the project program.

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



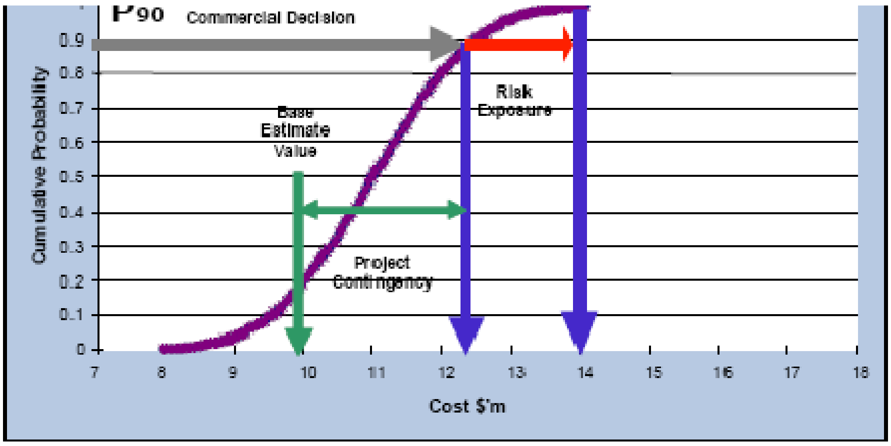
Source: Evans and Peck, Best Practice Cost Estimation Standard, p 28

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 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 cost benefit study should generally adopt (at each stage) the most accurate costing available at a 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 48 of Appendix 4 for some of these works such as 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. These include labour costs, maintenance costs, energy costs, utility services and overheads.

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 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:

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

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.

7. 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 result 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 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:

1. Travel Time Savings

Travel time costs are the cost of time spent in travelling. They vary with the amount sent 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 this 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[4] which is combined with average vehicle occupancies and flow periods to calculate the weighted average hourly value for travel time.

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

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.

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.

2. 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 Cost Benefit Analysis, 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). VOCs for vehicle type are also presented in Appendix 4 Tables 17 to 19). For rural projects, Appendix 4, Tables 24 to 40 provide detailed tabulations of VOC per vehicle kilometre for different vehicle types, speed, road types and road conditions (gradient, curvature and terrain and roughness).

3. 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 51) indicates that VSL ranges from $1.7m to $12.5m 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[5], 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

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.

4. 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.

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

5. 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.

6. 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, if 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.

7. 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.

8. 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 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).

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. As in with passengers, the benefit to consider is a reduction in travel time expressed in term of in-vehicle factor. 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 In Vehicle Time (IVT) minutes (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.[6]

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.

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:

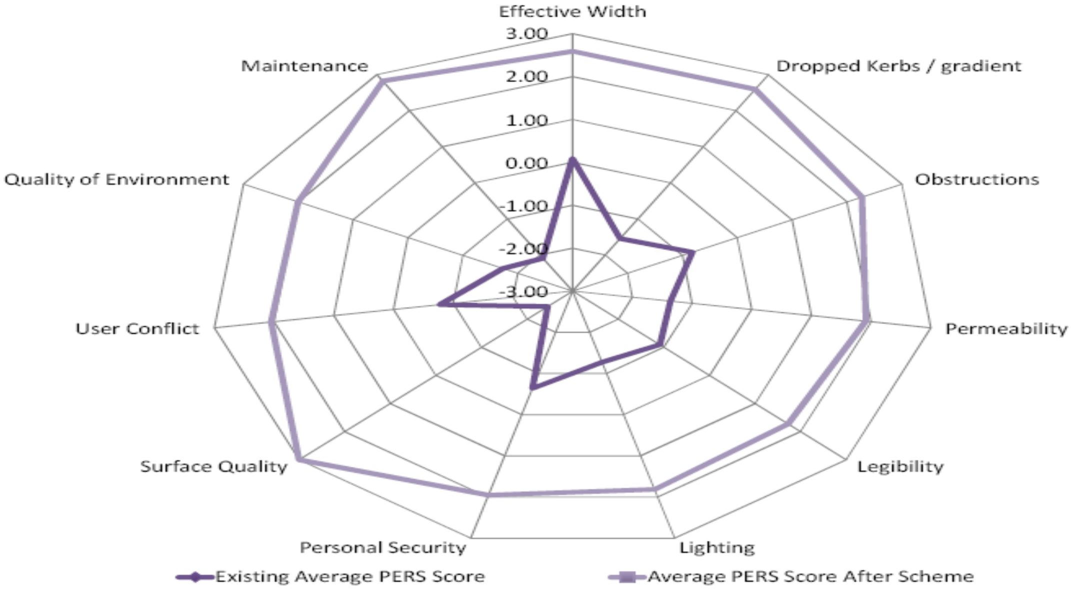
[6] While most sections of the National Guidelines has currently been refreshed during Stage 1 and Stage 2 review, the section relating to public transport will be dealt in Stage 3. Thus, new values may replace these values and these will be included in the future update of the Transport Principles and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

- 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 pedestrian 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 58 to Table 60 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 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, 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 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.

TfNSW recommends that consumer surplus benefits continued to be estimated from 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 66 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.[7] Such increases represent non-user benefits, namely 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,

7 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.

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

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.

$$Residual\ Value\ (SLD) = \frac{Capital\ Cost\ x\ Asset\ life\ remaining\ after\ appraisal\ period}{Asset\ life} \qquad Equation\ 2.3$$

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.

$$Residual\ Value = Initial\ Investment\ Outlays - Revenues \qquad Equation\ 2.4$$

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 & administration (less staff, less overtime, less costly skills, reduced turnover)	Comfort & convenience	Production levels
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 decisions 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.

8. 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.

9. 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 Government Guidelines for Economic Appraisal require projects to be evaluated at a real discount rate of 7% with sensitivity tests using the discount rates of 4 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.

10. 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.

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

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.

$$\boldsymbol{BCR1 = \frac{PV\ of\ Benefits}{PV\ of\ Capital\ Cost \pm PV\ of\ change\ in\ Recurrent\ Costs}} \qquad \textit{Equation 2.6}$$

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

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 form 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 be usually 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 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.

11. 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.

12. Identify Preferred Option

The preferred option is identified by:

- Ranking of options by NPV, BCR, IRR and NPVI of cost benefit analysis
- 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.

13. 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	**4%**	**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 realism 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

Benefit component		**PV, of Benefits $m**	**Year 10 benefits $m**	**Year 10 benefits % of total benefits**	**Physical Quantity** (time savings in hours, total VKT, accident)
Travel time savings	Passenger				Time savings, hours
	Freight and business				Time savings, hours
	Total travel time savings				
Reduced vehicle operating costs	Passenger				Total vehicle km travelled
	Freight and business				Total vehicle km travelled
	Total user benefits				
Generated Travel Benefits	Passenger				Total VKT Total time saved (hours)
	Freight and business				Total VKT Time saved (hours)
	Total road user benefits				
Accident reductions	Total safety benefits				
Environmental benefits	Reduced GHE				Net extra equivalent emitted
	Reduced local pollution				
	Reduced noise				
	Total environmental benefits				
Reduced maintenance costs	Total reduced maintenance costs				Extra square metres of pavement
Wider economic benefits	Agglomeration benefits				
	Other WEBs				
	Total WEBs				
Other benefits	Total other benefits				
<u>TOTAL BENEFITS</u>					

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 $5million. 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:

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

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 used the framework presented above but 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 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 Assurance, Evaluation and Benefits 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 benefit cost 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 benefit cost analysis covers the profitability aspect of the project at the enterprise level.

The basic difference between the two is that the financial cost benefit analysis compares the benefit and cost to the enterprise in constant financial prices while economic benefit and cost 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 cashflow 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 economic benefit cost 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 BCA 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[8]:

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

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.

[8] 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.

2.6.6 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

Economic Policy, Strategy and Planning 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:

a) the *whole-of-life* cost (or life cycle cost (LCC)) of the agency; and

b) 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 4% 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[9], 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[10] and Transit New Zealand[11]). The IBCR approach determines whether the additional costs of higher cost options are justified by

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9 Mutually exclusive project options arise when the acceptance of one precludes the rest.

10 "Methods for Selecting Road Investment", Economic and Finance Committee of PIARC (Permanent International Association of Road Congresses), Paris 1991.

11 "Project Evaluation Manual: Full Procedures", Transit New Zealand, Wellington 1991

additional benefits gained. Australian Transport Assessment and Planning Guidelines (ATAP) Cost Benefit Analysis provides the formula for IBCR as follows:

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

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:

a) list the options in order of whole-of-life agency cost;
b) 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 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);
c) 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;
d) 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;
e) repeat this procedure for the next higher cost option, until all options have been analysed;
f) 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[12]

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

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

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)**

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.

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)

The Multi Criteria Analysis (MCA) is a tool used for decision making between a range of projects or options. 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. 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, as some impacts are not quantifiable in monetary terms such as social or health effects.

The MCA is suitable for the evaluation of transport projects as there are multiple objectives which are often in conflict with each other.

A MCA model consists of an evaluation criteria or objectives, weights which indicate the importance of the criteria and a set of projects or options. 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. The criteria/objectives of each project option are scored on a scale. Weights are then applied to each criteria/objective and a weighted average is usually calculated to combine the scores and the relative weights.

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 has increased transparency as the criteria and objectives are stated and considered explicitly. On the other hand, the limitations of MCA are that there is a lack of theoretical framework, the weighting framework maybe 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, reduce 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 were 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 are not readily able to be quantified in monetary terms (such as social objectives), which are prevalent in transport and land planning projects. 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. The following illustrates the process of the GAM:

- **Formulation of a set of goals.** Each goal should have an associated metric so that the 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 in the evaluation of transportation plans 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.

- **Scoring or ranking of the alternative options against its 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** depending on relative importance, in a matrix format. 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.

- **Combining of 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 the 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. It is a simple tool that can be used by stakeholders as a means to promote community wide consultation, allowing differing impacts to be considered. It 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 more subjective rather than objectively determined. Furthermore, any interaction and interdependence of objectives are not taken into account.

Since GAM is able to take into account impacts that are difficult to monetise, it is a useful tool that is widely used in transport, land and environmental projects and planning.

3.1.3 Strategic Merit Test

Strategic merit testing is a technique used to check if the proposed project aligns with the economic, environmental and social objectives, policies and strategies of the government. This qualitative project appraisal tool used during the strategic planning phase includes a series of questions which 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. Questions are designed that answers to all the questions must be "Yes" to pass this test. The strategically fit proposals move to further stages of the project and the rest are discarded thus saving resources from being spent on any further stages.

For any project, questions to examine strategic fitness could mainly include the following:
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 in its national guidelines for transport system management has presented a Strategic Merit Testing template.

3.1.4 Objective Impact Assessment (OIA)

Strategic merit testing may result in passing of various projects, but it does not reveal the scale of alignment. Objective impact assessment is a process aimed at testing the degree of impact of projects on the objectives of government. This process generally involves the following steps:

1. Identify the problems that need to be resolved
2. Set down the project objectives

3. Identify the main options
4. Identify th e 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 fitness of the selected 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 individual rating for each impact.

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

3.1.5 Appraisal Summary Technique (AST)

The Appraisal Summary Technique has been broadly used in the assessment of the economic, environmental and social impacts of a project. The most commonly available 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 appears a lot 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. Objective impact table covers only the impacts on specific governmental or the relevant jurisdictional objectives. The final scores of the appraisal summary table help more 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 in 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 which can be passed on to consumers.

3.1.7 Wider Economic Benefits

Wider Economic Benefits (WEBs) 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 are the main classes of WEBs:

1. Agglomeration economies

As a city grows and becomes denser, its firms become more productive. The productivity benefits arise from proximity and clustering explained by economies of scale, access to more customers, access to more suppliers, knowledge spill overs and access to workforce enabling better job matching. Agglomeration economies of transport project are measured based on the following logic:

- Transport project reduces the generalised travel costs for its affected areas
- The reduced generalised costs lead to 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 employment 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 employments in different zones remain unchanged.

The calculation of agglomeration economies requires the productivity elasticity with respect to effective employment density by industry sectors by spatial travel zones. The agglomeration elasticity measures the percentage changes in output productivity as a result of a percentage change in employment effective density. Hensher et al (2012)[13] 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 UK are relatively 'inelastic' but elasticities in New Zealand are more 'elastic'. In a study of the wider economic benefits of Sydney's North West Rail Link project undertaken[14], 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 that the New Zealand has a lower employment density thus the marginal effects on density and productivity is higher. On the other hand, UK has higher employment density with established transport system thus the productivity is relatively inelastic with the transport improvement.

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

[13] 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

[14] 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

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)
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 have certain market power. These situations represent imperfectly-competitive markets, usually characterised by higher price and lower production than consumers would be willing to pay more for increased production.

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 leads to efficiency gain which is 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 with an extensive transport system already existing. The significant wide benefits owning to increased competition are normally not expected from transport schemes.

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 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 to 10 deliveries with the transport improvement, the delivery company may drop the price, in which consumer would benefit, or retain the improved profit margin.

In an imperfectly competitive market, firms could set prices above the marginal costs. This means that some consumers are willing to pay more for additional products. Consumer and supplier surplus benefits arise as a part of Wider Economic Benefits which are not captured in conventional economic appraisals. This benefit can be estimated by applying a factor to the value of business travel time savings and reliability gains to business.

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 for the NWRL project (a 23 km rail link in North West of Sydney). The key finding is that there exist 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 are about 17.6% of 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[15]. 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 derive from proximity between firms and other sources of agglomeration from workers, other firms and other facilities; (2) household agglomeration, which derived from proximity between households and sources of utility deriving activities (social, personal, business, and other

[15] 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.

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 ranging from 1.85% to 3.57% dependent on the average speed, and produces the wider social and economic benefits in the range of $2.1 billion to $4.1 billion, equivalent to 0.67% to 1.3% of the 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.

2. TfNSW WEBs Model

An in-house wider economic benefit model has been developed 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 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 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.

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 13.7% 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)		
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 the 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 estimate of 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 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 the TfNSW for conducting economic analysis of road safety projects including submissions to the Commonwealth Department of Infrastructure and Transport 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 road scheme on people other than road users must be considered and 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 decision-making process on the basis that the environment is not a free good.

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

External and environmental effects to be considered are:

- Noise;
- Vibration;
- Pedestrians/cyclists;
- Severance;
- Visual intrusion (scenic quality);
- Other environmental issues from the Environmental Impact Assessment, e.g. air quality, water quality, heritage, ecological;
- Public transport; 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 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.

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 effects on local business and 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 physically measured but cannot be quantified or monetised. This may allow the magnitude of effect for project options to be ranked and in some cases quantified. Other intangibles are not susceptible 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 so that their anticipation of the impacts may be uninformed, then comparison with situations of a similar nature elsewhere may assist in obtaining an assessment of likely impacts.

The following section outlines various techniques available for use of 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 $\mathbf{(B_D - C_D - B_P) > 0}$

b) Do not proceed with the project if $\mathbf{(B_D - C_D - B_P) < 0}$

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 as a natural environment. TEV are not generally easy to measure as they are not in the form of marketable inputs and outputs that have observable prices.

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

Reference can be made with the Department of Environmental and Climate Change NSW's 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

Direct procedures 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 the 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[16]:

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

- Existence value - value obtained from the knowledge that an environmental amenity exists;
- Vicarious value - value obtained from indirect consumption of an environmental amenity through print or media;
- Option value - value obtained by retaining the opportunity to use an environmental amenity 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. 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 shall be divided by 2 to 3 to get an acceptable 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 practitioner, 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 one of revealed preference methods of valuation. The "dose-response" relationship between pollution and some effect, and is a measure of preference for that effect applied. Examples of '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). Only then the WTP measures are applied taken from direct valuation approaches.

5. Hedonic Price Approach

The hedonic price technique is built upon 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.

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

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 developing the park is then derived by estimating how much the willingness to pay will increase if the facility is developed / improved.

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.

3.3.5 Environmental 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, there are some impacts which are not discussed in detail because the same level of information on measurement is not yet available. Accordingly, verbal qualitative descriptions shall also be presented, covering issues such as historical background, community attitudes, characteristics of the area affected, and effects of the projects. Specialists in the appropriate disciplines may be required for the evaluation of significant effects. Community consultation and opinion surveys shall 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 that 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.[17] 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.

2. 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.

[17] 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.

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.

3. 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 by intimidation, worry, apprehension, and danger. However different population groups have different reactions and needs. 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.

4. 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 is somewhat 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.

5. 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.

Designing highways 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.

6. 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 back on 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).

7. 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.

8. 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).

Table 3.5 Unit costs of road maintenance, by vehicle types

Vehicle types	Unit Costs (cent/vkt)
Cars and motorcycles	3.78
Rigid Truck Light (LCV)	3.78
Medium (2 Axle)	8.68
Heavy (3-4 axle)	13.04
Sub-group: Rigid Truck	**4.72**
Articulated trucks	
4 or less axles	12.84
5 axles	14.27
6 or more axles	16.64
Sub-group: Articulated Truck	**16.10**
Combination Vehicles	
Rigid 3 axle plus trailer	14.17
Rigid 4 axle plus trailer	22.05
B-double	21.72
Double Road Train	24.45
B-Triple	30.68
Sub-group: Combination trucks	**21.40**
Buses 2 axle light bus	3.78
Rigid bus	8.80
Articulated bus 3 axle	10.04
Sub-group: Buses	**7.10**
Special purpose vehicles	**11.84**
Sub-total light vehicles	**3.78**
Sub-total heavy vehicles	**12.99**
Total all vehicles	**4.39**

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.

9. 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 inclusion 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[18]. 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[19]. In the USA, the social exclusion issues are incorporated in "environmental justice" and "just transportations"[20]. In Canada, social exclusion has been regarded as a transport planning and transport equity issue[21]. In Australia, research has been undertaken on social exclusion for specific groups (e.g., children)[22] or specific region[23]. 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.

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

10. Disability

Public transport services are provided to not only 'normal passengers' but also people with a disability and wheelchair users. TfNSW provides accessible travel by investing on train station facilities and wheelchair or mobility device on trains, Taxi Transport Subsidy Scheme, wheelchair or mobility device on Sydney Busses and wheelchair Accessible Taxis (WAT). The question for economic evaluation is whether additional benefits to people with disability should be considered in economic evaluation.

Accessible infrastructure provides a person with disability with accessible paths, stairways, ramps underpass 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

Australian Bureau of Statistics estimates that approximately 423,000 persons (or 6% of population) in NSW have a profound or severe disability that restricts their ability to perform communication, mobility or self-care activities. Among them, 42% travelled as a passenger in a motor vehicle, 19% drove and 5% used public transport in a fortnight survey period. It is further estimated that around 26,000 wheelchair users live in NSW who make around 119,000 trips in 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 of $30 per trip.

It may be considered that economic benefits for the people with disability are higher than benefits to normal passengers especially for accessible travel projects / programs.

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

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.

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 allow for the effects of different land use patterns.

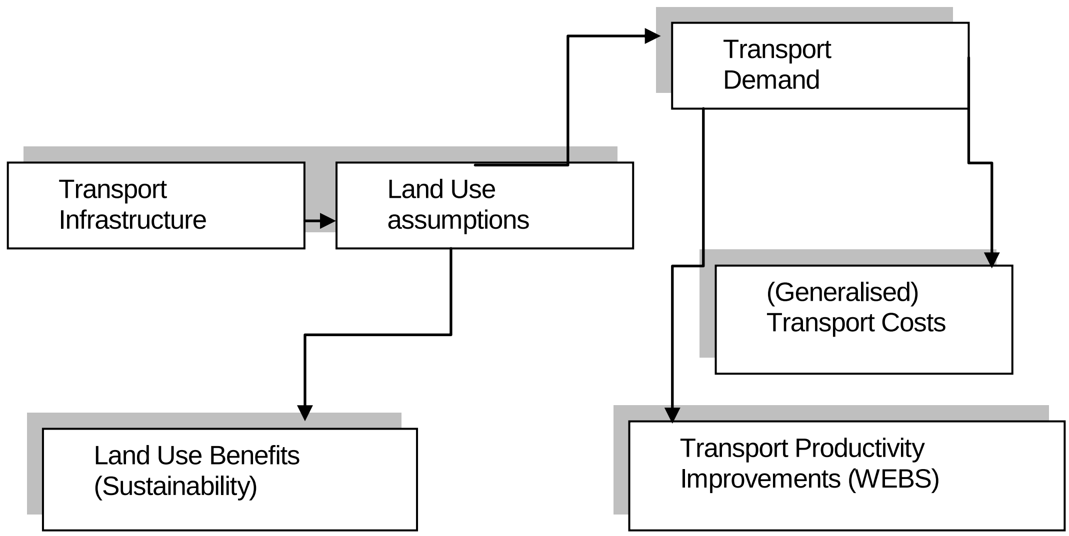
Some practical methods to capture specific land use adaptations include:

- 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.[24]

  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.

[24] 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 feedback loop between land use assumptions and demand facilitating capture of adaptations such as transport oriented developments
- 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 2,690 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 most 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 Bureau of Transport Statistics (BT) 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 in many cases, it refers to a feature of a residential location. Factors affecting the 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
- 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:

- Given a travel purpose, a higher accessibility results in less travel kilometres
- Accessibility could reduce travel time and cost
- Accessibility could improve prospects of finding suitable jobs, school and services
- The locations with a high accessibility mean availability of public transport. In these locations, public transport mode share is high. Researches indicate that a positive impact of accessibility on mode share is apparent in work trips but a relationship could not be clearly identified for school and shopping and recreation trips[25]
- A higher accessibility could increase land price.

A locational accessibility can be measured by a form of *accessibility index*, in that the accessibility of one location to all 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[26]:

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

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[27].

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.

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[25] Austroads, Application of accessibility measures, Dec 2011
[26] Australia Transport Council, national guidelines for transport system management in Australia, part 5, 2006
[27] For details see pages 5-8 in Application of Accessibility Measures, Austroads, 2011

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 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.

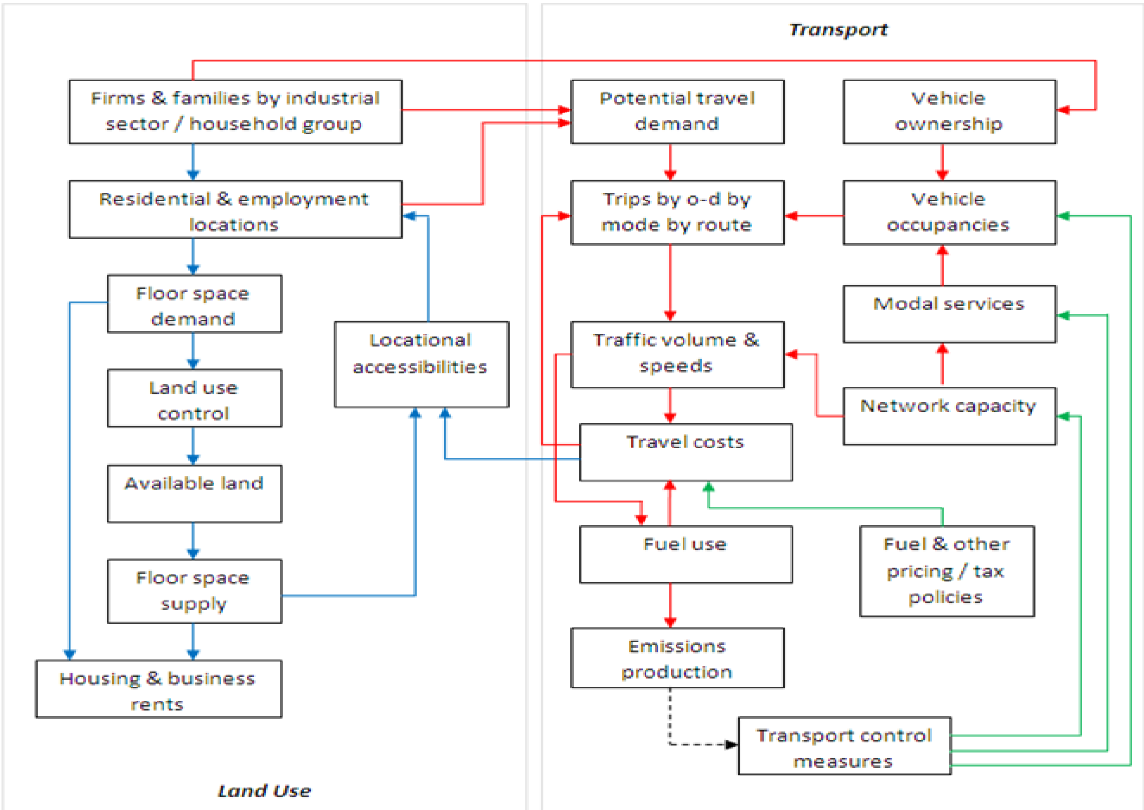
The LUPTAI tool assists planners to respond to the challenges of urban growth by comparing effectiveness of variables including changes to residential population density, different land uses and improvements in public transport infrastructure, services, and frequencies. For communities throughout Queensland 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 land use system

Figure 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 generations. Travel costs in the transport system provide the feedback to the land use system which affects the household's choice on where to live, where to work and land use patterns in a lagged fashion.

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.

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

Car use encourages urban sprawl by demanding large amounts of urban land for roads and parking, by degrading the urban environment and accommodating more greenfield developments. The negative impacts of transport related urban sprawl are:

- **Social impacts:** Wide roads and heavy traffic reduce community cohesion. Car oriented communities make non-drivers locational disadvantaged due to their relatively poor access by other modes. The urban scrawl and middle-class flight to farther suburbs is seen to racial and income segregation and social conflict. Long commuting time increases the physical separation between work and home. However, urban sprawl may be socially beneficial. Lower density residential locations provide more per capita recreational land. The suburban residents usually prefer their detached housing over inner-city apartments.

- **Economic development:** Increased density and clustering provides efficiencies of agglomeration due to the ability to reach desired activities and destinations.

- **Environmental degradation:** Land clearances and road pavements degrade environmental amenities. Roads sever and segment the residential neighbourhood and natural habitat. Roads further encourage car-oriented development and urban sprawl.

- **Transport and accessibility:** Urban sprawl creates less accessible land use patterns, which increases the amount of travel required for a given level of accessibility and reduces transport options. This increases per capita vehicle ownership, vehicle use and total transport cost. Households in lower-density car dependent communities spend significantly more on transport on average than in locations with more accessible land use and balanced transport systems. Sprawled land use tends to increase the costs of providing basic mobility to people who are transport disadvantaged.

- **Public service costs:** Urban sprawl tends to increase the costs of public services such as policing, emergency service, school, roads, public transport provision and viability, water and sewage.

- **Aesthetic degradation:** Roads, parking facilities and vehicle traffic can degrade landscape beauty.

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 the employment opportunities, property price, economic development, clustering and agglomeration. There is a growing interest in measuring these impacts in recent years known as Wider Economic Impacts (WEI) evaluation (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 assessment 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).

While there is some precedent of guidance domestically and internationally on preparing economic appraisals for passenger initiatives, there is not that much of 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 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 Freight cost benefit analysis (CBA)

5.2.1 Freight investment evaluation framework

The investment on freight network can fall in 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:

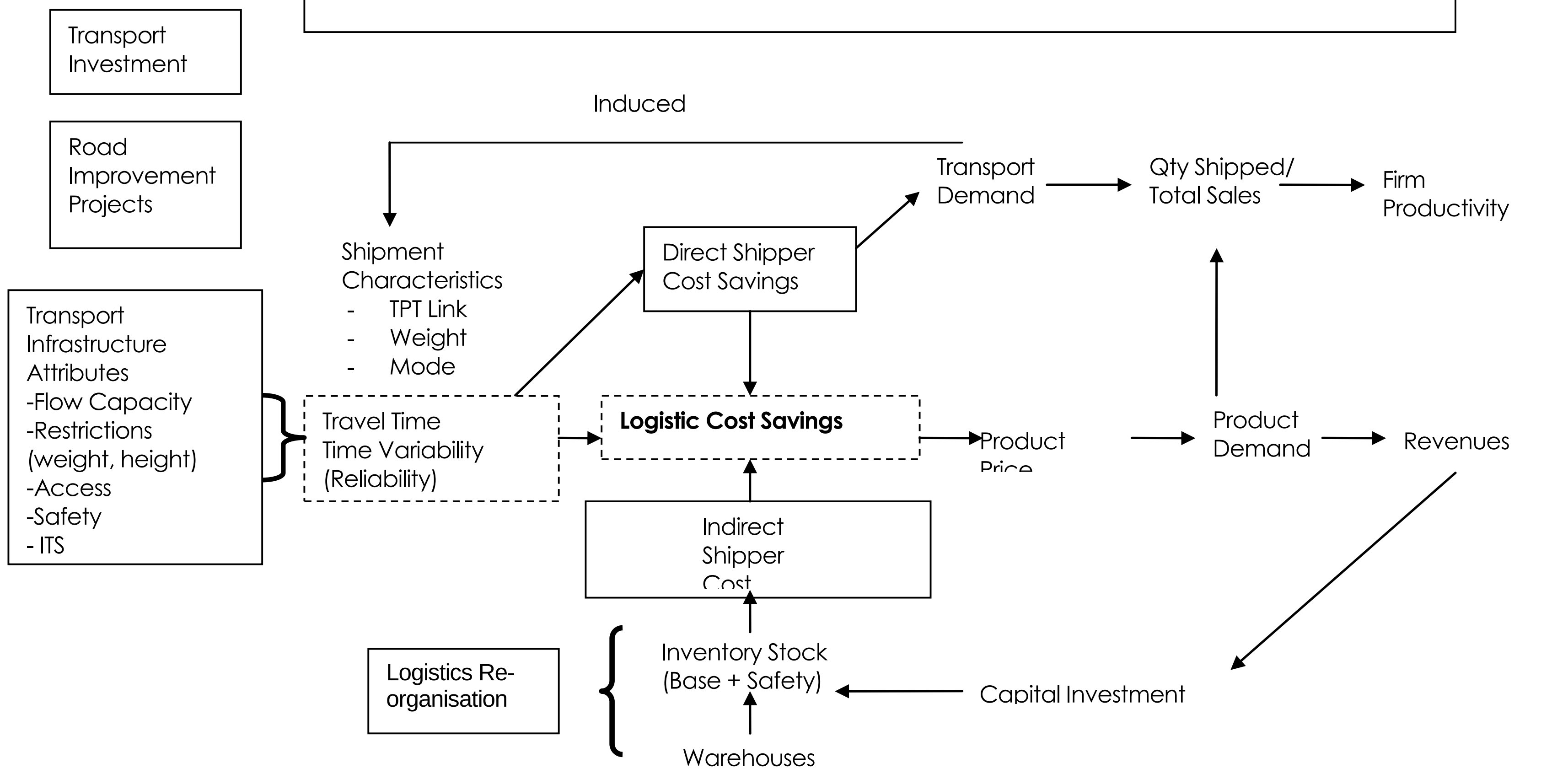
- Increased flow capacity;
- Less restrictions on vehicle weight and size and increased road speed limits;
- Relaxed limitation of road access, and logistic industry can access to both road and rail;
- Safety outcome by road accident reduction;
- Improved information systems.

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'[28] facilities, resulting in savings in warehouse cost and inventory stock. This process is generally referred to logistic reorganisation.

Freight transport demand increases with population growth. There is also an induced demand that occurs as the logistic cost was 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.

[28] 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 initiative 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 also 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).

The 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 schedule for loading or unloading freight vehicle at terminals. For freight rail projects that expect to divert traffic from road, there are significant benefits in road decongestion and reduction in air pollution and greenhouse gas emission.
- Wider economic benefits include logistic reorganisations, firm clustering and related productivity gains. These benefits can be assessed in the Wider Economic Impacts (WEI) framework illustrated in Chapter 3.
- Regional economy includes employments, exports, imports and competiveness in international market. These impacts can be assessed by Computable General Equilibrium (CGE) model as discussed in Chapter 5.

Several analytical tools are available for assessing and quantifying these impacts. These include:

- Cost Benefit Analysis Use of Input Output Model
- Use of Computable General Equilibrium (CGE) Model

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.

5.2.2 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, steels, metals, cement, timber and fertilisers. Non-bulk commodities are manufactured products also known as transformed or value-added products.

Bulk freight forecast in a region is a process of estimating production, consumption, import and export. The surplus of production plus import less consumption is the amount of export. The commodity flow matrix for origin-destination pairs is estimated.

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

The freight forecast produces the freight movements by inter 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 load based on industrial standard or surveys[29]. The accuracy achievable in demand forecasts in analysing freight initiatives depends to a large extent on how the market has been segmented and whether information on these is readily and reliably available.

The models used for freight demand forecast are statistical or econometric models specifically built for a project. These models utilise historical freight movements between regions, information obtained from surveys to freight industries and customers. Austroads developed a freight simulation model (FreightSim)[30] which has 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 Sydney Greater metropolitan Region (GMR) as a part of STM inputs.

Freight volume forecasts across the NSW network and through international gateways are to be sought from the Bureau of Freight Statistics (BFS) which is the reference point for freight demand modelling. The BFS forecasts freight demand through 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.

5.2.3 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 acceptable time, consistency and dependability in travel times of a given trip or travel time 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. 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.

c. **Better coordination** with attendant impact on inventories and spatial location with 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 is cautioned that some benefits, such as reduced freight cost, have been already captured in standard CBA.

e. **Environmental benefits –** Examples of these are when rail upgrades attracts freight from road to rail thus reducing emissions from less vehicle kilometres travelled (vkt)

[29] ABS Survey of Motor Vehicle Use provides useful statistics for deriving conversion factors
[30] Forecasting inter-regional freight transport from regional development, Austroads, AP-R226

or number or frequency of trips and where the upgrade results in additional usage in other parts of the routes or at the terminals.

f. **Logistic cost savings** - allow firms to reduce their price, thereby increasing product demand, sales and transportation used. 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. The Willingness to Pay based on logistic cost savings can be derived using inferred elasticity as a measure response to infrastructure or regulation improvement to measure benefits.

g. Re-organisation benefits: Firms do re-organise in response to transportation infrastructure improvements so as to reap the rewards of advanced logistics. The effect 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.
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

5.3 Evaluation techniques

The 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.

5.3.1 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 for provision of 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 where these are derived mainly from 2 data sources:

- National I-O table which shows input and output structure of industries
- Regional accounts used to adjust the national I-O table to reflect the region's industrial structure and trading patterns

This analysis will calculate 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[31] 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 also 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).

Box 2 Generalised Regional Input Output (GRIT) Models

This technique uses regional input-output tables derived 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. They provide detailed information about the supply and use of products in the Australian economy and about the structure of and inter–relationships between Australian industries. The annual input output tables are published three years after the reference period because of the data requirements and compilation process. The latest available I-O table was in 2012/13.

The regional benefits of the road upgrade project were estimated using this technique through the construction of the regional input output table. That estimated household income, employment, profit and final demand of the region as well as quotient multipliers to derive the regional input output table of the region.

The input output tables are then used to determine the effects of the road upgrade through the use of final demand impacts of changes in industry (e.g. manufacturing, transport). The results of the Input Output analysis shows that the expected impact of the upgrade project in terms of the Gross Regional Product, additional household income and full time equivalent jobs generated. (Application: Social Economic Impact of Bells Line Expressway, Western Research Institute, November 2005).

It is important to note that there are numerous issues with I-O analysis. Principally, it does not include resource constraints, deals only with market effects and includes multiplier effects. It is also important to understand how changes in travel performance from highway congestion relief or public transport investment should be used in an informed input output analysis. A simplified but incorrect approach is just feeding directly into the I-O model the net increase in regional output which is represented by the total monetised benefits including personal/freight

[31] 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.

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.

5.3.2 Use of Computable General Equilibrium Model (CGE)

For cost benefit analysis of majority of transport and road projects, knowledge of the project outcomes obtained from measuring total benefits or the majority of public sector benefit for the project will suffice as many of the assumptions in transport CBA will entail only minor loss of realism. In these cases, there will rarely be a call for the application of a macroeconomic or CGE type of models, which are often inappropriate evaluation tool for all but the largest of infrastructure projects (e.g. influencing large parts of the network). For large projects, CGE analysis can serve as an extension to the CBA assessment and can provide policy impact analysis of the particular investment or policy initiative.

The CGE is an economy-wide (national, state or regional) mathematical model employed to perform simulations related to the behaviour of industries, producers, consumers and governments in response 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. This will require the use of the latest ABS national account tables for the Australian or the State component of the CGE model. The CGE models can be used to analyse key issues such as policy changes in an integrated global economic framework. Box 3 contains CGE models that can be used for freight investment evaluation.

Box 3 CGE Models

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
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 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. The 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.

5.3.3 Hybrid model

The hybrid model combines the conventional cost benefit analysis with regional economic impact into a single framework. An example of such model is the Transportation Economic Development Impact System (TREDIS), a flexible and modular framework for economic impact and benefit/ cost analysis of transport projects, programs, and policies developed by Economic Development Research Group (EDRG), Boston, USA.

TREDIS is an analysis framework that uses scenario level input data to holistically estimate economic impacts, cost benefit measures and financial impacts of implementing a "build" alternative versus a "no build" or "do minimum" alternative. It provides a consistent system for applying the different forms of economic analysis across space, time and elements of the economic. 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, the TREDIS not only calculates 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 case study of a bus rapid transit (BRT) proposal in Sydney. [32]

Evaluation and Benefits 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.

TREDIS sort 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.

[32] 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

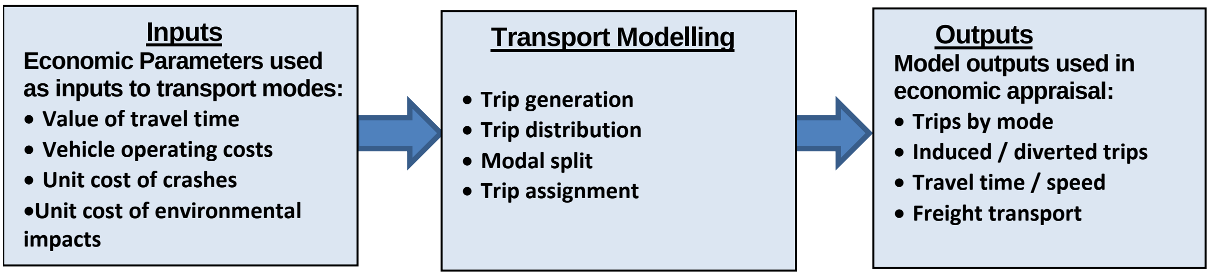
6. Patronage demand measurement: Estimating Trip Movement

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 with strategic models, road traffic model, rail and bus patronage forecasting models. Two case studies provided in the final section to illustrate the interrelationships between transport modelling and economic appraisal.

6.1 *Linking demand models with economic appraisals*

Transport demand modelling and economic appraisal are interrelated and interdependent, as shown in Figure 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 expected to be updated annually.

6.1.1 Outputs

Economic appraisals rely on the accurate forecast of transport demands. The following outputs are frequently used in economic appraisals.

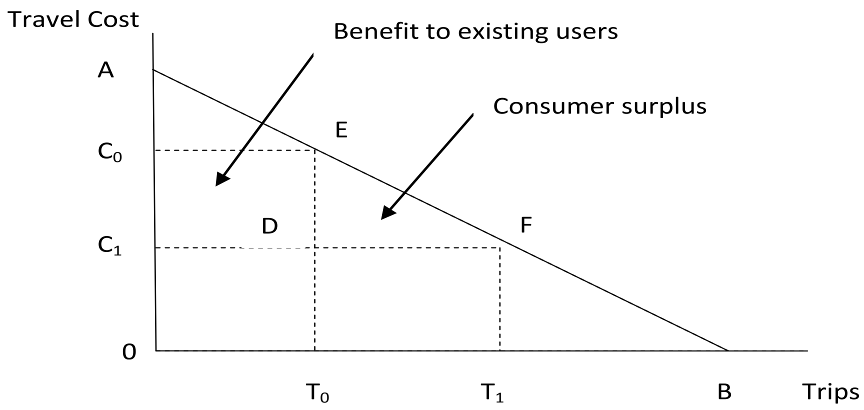
- ***Traffic volume on roads***: In order to determine the value of annual costs and benefits, it is necessary to produce an estimate of future traffic volumes of the base case and project options. The forecast future demand will affect both the extent and quantity of the savings.

- ***Public transport usage***: A transport improvement project will impact people's 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 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. Environmental benefits are expected if car drivers are diverted to public transport as public transport generates a lower level of pollutions, greenhouse gas emission and noise.
- ***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 on warehousing, inventory and supply chain. 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 cost of consumer surplus. The use of consumer surplus to value the 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.

6.2 Demand forecast

A transport model is a simplified representation of complex transport system. The four broad categories of transport demand models used in transport planning and project analysis are traditional four step transport models, behavioural travel demand models, linked land use and transport model and integrated land use transport model.

6.2.1 Four step transport models

The conventional four step transport model was implemented in 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*** – distribute 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 the 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 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*** - the 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 of public transport modes.

The four step models are still widely used in transport demand forecasting, although there were critiques on it. Most critique relates to is uni-directional modelling process starting from trip generation and ending at trip assignment at travel zonal level, assuming that each step is independent to the steps below it. The 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 process unsuitable for long term land use transport planning.

6.2.2 Behavioural travel demand models

The behavioural travel demand models are random utility models representing the individual choice when a traveller faces alternatives. Travel related choices include modes, routes, time of travel and trip frequency.

Analysis of 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 to joint revealed and stated preference data. The of different travel modes is 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 demand side of transport system and the supply side is not explicitly represented in the model specifications.

6.2.3 Linked urban land use and transport models

At early stages the transport models treated land use variables as being exogenous. The linked land use and transport models recognise the relationships and feedbacks between land use and transport systems33. A typical modelling approach uses the spatial interaction incorporating the locational accessibility to simulate the relationships among the places of work, residence and service activities (shops, education and recreational facilities).

The generalised travel costs are calculated by mapping travel demand on the networks. The generalised travel costs go back to trip distribution step, and to land use system as a lagged impact on locations of employments 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 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 of other purposes are likely being responsive to travel costs.

6.2.4 Integrated urban land use and transport models

Integrated urban land use transport models recognise complex connections between land use and transport systems. The urban land use usually refers to spatial distribution or geographical 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 model causes and effects within the transport system. The land use provides the transport system of the location and the volume of travel generation. The transport system affects the land use through accessibility in a temporally lagged manner. Changes in travel costs drive the relocations of labour, residence, business and economic activities.

The limitation of integrated land use transport models is that the trip chaining has not been addressed effectively. 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 out of options in the second leg of the trip. The activity-based travel modelling can overcome this limitation.

6.2.5 Generalised cost specification

The generalised travel cost is the most important specification of transport demand modelling. In the four-step modelling, generalised cost equation affects mode choice and trip assignment

[33] Bureau of Transport Economics Working Paper 39, Urban Transport Models: A Review, 1998.

in driver's route choice. In the integrated land use and transport models, generalised travel cost impacts on 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

$$GC_{car} = T_{in\_veh} * VTT_{car} + VOC + Toll \quad \textit{Equation 6.1}$$

$$GCPH = T_{in\_veh} * VTT_{in\_veh} + T_{auxiliary} * VTT_{auxiliary} + T_{waiting} * VTT_{waiting} + P_{transfer} * Transfer + Fare \quad \textit{Equation 6.2}$$

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 urban vehicle start-stop model and freeway model. The 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 the average vehicle occupancy.
- The road tolls between origin-destination pairs are output of transport modelling.

GC_{PH} represents the generalised travel cost of train passengers. It consists of five parts: value of in-train time, value of auxiliary time, value of waiting time, transfer penalty and train fare.

- 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.

Economic parameters (Appendix 4) 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 to specify the generalised travel cost functions.

6.3 Demand models used in Transport for NSW portfolio

6.3.1 Sydney Strategic Models

Sydney Strategic Travel Model (STM)

The STM is developed and maintained by the Bureau of Transport Statistics (BTS). 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 tour based model that recognise 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 estimates 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 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 system. It is based on travel zones, in which input data and outputs contains approximations which mean that the STM is not the right tool for studies of small area or non-major links. In addition, feedback to land use changes is not provided in the model which requires estimation outside the model and specified as input. For detailed use of the STM, contact BTS.

NSW 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 and between other States. 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 support bridge economic appraisal 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.

6.3.2 Road traffic models

The models used by Roads and Maritime Services (RMS) can be categorised into several levels of details 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 contexts 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[34]. 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.

[34] Roads and Maritime Services, Traffic Modelling Guidelines October 2011.

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)[35]. 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.

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 intersections. 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) the is the model

[35] Traffic modelling guidelines, RMS, 2012

being used by RMS in in economic appraisal of rural road projects. The description of REVS in this section draws on RTA REVS User Guide[36] 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).

The 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 SWIDE file include

- 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.

The contents of AWIDE file include

- 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.

The TfNSW Evaluation and Benefits publishes annual economic parameters on value of travel time, accident cost and road user costs, which are used to update the recommended SWIDE file in annual basis. . The standard file of SWIDE is maintained by RMS Transport Planning Section. The REVS users are expected to specify localised AWIDE file. A case

[36] RTA Rural Evaluation System – REVS, User Guide, by Transport Planning Section, June 2010

study has been provided to demonstrate the process of REVS. For further assistance on standard SWIDE file, specification of AWIDE file and running REVS model, contact RMS Transport Planning Section, Vince Taranto (02) 8849 2581.

g. VEHOP

The VEHOP is Vehicle Operating Cost Model. The same as REVS, the 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).

The 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 TfNSW Evaluation and Benefits Branch publishes annual economic parameters on value of travel time, accident cost and road user costs. Based on these parameters, VEHOP price file is reviewed and updated annually to estimate the vehicle operating cost at most recent price year.

The vehicle operating cost can be estimated in a combination of the following variables:

- Vehicle type: For 8 vehicle types including car, 2 axle 4 tyre truck, 2 axle 6 tyre truck, 3 axle, 4 axle, 5 axle, 6 axle 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

The TRARR represents 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 for research into two-lane road traffic flow and capacity. 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.[37]

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, more heavy trucks, or long term changes in vehicle size and power. Observed traffic characteristics

[37] Sourced from Austroads Report, TRARR06 Model Interface 9T06): User Guide and Tutorial, may 2006

include speed, travel time, vehicle bunching or platooning, time spent following, overtaking rate and fuel consumption.

The 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.

The TRARR produce 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)

6.4 Rail patronage forecast

The rail patronage forecast is analysed at strategic level and station-to-station forecast[38]. The strategic forecast is provided by:

- Sydney Strategic Travel Model (STM) developed and maintained by BTS
- 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

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 requires 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

6.5 Bus patronage forecast

The Transport Services of Transport for NSW developed a procedure to estimate the bus patronage in bus route design[39]. 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 the increased patronage.

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[38] Station to Station forecasts are produced by Bureau of Transport Statistics (BTS), TfNSW.
[39] Advice from Transport Services Division, TfNSW

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. The data behind the procedure was sourced from 2006 Census which is 5 years old already. However, the procedure is particular useful for comparing bus routes in that the changes rather than total number of patronage of different routes are the focus.

6.6 Fixed Trip Matrix and Variable Trip Matrix Techniques

6.6.1 Definition

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. Project option is defined as 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 in that the number of induced trips is insignificant thus the number of trips in the base case and the project option is assumed 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

Fixed trip matrix techniques ignore these impacts. **Variable matrix method** differs from the fixed trip matrix techniques in that these effects are considered thus demand in the project option matrix is generally higher than that in the base case matrix for a given forecast year.

6.6.2 When to use of the variable trip matrix

The variable trip matrix techniques are recommended in UK Department for Transport and 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 of benefit amounts between the fixed trip matrix technique and variable trip matrix is 10% or more.
- A substantial level of congestion, in that the congestion would add at least 10 percent to the typical peak hour travel times compared to free-flow condition. 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. In all other circumstances it is not usually valid to use a fixed trip table. The Transport for NSW recommends using a variable trip matrix for large transport improvement projects that likely cause induced demands, mode shifts or route changes.

6.6.3 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.

6.6.4 Benefit estimate in variable matrix technique

In the fixed matrix evaluations, the benefits are the change 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 resource consumption.

The benefit calculation formula is:

Equation 6.3

$$\mathbf{Benefits} = (\mathbf{Base\ Trips\ x\ Base\ Resource\ Cost} - \mathbf{Option\ Trips\ x\ Option\ Resource\ Cost}) + \tfrac{1}{2}\,(\mathbf{Base\ Perceived\ Cost} + \mathbf{Option\ Perceived\ Cost})\ \mathbf{x}\ (\mathbf{Option\ Trips} - \mathbf{Base\ Trips})$$

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, variable matrix technique is a resource cost correction for induced travels.

6.6.5 Economic parameters to support variable matrix technique

While the fixed matrix technique requires the resource costs only for estimating the project benefit, variable matrix technique requires both resource costs and the perceived costs.

Three sets of economic cost parameters for use in economic appraisal are presented in Appendix 4 of this Guidelines and these are for:

- 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 benefit. 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 and the less traditional projects such as improved incident removal, better management of transport systems, improvements in transport operations or provision of information systems.

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 project 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 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 in terms of formulated utility 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 assumes 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 at after the time of arrival.[40]

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.

[40] The valuation of travel time variability, Mogens Fosgerau, OECD Roundtable, Discussion Paper 2016-04, November 2015, Paris

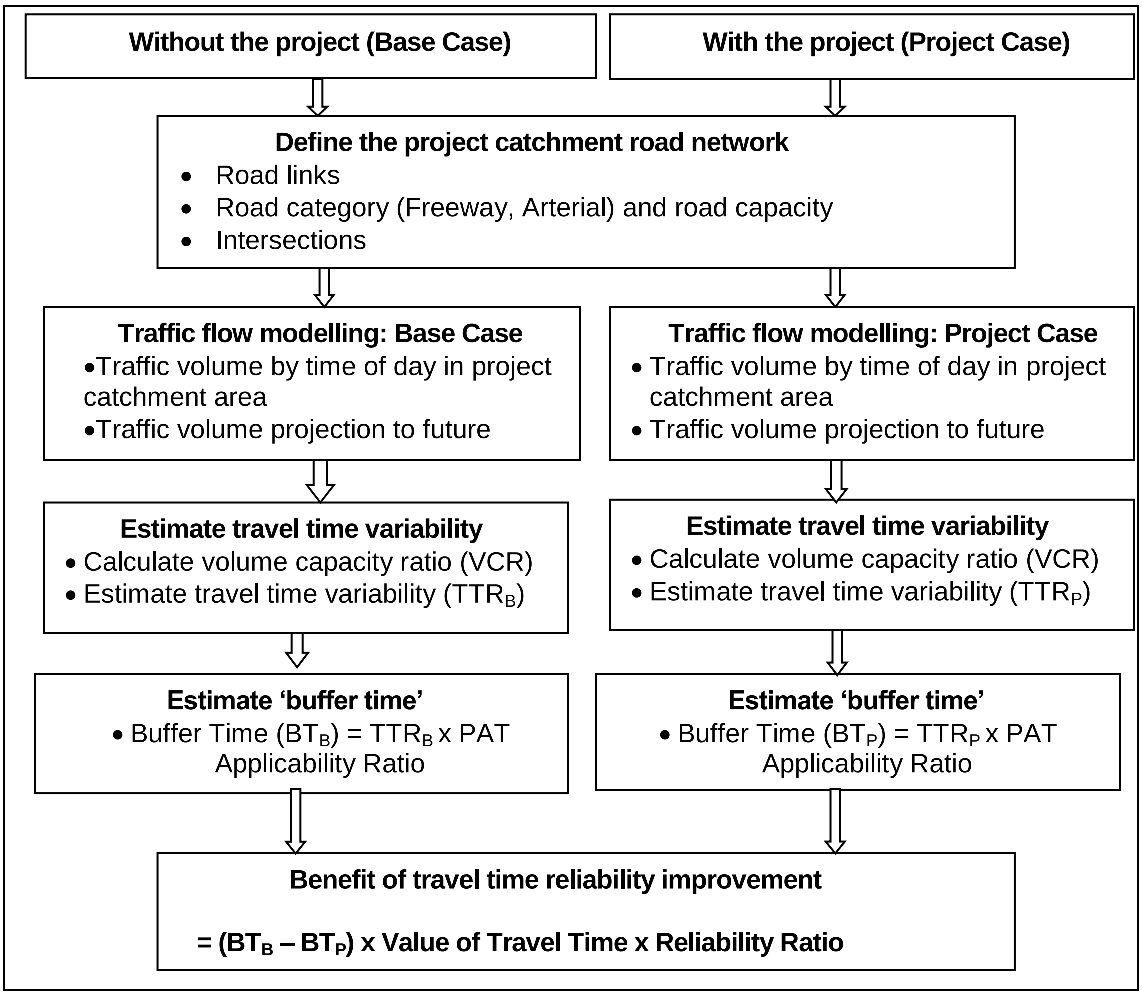
The valuation of travel time reliability considers the buffer time that the travellers have budgeted before departure. It is worth noting that, in this framework, the values of travel time reliability does not include other logistic costs such as worker's cost at warehouses waiting for loading or unloading 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.

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 but random events and drivers cannot predict when and where an incident will happen. Better road environment can reduce these incidents
- **Roadwork** –Predictable to some degree. Location and duration of roadwork are usually known before the start of journey and the delay is generally expected
- **Extreme weather** – Uncertain. Drivers expect delay in extreme weather conditions but occurrence of extreme weather can be difficult to foresee
- **Special events -** Largely predictable. Drivers 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 their impact on journey time. Traffic incident is considered unpredictable but the theory on its impact on travel time reliability is not mature yet thus 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 travel time reliability change 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 in 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 was also examined. 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. [41] The UK Department of Transport recommends that the model be calibrated to local conditions, but such calibration has not been done in Sydney.

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[42]).

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 ratio is readily available for all road types, the model can be used for estimating the travel time variability for motorways, urban arterial and other roads and signalised intersections.

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[41] The UK model forecasts the SD of journey time based on travel time and distance as shown in following equation: $\mathbf{SD}_{ij} = \mathbf{0.0018} \cdot \boldsymbol{T}_{ij}^{\mathbf{2.02}} \cdot \boldsymbol{D}_{ij}^{\mathbf{-1.41}}$ where: $\boldsymbol{SD_{ij}}$ = Standard deviation of travel time from origin location *i* to destination *j*, in seconds, $\boldsymbol{T_{ij}}$ = Travel time from origin location *i* to destination *j*, in seconds and $\boldsymbol{D_{ij}}$ = Distance from origin location *i* to destination *j*, in km.

[42] NZ Transport Agency (2013) Economic Evaluation Manual

$$SD_{Travel\,Time} = S_0 + \frac{S - S_0}{1 + e^{b(VCR-1)}}$$ *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) *b* is estimated model constants 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:

$$Variability_{Trip} = \sqrt{\sum_{L=1}^{n} SD_L^2 + \sum_{I=1}^{m} SD_I^2}$$ *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)[43] 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.

[43] Ensor, M. (2004) A procedure for evaluating the trip reliability benefits from individual roading projects, Beca Infrastructure, New Zealand.

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,

$$\boldsymbol{Buffer\ Time = Expected\ travel\ time\ variability\ x\ PAT\ AR} \qquad \textit{Equation 7.3}$$

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.

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 the work, 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 76 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 of in-vehicle travel time, that is, the **Reliability Ratio is equal to 1**. This recommended value is based on a review of international evidences.

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
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 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 strategic phase of project development and probably for smaller scale projects, a more granular travel time reliability modelling which can use with broad time of day segments maybe more applicable. A model developed for Roads and Maritime Services (RMS) by Industrial Services Group (ISG)[44] 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.

$$STD = \beta_1 \; x \; Delay \; \beta_2 \; x \; VCR \; \beta_3$$ *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:

$$SD_{ij} = 0.0018 \cdot T_{ij}^{2.02} \cdot D_{ij}^{-1.41}$$ *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

[44] Assessing network reliability & benefits through Smart technologies, Research Centre for Integrated Transport Innovation (RCTI) and The Industrial Sciences Group (ISG), June 2015

D_{ij} = Distance from origin location *i* to destination *j*, in KM.

For specific projects, the UK Department for Transport (2014)[45] 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 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) [46] 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

$$\boldsymbol{Variability\ cost\ for\ analysis\ week\ (VC^{\ rtod}) = n_{\ rtod} * \sigma_{\ rtod} * \frac{VOT^{y}}{60} * Reliability\ ratio}$$

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

[45] Department of Transport (2014) Transport Analysis Guidance (TAG), TAG Unit A1.3, User and Provider Impacts,

[46] Final Business Case for the Northern Beaches B-Line Program (B-Line), Ernst and Young, 2015

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 and 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 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, any estimates of reliability benefits using this method are only allowed for Appraisal Summary Table (AST) but not permitted in main CBA. TfNSW does not recommend this model for estimating the 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 prototype investments. The case studies outline the process following the major steps and using the economic parameter values calculates the costs and benefits of each feasible 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[47]: 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.

[47] It is acknowledged that this case study is provided by RMS Transport Planning Section

3. 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.

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, 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 analysis48. Sensitivity testing was also conducted at the NSW Treasury standard 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 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.

[48] As advised by the Project Manager.

4. 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).

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 Economic Evaluation

Background

The North Sydney Freight Corridor (NSFC) Program comprises of a number of projects over three stages to improve rail services along the Sydney to Newcastle rail corridor. The stage 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 part of the main freight line along the east coast interstate rail network, managed by Australian Rail Track Corporation (ARTC). Freight services are restricted to off peak times when they cross into RailCorp owned track, as the Main North Line is frequently used for passenger services. 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

The 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 cost. Operating/recurrent costs include driver time, fuel and repair & 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 Benefits Branch, Finance and Investment for a copy of the model.

Bus Acquisition Cost-Benefit Analysis Tool

Read Instructions

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Transport for NSW

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For any feedbacks or comments please send an e-mail to: EconomicAppraisal.EPSP@transport.nsw.gov.au

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 for the interchanges the conventional economic benefits due to improvement in these interchanges should be estimated, such as the travel time savings and safety benefits.

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 automatically provide a mechanistic way of estimating 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.

Each interchange project is first scored separately using **Transport Factors**

- Accessibility
- Impact on safety
- Wider economic impact
- Sustainable level of service (LOS)
- Environment and
- Integration

Maximum Score = 28

Projects are then scored on **Planning Factors**

- Economy
- Resource funding options
- Land use policy
- 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

A panel of 4 staff has 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**
ENVIRONME NT	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 pg.29.
- 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 Benefits Branch, Finance and Investment for a copy of the model.

ITS-CCTV Cost-Benefit Analysis Tool

Read Instructions

Update Inputs and Assumptions

View CBA Summary Results

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Evaluation & Benefits

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Transport for NSW

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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.[49]
- 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[50]. The VMS will reduce 40% of secondary accidents. In the off peak hours, an incident will cause additional 5% secondary accidents.[51] 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

[49] RTA 2011 Annual Report

[50] Virginia Centre for Transportation Innovation & Research (2011), Primary & Secondary Incident Management: Predicting Duration in Real Time, April 2011.

[51] US DOT, Intelligent Transport Systems for Traffic Incident Management, US Department of Transportation

reduction in secondary accidents from VMS installation and the average two vehicle 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 accident 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 Economic Policy Strategy & Planning, FINANCE 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 & Benefits

Finance and Investment

Transport for NSW

Version 1: April 2013

For any feedbacks or comments please send an e-mail to: EconomicAppraisal.EPSP@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 Benefits Branch, Finance and Investment for a copy of the model.

Bicycle Facility Cost-Benefit Analysis Tool

Read Instructions

Update Inputs and Assumptions

View CBA Summary Results

View Detailed Costs & Benefits Analysis

Sensitivity Tests

Evaluation & Benefits

Finance & Investment

Transport for NSW

Version 2: June 2016

For any feedbacks or comments please send an e-mail to: EconomicAppraisal.EPSP@transport.nsw.gov.au

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 to Economic Evaluation Guidelines.

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 Benefits Branch, Finance and Investment for a copy of the model.

HOV Cost-Benefit Analysis Tool

Read Instructions

Update Inputs and Assumptions

View CBA Summary Results

View Detailed Costs & Benefits Analysis

Sensitivity Tests

Evaluation & Benefits

Finance and Investment

Transport for NSW

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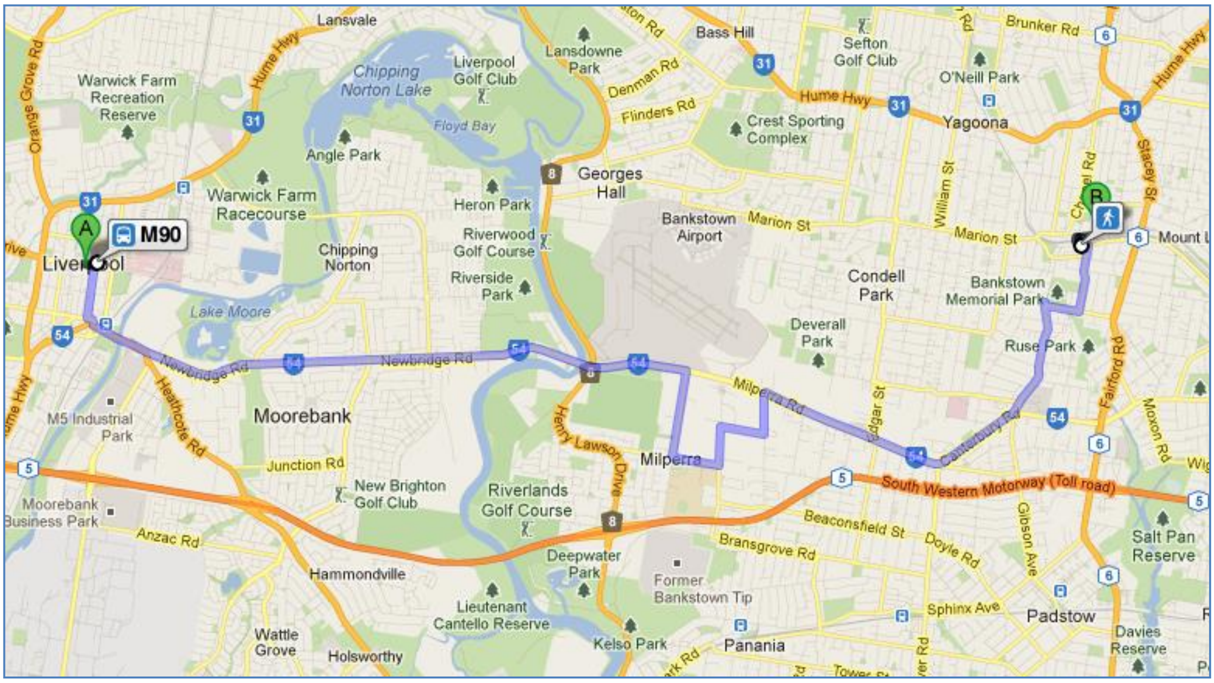
8.3.7 Strategic Bus Priority Measures

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), bus 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.

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%, 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.

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 Benefits Branch, Finance and Investment for a copy of the model.

Bus Corridor CBA Model

Read Instructions

Summary - PTIPS

Summary - PTIPS + INFRA

Travel Time Calculations

Vehicle Operating Cost Savings

Safety Benefits

Environmental Benefits

Sensitivity Testing

Evaluation & Benefits

Finance and Investment

Transport for NSW

Version 1: April 2013

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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[52]. 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[53]:

- 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.

[52] Sydney Clearways Strategy December 2013
[53] 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.

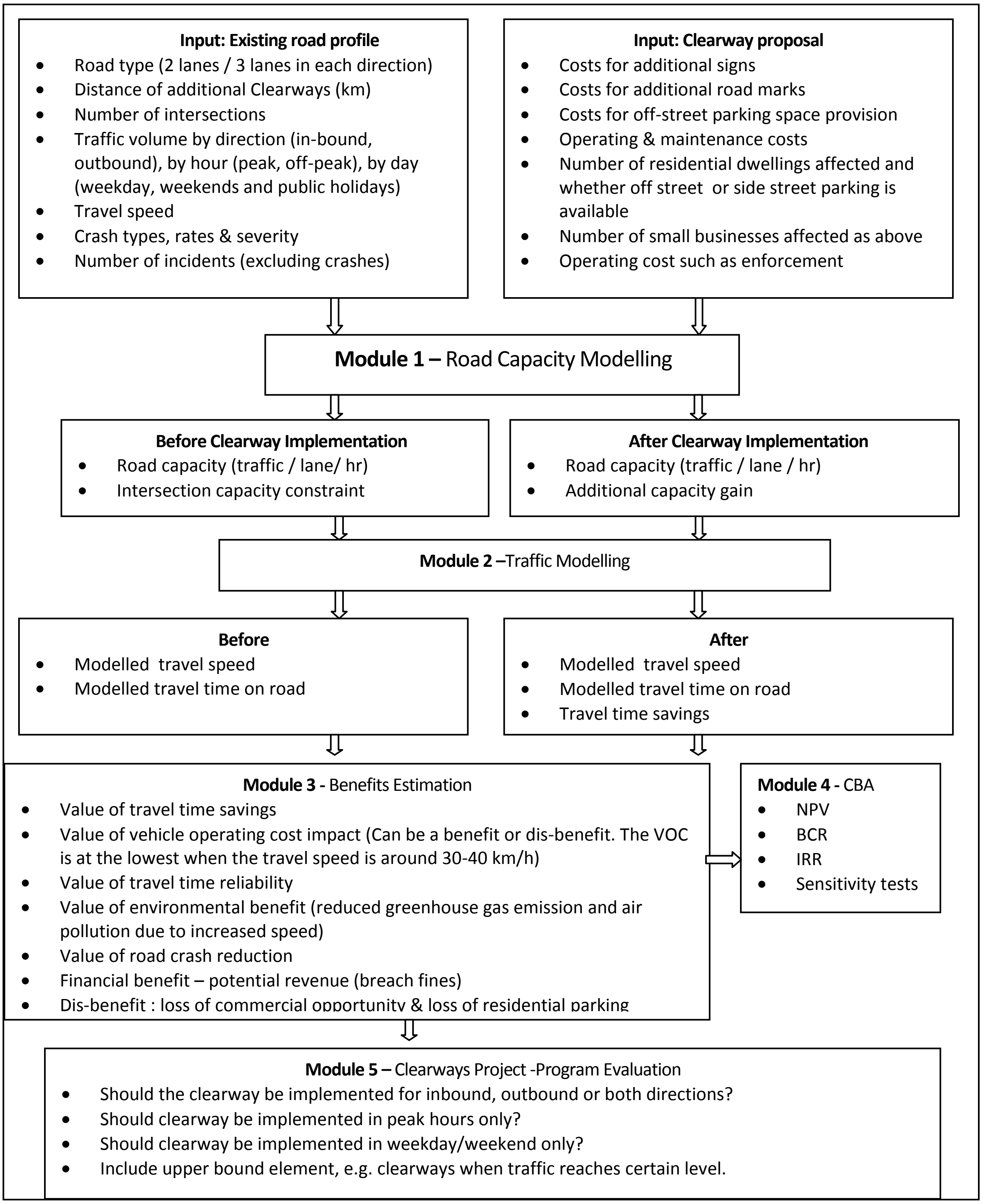
The economic appraisal of Clearways encompasses:

- 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)[54].

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.[55]

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

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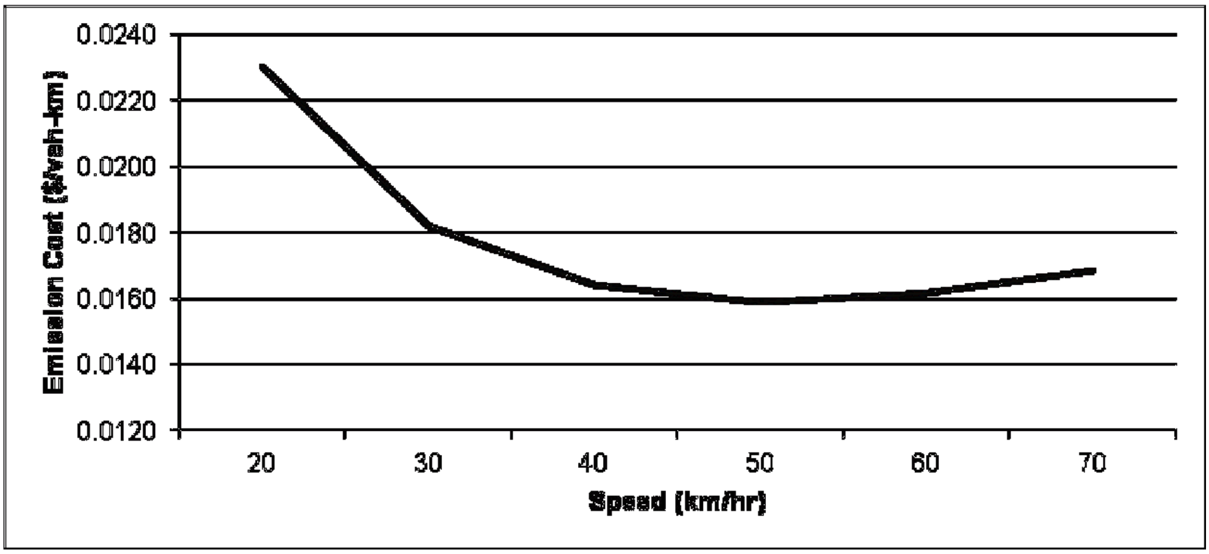
[54] Data provided by Bureau of Transport Statistics, 2010/11 Household Travel Survey, trips by mode and purpose
[55] TfNSW (2013) Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Appendix 4

consumption of vehicles by speed was estimated and multiplied by the CO_2-e conversion factor[56] and the carbon price ($57.30/tonne)[57] 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.

[56] 2.3kg of CO_2-e produced from 1L of fuel burned
[57] TfNSW (2013) Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Appendix 4, Table 54, indexed to 2013/14 dollars.

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 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.

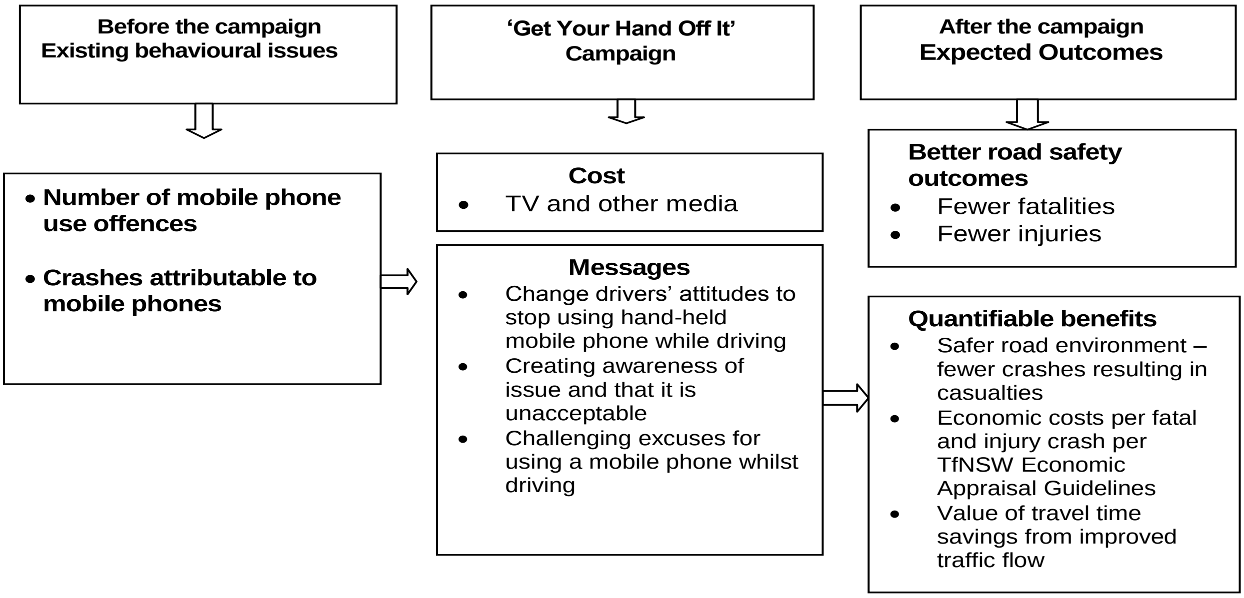
8.3.9 Economic Evaluation of Road Safety Campaigns

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(l) 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

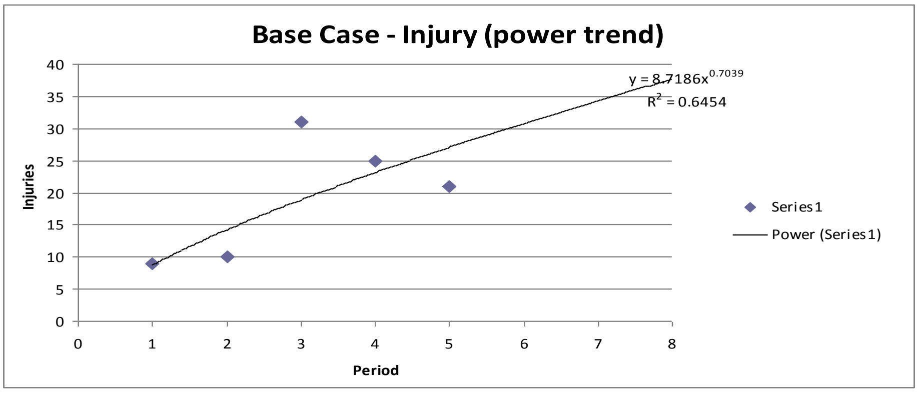


Figure 8.7: Base case trend chart for PDO crashes

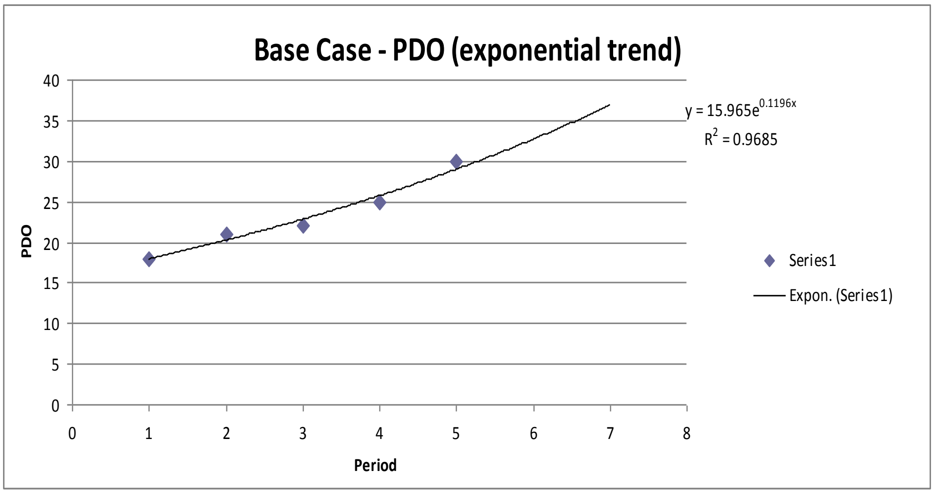


Table 8.3(n) shows the Base Case under a 'Do Nothing' scenario which reflects the forecasts in the trend for Fatal, Injury and PDO crashes when nothing is done. There is a general upward trend in injury and PDO crashes. The definition of the Base case ensures that the net effect of the 2014/15 campaign 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 research58 indicates that the effects of advertising campaign decay rather quickly and there would be only miniscule effects left after 3 years.

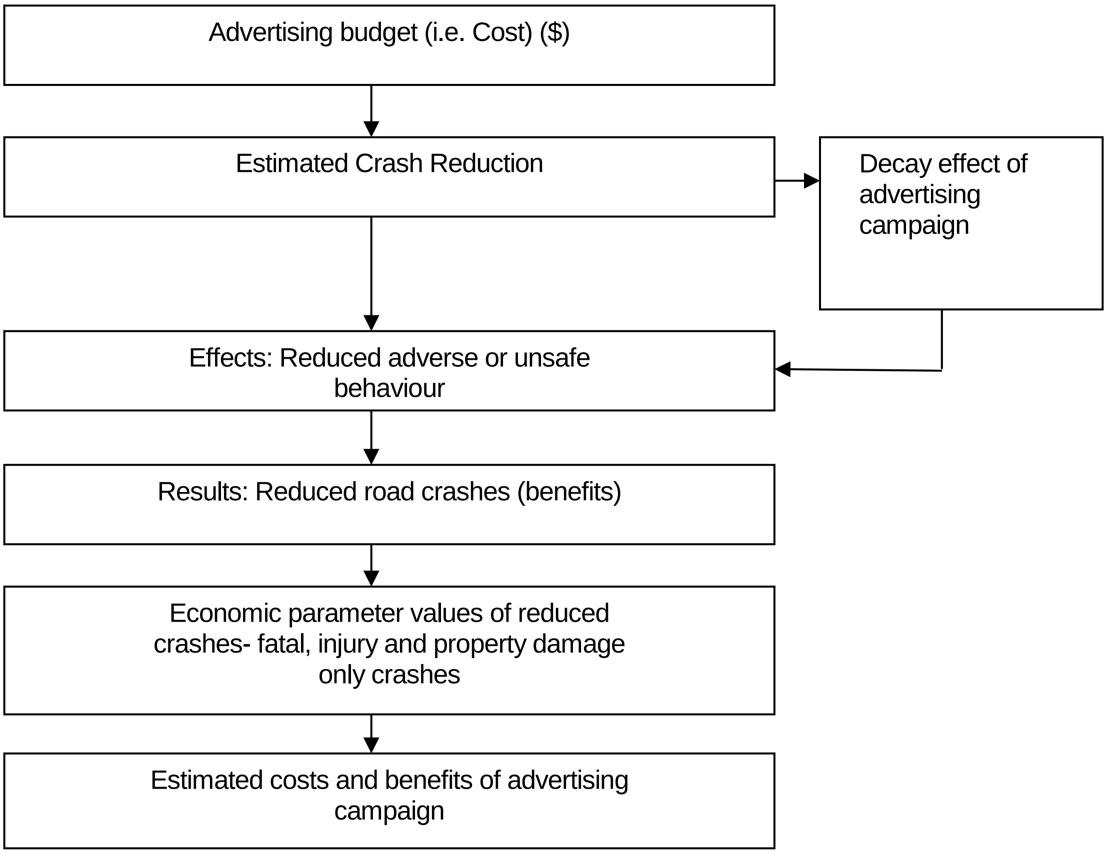
Step 4 – Estimate crash reduction attributable to the campaign. This is not straight forward because other factors may also play a part in the reduction of crashes or outcomes other than the campaign. This step illustrates four possible methods that may be used to estimate the likely crash reduction.

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.

[58] (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%

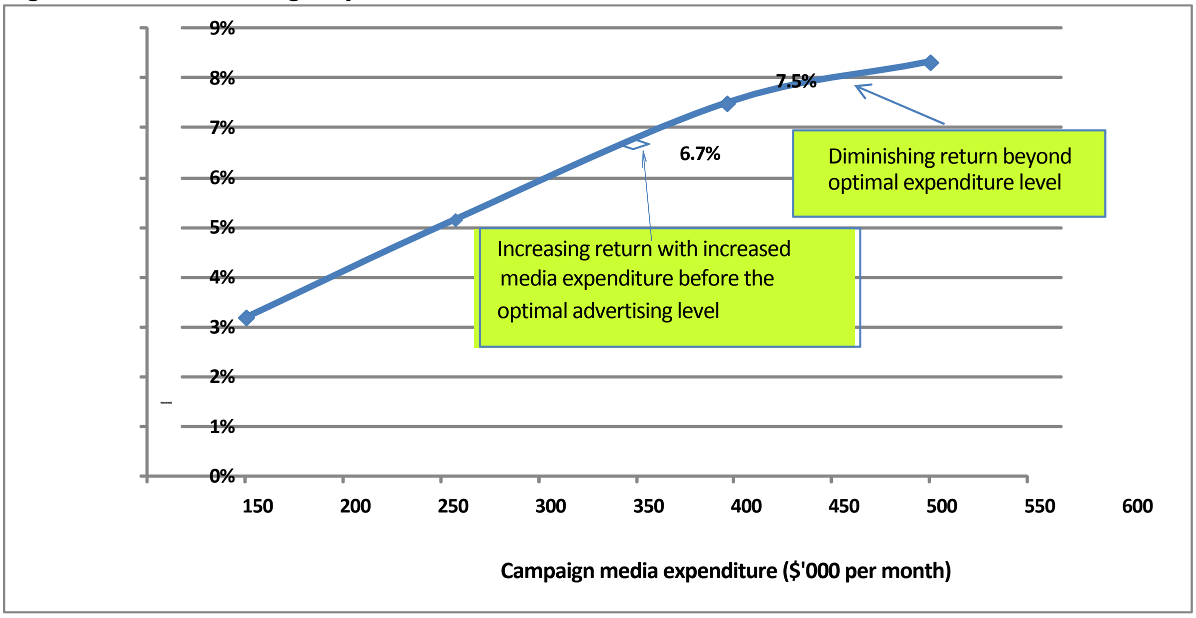
1. **Diminishing return model**: This approach is an application of the classic economic concept of diminishing returns, that as more expenditure in campaign is made, the overall impact or return on the expenditure increases at a declining rate, assuming that all other variables remain fixed. To continue 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).[59] This assumption is tested in the CBA analysis by increasing and reducing the crash rate as well as the retention rate.

[59] 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.

$$\begin{aligned}&\textit{Casualty Crashes with Advertising Campaign}\\&= \textit{Existing Casualty Crashes} \times \textit{TARPs}^{-0.0077}\end{aligned}$$

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[60]). 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)[61]. 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

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[60] The average cost of a TARP is $827 (2013$) based on Cameron and Newstead (1996).
[61] 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.

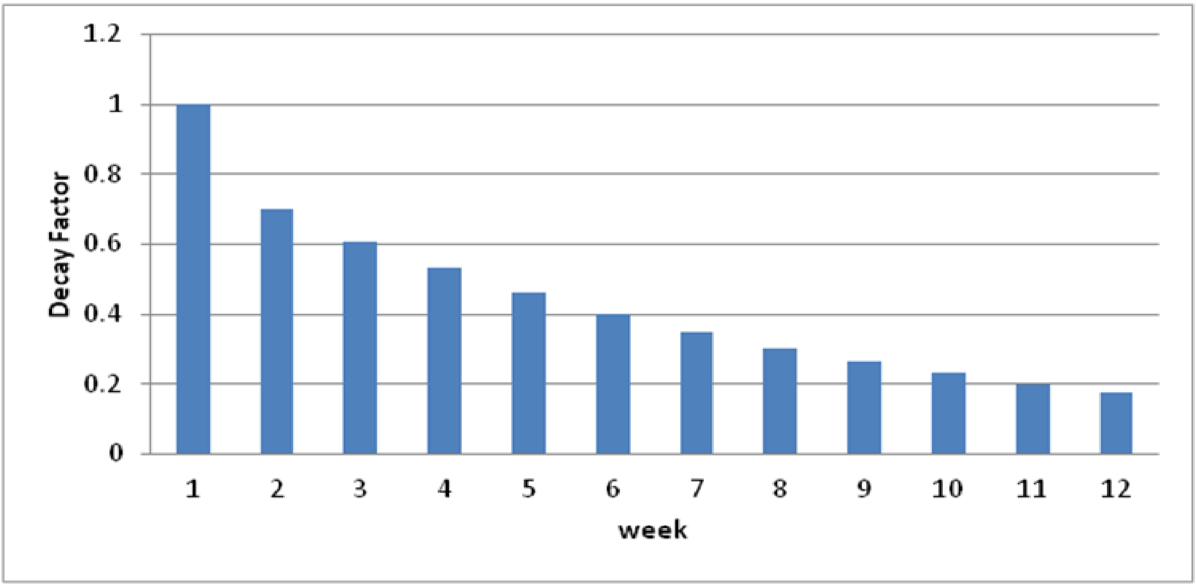
approach is more often used. Controlled before and after analysis can also be used if a road safety campaign is deployed in specific regions, in that case, other non-campaign regions can be used as a control region.

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).62 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



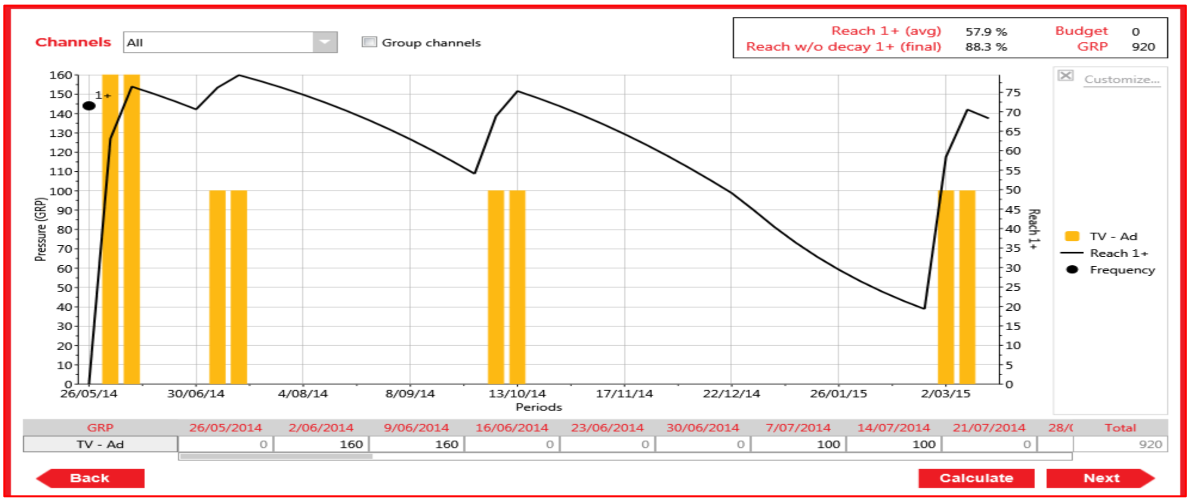
Source: Based on MUARC (1993).

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

[62] 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.

assumed to apply to all crashes targeted by the campaign not just casualty crashes as assumed in the MUARC study.

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%	**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% use**d 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 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).

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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.

EA Summary Report Form - A requires project description, identification of the strategic objectives and how much it is being addressed by the proposed projects or initiative, the feasible options, the individual benefits assessed for each option and the cost information (to be based on lifecycle costing).

EA Summary Report Form -B requires information on expected costs and benefits under each option relative to the base case for the base and the project periods. This form also requires that the key risk be identified to costs and attainment of benefits which are to be assessed as high, nominal or low.

The following are general principles to consider in preparing and presenting the Economic Appraisal results:

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 (approval, funding and prioritisation).

2. **Delineation of data and assumptions** – should clearly describe 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 its results.

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[63], assumptions and results. If key elements are extremely uncertain these should be clearly indicated and explored how resolving these uncertainties affects the conclusions of analysis.

5. **Highlighting non-monetised and unquantified effects** – reasons why these consequences cannot be valued in monetary terms are important to communicate as well.

[63] In general, upper and lower bounds are specified as ±10% of original values. For high uncertain inputs, ±20% of original values may be used.

6. **Presenting aggregate and disaggregated results –** the analytic framework should be organised to provide information on separate economic consequences of the project or component parts, total effect, effect on transport consumers, non-users, government, and other community groups not captured already in cost benefit analysis and economic appraisal.

An economic evaluation report should cover the following contents:

- An executive summary including the analysis results, decision criteria and recommendations.
- An detailed analysis report covering the project background, objectives, definition of the base case, description of options, estimating costs, benefits and key assumptions, calculation of decision criteria, risk factors and result 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 below)**

In general in presenting the results of a CBA, together with a description of the project objective and project options, a DCF analysis for each project option should be shown. All parameters, including discount rate, project lifetime, etc., must be given. All assumptions must be listed and the results of sensitivity analysis on the assumptions must be reported. Any qualitative benefits or costs that could not be put in economic terms should also be reported where these could affect the decision. The general conclusion of the CBA in terms of the ranking of options should be made explicit. 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/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	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 Ave. 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				
		@7% Discount Rate	**@4% 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%	**@4%**	**@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							

[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.

It is widely recognised that taking a long-term view of transport infrastructure needs requires not only strategic planning and a deep pipeline of projects, but also a robust framework for assessing significant infrastructure proposals. A thorough benefit-cost analysis provides information on the relative merits of infrastructure proposals.

A greater emphasis on the use of benefit-cost analysis would assist the transport and the government to better prioritise projects. Though it is not the only consideration in developing a project pipeline, robust economic assessment methodology is a useful tool for priority setting in the context of investment to address the State's and transport's strategic objectives. It would also help explain better its priorities to the community.

This process takes the information from the Project Evaluation and Program / Project Review and produces a list of selected projects.

Going through this process increases the transparency of allocating available funding across the portfolio and within the core programs, which is expected to improve the communication flow between stakeholders around the rationales underlying the funding of projects.

The allocation process takes into account the whole of government priorities and TNSW 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 funding is approved, it should be able to demonstrate that it will contribute in an efficient and effective manner to the TNSW 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.

Going through this process increases the transparency of allocating available funding across the portfolio and within the core programs, which is expected to improve the communication flow between stakeholders around the rationales underlying the funding of projects.

Some basic allocation rules that can determine broad allocation of funds and prioritisation of proposals for budget funding are discussed in the section below.

Some Fund Allocation Rules:

1. **The first call on funds will be the funding of fixed services.** The nature of these services is that they are recurring, contractual, corporate support, non-program related, legislated or customer focussed. There is some scope to influence the cost of some of these services in a budget year but to get significant efficiencies would generally take longer timeframe. **The driver for these services is to deliver at the agreed service level at the minimal costs.** Once a base level of funding has been agreed for these activities any incremental expenditure (above CPI / wage increases) will be subject to cost benefit analysis (CBA).

2. **The second call on funding will be the programs that are of a routine maintenance or operational in nature** but a full quantification of the benefits is not easily determined but a program effectiveness assessment is carried out based on asset age profile or by risk-based methodology that takes into account probability and impact factors. The driver for these programs is to find the optimal balance between costs and benefits on the premise that "a certain amount of this is needed but more is not always better"**.** Parameters to determine program effectiveness need to be established and reviewed to coincide with each budget cycle.

3. **The remaining funds are to be allocated by project based on the prioritisation criteria (both quantitative and qualitative criteria).** The method to assess each proposal will vary depending on the activity group in which the proposed project belongs. Where appropriate each proposal will be assessed against three factors:

    - Economic Efficiency of the proposal (BCR and NPV)
    - Seriousness and urgency of the transport issue being addressed (SMT & OIA)
    - Government priority areas for funding priority (SMT & OIA)

Definitions and the processes involved in investment planning and prioritisation are discussed in the Investment Portfolio Management Framework being developed by Planning and Programs, TfNSW.

The strategic assessment framework which is being proposed looks at the status of the investment against the investment lifecycle, capacity to change, value assessment and assessment of project achievability.

Value assessment is to assess the project's or investment's contribution to the Government and transport strategic objectives. This is essentially similar to the Strategic Merit Test (SMT) proposed in the National Guidelines and discussed in Section 3.1.c above.

The proposed projects for funding should be prioritised in a consistent way, and grouped into a forward investment programme where the first years of the programme 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 (CBA)	Incremental BCR	IBCR > 1
Growth (Asset Renewal, Expansion, Protection	Optimisation: Economic, environmental & safety outcomes	CBA	BCR, Incremental BCR, FYRR, IRR	BCR > 1

Ranking could be across all projects and programs or across modes or within programs or modes, e.g., rank across all projects pertaining to roads bridges rail bus ferries (project centric) or rank projects within roads, within rail, within bus, within ferries (program centric).

Prioritisation of proposed investment generally considers 3 factors:

- Net Strategic Value of proposed investment to the transport once it is delivered;
- Measure of the investment's financial and economic viability, e.g., Benefit cost ratio (BCR) or NPV; and
- Net risk including delivery risk and strategic risk to the TfNSW.

The specific prioritisation method to be eventually adopted in TfNSW are decided and described within the IDSF framework prepared by Planning and Program.

In general, however, the basic method will involve the following steps:

1. Calculate each investment net strategic value.
2. Review project appraisal results by validating the calculated decision criteria (NPV, BCR, IBCR, FYRR, NPVI).
3. Consolidate project data (cost and benefit streams).
4. Sort and rank projects and provide the analysis.

Investment Net Strategic Value

The investment strategic value can be calculated by assigning scores for "contribution to strategic objectives", e. g., between -5 and +5 for each investment project. If it is believed that some strategic objectives should be considered as more important than others, these strategic objectives may be weighted, but with caution, and sensitivity analysis for the final result around weightings provided should be undertaken. Tools to help decision makers in determining weightings of strategic value, such as paired comparisons, are useful at this stage.

Note that by not weighting strategic objectives, the strategic objectives are considered as equal in importance.

Calculated Decision Criteria

Cost Benefit Analysis (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 the DCF example.)

SUMMARY OF RESULTS				
	BASE CASE	OPTION 1	OPTION 2	OPTION 3
NPV	$50m	$79m	$150	$80
BCR	0.9	1.79	1.0	1.5
NPVI	03	0.41	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 as demonstrated by the case 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, Project 2 makes a net gain of $150 not just $100, for the society. Thus, based on NPV, Project 2 represents the best option.

Ranking Projects
When ranking projects for program or budgetary funding, the following methodology can be used:
Either:

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, or
2. Rank the projects by BCR; keep selecting projects in order of decreasing BCR until the budget runs out.

Both methods give the same results.

Example is set out below:

Project	PV of Benefits	PV of Costs	NPV	BCR
1	200	100	100	2.0
2	140	50	90	2.8
3	120	50	70	2.4

With a budget of $100, two options are possible; either adopt Project 1 at a cost of $100 or adopt Projects 2 & 3 again at a cost of $100. To make the decision, using method 1, Project has an NPV of $100 but the combined NPV of Projects 2 & 3 is $160. Therefore Projects 2 & 3 represents more benefits to society within the budget and should be chosen.

Using method 2, Project 2 would be chosen first and then Project 3. This will exhaust the budget.[64]

Constrained Optimisation
The process of portfolio selection is essentially a constrained optimisation problem, specified as:

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 will aim to maximise benefits from available funding. The fundamental constraints are the constraints upon spending in each financial year, i.e.

- 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.

[64] Example provided by Mark Harvey, BITRE, Commonwealth Department of Infrastructure and Transport.

- 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

A preferred Optimisation Model with selection algorithm will be developed and will be presented in the next version of the Guidelines or in another document.

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 require that projects greater than $10 million be subject to an ex post evaluation, though all major projects should be subject of some form of review in terms of assumptions 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.

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 (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 provides 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 twelve to twenty four months after the commencement of the operating phase, e.g., road is opened to the public.
- 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 that are subject to a safety audit every five years.

11.1 Benefits of Conducting a Post Completion Evaluation

Post completion reviews enable management to examine 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 are:

- Reinforcement of the link between the past and the future in thinking;
- Allows an assessment of the quality of forecasts and of the forecasting process of decision parameters;
- Ensures that capital expenditure procedures are understood and followed;
- Review the appropriateness of sensitivity analysis of the key variables and specifically of the contingency reserves and allowances;
- Improve the management control of projects;
- Serves as a basis for the identification of the need for and the implementation of corrective actions. PCEv 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;

- Identify the causes of significant deviations. PCEv provides explanation to 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 adopted:

- 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, 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 since the review may identify the reason for success such as favourable environmental or some aspect of the decision and implementation process.
- Projects most likely to provide learning - a cost benefit analysis should be used on deciding whether or not a post completion evaluation should be performed since conducting this may be costly.

11.2 Principal Areas of Interest in Post Completion Review

Post completion evaluation can be made from a number of different points of view using various degrees of precision depending on the aims and objectives of the evaluation and which group 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)

11.3 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 cost of capital 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 at the assessment period; determine the contributing reasons for the deviation noted.

- 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. Establish reasons for deviation observed and reconsideration of alternative options.

- A review of the procedures used to obtain an effective and efficient project control process and examine the project design and implementation to assess the scope for improvement to the option adopted.

- A review of conformance with policy.

11.4 Approaches to Post Completion Evaluation

There are several approaches in undertaking a post completion evaluation.

- **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 objective 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.

11.5 Reporting Post Completion Evaluation

A post completion evaluation should clearly indicate what was expected, when the project was initiated, and what actually occurred. It provides 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 firm. The report's major objective is to identify lessons for the future.

The report should provide information to the management on whether:

- The options have been considered in accordance with each stage of the project.
- The sensitivity of the various options to alternative environmental assumptions has been tested.
- The problems have been encountered with a major section or with individual data.

- The project was implemented in accordance with original or revised plans.
- The project has delivered the benefits expected originally or subsequently.
- The extent to which the success or failure of the project was due to the internal management and/or planning the project and/or to environmental changes.

11.6 Benefit Realisation

Benefit is a positive outcome arising from the implementation of an initiative. Traditionally, major capital investment projects are 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 to manage the whole life cycle of programs and projects.

Benefit realisation management is the process that proactively identifies benefits, plans for their realisation and tracks achievement versus plan. It involves executing and measuring the benefits, organising and managing so that potential benefits expected from investment in a project are actually realised. It is a continuous process running through the whole project lifecycle. It defines key dates, the person who is responsible for delivery and how the benefits will be reported.

The use of BRM practices drive more benefits from a funded investment, validate the success of a completed investment, generate performance information and provide lessons that will inform the shaping of future investments and support better decision making. More specifically, BRM

- requires that benefits are identified and defined clearly at the outset and aligned to the Transport vision and strategic objectives
- ensures business areas are committed to realising their defined benefits with assigned ownership and responsibility for adding value through the realisation process
- drives the process of realising benefits, involving benefit measurement, tracking and recording benefits as they are realised
- uses the defined, expected benefits as a roadmap for the program, providing a focus for delivering change

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.

Refer to NSW Benefit Realisation Management Framework and the TfNSW Transport Benefit Realisation Management Guidelines and Templates 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. (Reference: Comparative Assessment of Economic Appraisal Guidelines, Transport for NSW, Sept 10.)

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 Council, The National Guidelines for Transport System Management in Australia (NGTSM). This is currently being updated through the Transport & Infrastructure Senior Officers' Committee (TISOC) with the Refresh (updated document) expected to be completed by end 2015.
	Infrastructure Australia, Better Infrastructure Decision Making: Guidelines for Making Submissions to Infrastructure Australia's Infrastructure Planning Process, through Infrastructure Australia's Reform and Investment Framework
	Department of Infrastructure, Transport, Regional Development and Local Government.
	Handbook of Cost Benefit Analysis, January 2006, Department of Finance and Administration
NSW Government	NSW Treasury – NSW Guidelines for Economic Appraisal
	NSW Treasury – NSW Guidelines for Financial Appraisal
	NSW Roads and Traffic Authority – Economic Analysis Manual
	State Rail Authority of New South Wales – Guide to the Evaluation of Capital Projects
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 Council National Guidelines in 2004 and 2006 and the

Infrastructure Australia Guidelines in 2012[65] are now the primary guidance documents.

- The primary guidelines at the state level are the publications by the NSW Treasury. The NSW Treasury Economic Appraisal Guidelines provide a framework for undertaking financial and economic appraisals across all public sector agencies while the RTA Economic Analysis Manual is particularly relevant for road projects.
- 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. NSW Treasury – NSW Guidelines for Economic Appraisal.
2. NSW Treasury – NSW Guidelines for Financial Appraisal.
3. NSW Roads and Traffic Authority – Economic Analysis Manual.
4. State Rail Authority of New South Wales – Guide to the Evaluation of Capital Projects.
5. Australian Transport Council (ATC) – National Guidelines for Transport System Management in Australia.
6. Infrastructure Australia – Better Infrastructure Decision Making: Guidelines for Making Submissions to Infrastructure Australia's Infrastructure Planning Process, through Infrastructure Australia's Reform and Investment Framework.
7. Commonwealth Department of Finance and Administration – Handbook of Cost Benefit Analysis.
8. Queensland Government Department of Infrastructure and Planning – Project Assurance Framework Guidelines.
9. Victoria Department of Transport – Guidelines for Cost Benefit Analysis.
10. New Zealand Transport Agency (NZTA) –Economic Evaluation Manual (EEM).
11. New Zealand Government Agglomeration Elasticities in New Zealand (by D Mare and D Graham).
12. United Kingdom Department for Transport (DfT) – Transport Analysis Guidance.
13. Victorian Transport Policy Institute (VPTI) – Transport Cost Benefit Analysis: Techniques Estimates and Implications.
14. Commonwealth Productivity Commission – Valuing the Future: The Social Discount Rate in Cost-Benefit Analysis.
15. Austroads – Guide to Project Evaluation Part 1 – Part 8.
16. Transportation Research Board - Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners.
17. U.S Department of Transportation Federal Transit Administration - Guidance for Major Capital Investments (New Starts and Small Starts)

[65] 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.

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%
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%

Cost Benefit Analysis

Discounted Cash Flow Analysis (DCF)

PRO FORMA

Last Update June 2016

Evaluation and Benefits, Finance and Investment

For any feedbacks or comments please send an e-mail to: EconomicAppraisal.EPSP@transport.nsw.gov.au

PROJECT XXX – DISCOUNTED CASH FLOW ANALYSIS – OPTION 1

		COSTS $000			BENEFITS $000								NET BENEFIT (COST)
		Capital Cost	**Operating & Maintenance Costs**	**TOTAL COSTS**	**Travel Time Savings**	**VOC Savings**	**Safety Benefits**	**Environmental Benefits**	**Amenity Benefits**	**Incremental Revenue**	**Residual 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 Benefit to Total					**45%**	**26%**	**15%**	**4%**	**3%**	**2%**	**4%**	**100%**	

	Capital Cost	**O&M Costs**	**TOTAL COSTS**	**Travel Time Savings**	**VOC Savings**	**Safety Benefits**	**Environ mental Benefits**	**Amenity Benefits**	**Increme ntal Revenue**	**Residual Value**	**TOTAL BENEFITS**	**NET BENEFIT (COST)**
NPV@7%	$188,825	$35,153	$215,643	$177,387	$104,067	$59,129	$17,739	$11,826	$9,461	$35,958	$386,233	$79,012
NPV@4%	$199,300	$48,945	$241,138	$239,742	$140,648	$79,914	$23,974	$15,983	$12,786	$36,995	$526,924	$209,279
NPV@10%	$179,313	$26,335	$197,300	$137,414	$80,616	$45,805	$13,741	$9,161	$7,329	$34,977	$297,295	$5,756

SUMMARY OF RESULTS			
Present Value Benefits @7%	**386,233**	**BCR1 =**	**1.79**
Present Value Costs @7%	**215,643**	**BCR2 =**	**1.63**
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 vis a vis 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 Benefits, 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 1.79. Cost is more than covered by the economic benefits from carrying out this option. Net Present Value of Initial Investment (NPVI) is 0.41. This will need to be compared with NPV per dollar investment of other options. The Option with the highest NPVI provides the highest return on the incremental expenditure. First Year Rate of Return (FYRR) (Note: if FYRR < Discount Rate, the implementation should be deferred until FYRR ≥ the discount rate). 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. 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				
	BASE CASE	**OPTION 1**	**OPTION 2**	**OPTION 3**
NPV	**$50m**	**$79m**	**$150**	**$80**
BCR	**0.9**	**1.79**	**1.0**	**1.5**
NPVI	**03**	**0.41**	**0.2**	**0.4**
FYRR	**6%**	**12%**	**7%**	**7%**

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 case 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 cost or benefit.

APPENDIX 4

Economic Parameters Values and Valuation Methodologies

All values are as at March 2016

Evaluation & Benefits Branch
Finance and Investment
Transport for NSW

June 2016

1. Value of travel time

1.1 Value of private and business travel time

The value of travel time savings (VTTS) represents the dominant user benefits, typically around 60% and up to 80% of traditionally quantified benefits. The valuation of travel time savings has followed the willingness to pay approach and linked to people's productivity and earnings. Before 1997, methods of estimating VTTS employed by Australian jurisdictions varied. Since the mid-1990s, Austroads has attempted to harmonise the methodologies and values in Australian project evaluations. A travel time valuation study in 1997[66] provided the foundation for travel time value updates in Australia. In general, Austroads recommended the following valuation principles:

- Private travel time is valued at 40% of the average hourly earnings, applicable for travel modes of private car, motorcycle, bicycle, pedestrian and public transport for commuting and recreational trip purposes.
- Business travel time is valued at 128% of the average hourly earnings of the population, applied for all business trips. The 128% of average weekly earnings were recommended by Austroads (2012)[67], comprising the business time valued at 135% of AWE less payroll tax of 7%. It is assumed that time spent travelling for business purposes is unproductive and therefore foregone working time.

Below are some reasons explaining the lower value of non-business travel time:

- The average hourly wage rate contains a tax component. The traveller's willingness to pay is based on after-tax income.
- A worker's after tax income is shared by household members. The willingness to pay is then related to household disposable income and number of persons in the household.
- For most people, the marginal disutility of travel is lower than that of work. In Sydney, average work trip duration is 35 minutes (one way), and the daily travel time per capita is 79 minutes[68]. Most people seem to enjoy a certain amount of personal travel, about 30 minutes per day, and dislike travelling more than 90 minutes per day[69]. The benefit of a travel time reduction, say from 34 minutes to 30 minutes, would be marginal or negligible for many people.

In general, however, the value of travel time reflects the willingness of travellers to trade time for money. These values are often determined from revealed preference and stated preference data. Willingness to pay depends on factors including traveller's income, the value and urgency attached to the journey purpose and comfort of the trip etc. Thus, although it has been a widely accepted assumption that the travel time is valued based on the average hourly earnings, it has been suggested that the value of business travel time is not necessarily equal to worker's hourly rate plus on cost, and the value of private travel is not precisely equal to 40% of worker's hourly

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[66] Value of travel time savings by D Rainey, AP-119/97, Austroads, 1997, Sydney, NSW. UK, New Zealand and British Columbia also used the assumption of 40% of earnings.

[67] Guide to project evaluation – part 4: project evaluation data (updated road user effects unit values), ARRB Austroads report, March 2012

[68] 2011/12 Household Travel Survey, Summary Report, Bureau of Transport Statistics, 2013 release.

[69] Transportation cost and benefit analysis II, Victoria Transport Policy Institute, Canada & Mokhtarian, P & Salomon, I, 2001, How derived is the demand for travel, some conceptual and measurement consideration, Transportation Research A, Vol. 35, No 8

earnings. US Federal Highway Administration assumes the value of non-business travel time to be 60% of the value of business time.[70]

Table 1 provides the vehicle occupancy, value of travel time of occupants and value of travel time of freight based on the 2015 National Guidelines for Transport System Management (NGTSM). Value of travel time for occupant is the same for both urban and rural roads. In economic evaluation, the occupancy rate can be replaced with values derived from project specific surveys. Value of vehicle hour for a vehicle type can be calculated from the occupancy, value of the occupant and value of the freight. A generic value of vehicle hour can be estimated from vehicle composition obtained from travel studies.

[70] Updating Austroads RUE unit values and related methodologies, Austroads research report 2011.

Table 1 Value Of Travel Time, Urban & Rural Roads

Vehicle type	Non-urban			Urban			Non-urban		Urban	
	Occupancy rate (persons /vehicle)	Value per occupant ($/person-hour)	Freight ($/Vehicle-hour)	Occupancy rate (persons /vehicle)	Value per occupant ($/person-hour)	Freight ($/Vehicle-hour)	Value/ occupant ($/km)	Freight ($/Vehicle-km)	Value per occupant ($/km)	Freight ($/Vehicle-km)
Cars (all types)										
Cars- Private	1.7	16.26		1.5	16.26		0.181		0.325	
Cars- Business	1.3	52.76		1.1	52.76		0.586		1.055	
Utility vehicles										
Courier van utility	1	27.57		1	27.57		0.306		0.551	
4WD mid -size Petrol	1.5	27.57		1.5	27.57		0.306		0.551	
Rigid trucks										
Light Rigid	1.3	27.57	0.78	1.2	27.57	1.54	0.306	0.009	0.551	0.031
Medium Rigid	1.2	27.90	2.12	1.2	27.90	4.17	0.310	0.024	0.558	0.083
Heavy Rigid	1	28.41	7.25	1.2	28.41	14.25	0.316	0.081	0.568	0.285
Articulated trucks										
4 axle	1	29.09	15.59	1.2	29.09	30.71	0.323	0.173	0.508	0.537
5 axle	1	29.09	19.88	1.2	29.09	39.16	0.323	0.221	0.508	0.684
6 axle	1	29.09	21.44	1.2	29.09	42.22	0.323	0.238	0.508	0.738
Combination vehicles										
Rigid + 5 Axle Dog	1	29.51	30.65	1.2	29.51	63.23	0.328	0.341	0.516	1.105
B-Double	1	29.51	31.58	1.2	29.51	65.16	0.328	0.351	0.516	1.139
Twin steer + 5 Axle Dog	1	29.51	29.61	1.2	29.51	61.12	0.328	0.329	0.516	1.068
A-Double	1	30.36	41.47	1.2	30.36	85.57	0.337	0.461	0.530	1.495
B-Triple	1	30.36	42.33	1.2	30.36	87.34	0.337	0.470	0.530	1.526
A B combination	1	30.36	50.98	1.2	30.36	105.20	0.337	0.566	0.530	1.838
A-Triple	1	30.86	61.12	1.2	30.86	126.12	0.343	0.679	0.539	2.204
Double B-Double	1	30.86	61.82	1.2	30.86	127.57	0.343	0.687	0.539	2.229
Buses										
Heavy Bus (Driver)	1	27.90		1.2	27.90		0.310		0.468	
Heavy Bus (Passenger)	20.0	16.26		20.0	16.26		0.181		0.284	

Assumptions: Non-urban speed (km/hr): 90, Urban speed-cars & rigid trucks (km/hr): 50, Urban speed - articulated truck and combination vehicles (km/hr): 57.23

Source: Values are based on Transport & Infrastructure Council 2015 National Guidelines for Transport System Management Australia (NGTSM). Values of travel time of the occupant have been indexed from May 2013 to Nov 2015 using Average Weekly Earnings (Table, 12A), seasonally adjusted full time Adult Ordinary Earnings, NSW. Values of freight time value have been indexed from June 2013 to March 2016 using Producer Price Index (PPI, Table 21), road freight transport section. The original Value of Travel Time reported in NGTSM is based on Australia AWE May 2013 value indexed to June 2013 by CPI and then divided by 38 hours/week to get the average hourly wage rate of which 40% is applied.
Urban occupancy rate is estimated by TfNSW based on BTS Household Travel Surveys, 2009/10-2013/14.

In 2010, RailCorp engaged Douglas Economics to update the value of rail travel time used in economic evaluations. This study was updated in 2013. The values were estimated by Stated Preference market research that asked passengers to choose between two hypothetical rail journeys varying in travel time, fare and departure time. Surveys were conducted in September 2013. The overall value of on-board train time was estimated at $13.47 per hour with a peak value of $13.46 and an off-peak value of $13.50, as shown in Table 2 below. Table 2 also compares the VTT from RailCorp survey and that recommended by Austroads.

Table 2 Value of on-board train time ($/hr)

	Short	Med	Long	All	Overall
	≤ 25 mins	26-29	≥ 60		
In September 2013 dollars[1]					
Peak	13.52	13.72	13.5	13.46	13.47
Off peak	14.23	13.01	13.07	13.50	
Indexed to Nov 2015 dollars					
Peak	14.53	14.75	14.51	14.47	14.48
Off peak	15.29	13.98	14.05	14.51	

Compare the value of travel time from Sydney Trains survey and NGTSM

	Sydney Trains Concession fare	Sydney Trains Non-concession	Sydney Trains Overall	NGTSM Private trips
Value of time	$8.15	$16.81	$14.48	$16.26
Concession entitlement	27%	73%		
Compared with Austroads private trip		3.36%	-10.98%	

Source: 1. Service Quality Values of Rail Transport in Sydney, Report to RailCorp by the DOUGLAS Economics, August 2015. Indexed to Nov 2015 using Average Weekly Earnings (Table, 12A), seasonally adjusted full time Adult Ordinary Earnings, NSW

The difference of Sydney Trains and Austroads values can be explained by:

- Austroads value is anchored at 40% of Average Weekly Earnings, while Sydney Trains value was based on Stated Preference surveys to train users. The value of stated preference survey can be affected by many factors such as sampling, income, trip purpose and general consumer sentiments at the time of survey. Sydney Trains value is 10.98% lower than Austroads value.
- Travel time of concession rail users is only 49% of non-concession users. Value of non-concession users is close to the VTT recommended by Austroads. In addition, time spent travelling by train may be used more productively or entertaining (e.g., reading document or internet surfing) than time spent driving. This may reduce travellers' value of onboard time.
- Various surveys on value of travel time have consistently indicated that the value of travel time for public transport is lower than car driving. Abrantes and Wardman (2009), having undertaken meta-analysis of UK values of travel time of 1749 valuations in 226 studies from 1980 to 2008, reported that value of bus users was 35% below that of car users, and value of time of rail users was 15% below car travel. Bus users tend to be from low income group suggesting a lower value of travel time. However, one would expect that bus travel is less comfortable than car travel, suggesting bus users are willing to pay a higher cost to cut bus travel time.

- Lower value of train users can be partly explained by fare concessions. Based on the 2014/15 Household Travel Survey undertaken by Bureau of Transport Statistics, business trips represent 6% of total train trips in weekdays, or 5% in 3 hour morning peak (6:30AM – 9:00AM) in weekdays. The Sydney Trains results can be largely interpreted as the lower value of private leisure time.

1.2 Recommended value of travel time

The VTT is used in both transport demand models and economic evaluations. Transport modelling uses the behavioural values in that the value of travel time can be differentiated by income groups (higher income means high value of time), trip purpose (business trip and private trip) and time of day (peak and off peak). These parameters can be derived from stated preference surveys and represent people's willingness to pay.

From the perspective of strategic resource allocation, the value of travel time used in economic evaluation in all transport projects should be harmonised. If a higher value of time is used for economic appraisal of road projects compared with the values used for public transport projects, resource allocation is then tilted towards road projects at the expense of public transport investments. To harmonise the economic evaluation, TfNSW recommends that:

- **Value of travel time (private) = $16.26 per hour** applicable to private car occupants, on-board train time, on-board bus time, ferry travel, cycling time and walking time

- **Value of travel time (business) = $52.76 per hour** applicable to all business travels

Transport for NSW has undertaken a Value of Travel Time Study in 2015-2016, using stated preference survey method across transport modes and estimated VTT values for each mode surveyed. The estimated VTT are behavioural values and are considered appropriate for transport modelling and travel demand estimates. The estimated value of travel time for car, bus, train, light rail and ferry are as follows:

Value of travel time

Mode	Mode share	Personal income ($000 PA)	Value of travel time ($/hr)	
			Non income standardised	Income standardised
Car	85.4%	$62	$15.48	$15.22
Train	6.7%	$44	$13.49	$15.14
Bus	7.4%	$38	$7.73	$10.04
Ferry	0.4%	$69	$15.01	$13.91
Light rail	0.1%	$63	$20.67	$20.23
Public transport	14.6%	$42	$10.65	$12.55
All	**100%**	**$59**	**$14.78**	**$14.83**

Source: Value of time for NSW Car Users, Douglas Economics, Report to TfNSW, March 2016

The important finding of the study is that the estimated VTT weighted by mode share ($16.66/hour) is very close to of $16.26/hour, the recommended Value of Travel Time Savings (VTTS) of private travel which is an equity (or resource) value for use in economic appraisals of roads and public transport initiatives. The equity value is estimated at 40% of the wage rate for private travel and 100% + on-cost (38%) for business travel.

1.3 Real value of travel time escalation in project evaluation period

Economic appraisal uses constant dollars in the project evaluation period, that is, all dollar values exclude inflation. However, the value of travel time savings measures the next best alternative use of travel time. For business travels, it is worker's productivity. For commute travel, it is a mix of worker's productivity and leisure time. For recreational and other private travel, it is the leisure time and quality of life. Based on these considerations, the value of travel time savings should escalate in alignment to the real increase of worker's productivity net of inflation.

It is also acknowledged that not all travel time savings are used in productive activities. Thus, elasticity should be applied for the value of travel time savings escalation. That is:

Real value of travel time savings escalation can be estimated as:

Real productivity increase per worker x Elasticity of value of travel time savings with respect to real productivity increase per worker

Recommended values of productivity growth and elasticity are provided in Tables 3 and 4.

Table 3 Real productivity increase per worker

Indicators of productivity growth	Data sources
Real labour productivity growth = 1.8% pa	Pye, E (2012) *GDP per capita and labour utilisation in Australia*, Federal Department of Industry, Innovation, Science, Research and Tertiary Education, Working Paper 03-12
Real Gross State Product (GSP) growth per capita = 1.47% pa	TfNSW's analysis on real GSP growth in New South Wales from 1998 to 2012
Real Average Weekly Earnings (AWE) growth = 1.5% pa	TfNSW's analysis on real income growth in New South Wales from 1998 to 2012
TfNSW's recommendation: **Real productivity growth for VTTS escalation = 1.5% PA**	

Table 4 Elasticity of VTTS with respect to labour productivity growth

International jurisdiction	Literature	Elasticity
Australia	Hensher & Goodwin (2003)	0.5
UK	UK DfT (2012)	0.8-1.0
US	Fosgerau (2005)	1.0
Denmark	Fosgerau (2005)	1.0
Netherlands	Gwilliam (1997)	0.5
World Bank	Belli (1998)	1.0
European Union	HEATCO(2006)	0.7
Norway	MOF (2012)	0.8-1.0
TfNSW's recommendation: **Elasticity of VTTS with respect to labour productivity growth = 0.5**		

Note: The international literature suggests the elasticity ranging from 0.5 – 1.0. A low value has been recommended by TfNSW recognising potential uncertainly of how travellers would use travel time reductions.

Thus, the real value of escalation can be calculated as: 1.5% x 0.5 = 0.75% pa

Escalation of real value of travel time savings diverges from the traditional economic appraisal methodology where all values are in constant dollars in the base year. In addition, there are uncertainties whether labour productivity will continue to grow at the same rate as observed in the previous 14 years, and how travellers use the travel time reductions due to transport improvements.

TfNSW recommends:

- Real value of travel time savings escalation = 0.75% pa
- Real value of travel time savings escalation to be used as a sensitivity test. The base economic appraisal should still use constant dollars of VTTS as at in the base year.

1.4 Value of access, waiting, transfer and unexpected delay time

The access time, waiting time and unexpected delay time are valued as multipliers as shown in Table 5. The multipliers convert access time, waiting time and delay time into equivalent on-board train time. For example, one minute walking time is equivalent to 1.5 minutes on-board train time, or 1-minute train-delay is converted into 3 minutes of on-board train time.

The value of access time savings forms a large proportion of economic benefits of rail infrastructure projects. The mode share (walk, car or bus) of train access depends on local socioeconomic characteristics such as car ownership, bus service coverage, residential and employment density and commuter car parking availability.

The value of waiting time can be used to evaluate the service frequency. The increased service frequency would reduce platform waiting time and transfer waiting time. Increased bus frequency would reduce bus waiting time. Unexpected delay time multiplier is for valuing service reliability. Departure delay waiting is valued higher than arrival on vehicle waiting.

TfNSW recommends that unexpected delay time is valued 3 times of in-vehicle time.

Table 5 Access, Waiting, Transfer and Unexpected Delay Time Multipliers

<table>
<tr><th>Category</th><th>NGTSM recommended</th><th>TfNSW recommended</th></tr>
<tr><td>Access / egress walking</td><td>1.5</td><td>1.5</td></tr>
<tr><td>Waiting time</td><td></td><td></td></tr>
<tr><td>Bus stop/Rail platform waiting time</td><td>1.4</td><td>1.4</td></tr>
<tr><td>Transfer waiting time</td><td>1.5</td><td>1.5</td></tr>
<tr><td>Unexpected delay time</td><td></td><td></td></tr>
<tr><td>Departure delay waiting</td><td>6.4</td><td rowspan="4">3.2</td></tr>
<tr><td>Arrival on vehicle delay waiting</td><td>2.9</td></tr>
<tr><td>Non-specific delay waiting</td><td>2.3</td></tr>
<tr><td>Average delay waiting</td><td>3.2</td></tr>
</table>

Source: Douglas Economics Report 2015, National Guidelines for Transport System Management in Australia, Public Transport update

1.5 Value of transfer

Because of the inconvenience involved, a traveller attaches a disutility to a transfer. A stated preference study[71] undertaken by Transport for NSW indicated that public transport users attach a large penalty to bus related transfers. The penalty for a bus to bus transfer is equivalent to an IVT of 14.8 minutes of in-vehicle-time (IVT), while a transfer between bus and train is equivalent to the IVT of 13.7 minute IVT. A train to train transfer is equivalent to the IVT of 7.2 minute IVT while a smaller penalty (5.2) is attached to a light rail related transfer[72]. Table 6 provides the transfer penalties in terms of IVT and dollars values for same mode and different mode transfers.

[71] Passenger service quality values for bus, LRT and rail in inner Sydney, Douglas Economics, August 2014, report to Bureau of Transport Statistics, TfNSW

[72] The train to train penalty is higher than the value estimated by RailCorp Economic Unit in 2011, which recommended a transfer penalty equivalent to an IVT of 6 min. This value is based on various RailCorp stated preference surveys conducted more recently.

Table 6 Value of transfer

	NGTSM recommends transfer as in-vehicle time (IVT) (min/transfer)[1]	TfNSW recommends transfer as in-vehicle time (IVT) (min/transfer)[2]		
Mode		**Train**	**Bus**	**Light Rail**
Train	Same mode transfer: 6 Different mode transfer: 10	7.2	13.7	4.1
Bus			14.8	3.8
Light Rail				5.2

Source: 1. Douglas Economics Report 2015, National Guidelines for Transport System Management in Australia, Public Transport update 2015. 2. Passenger service quality values for bus, LRT and rail in inner Sydney, Douglas Economics, August 2014, report to Bureau of Transport Statistics, TfNSW.

1.6 Value of travel time of vehicles in urban

Tables 7 and 8 present the vehicle occupancy and composition categorised by peak, business and other hours for cars and commercial vehicles.

Table 7 Vehicle occupancy - Urban

Hours	Private Car	Business Car	Commercial	
			Light	Heavy
Peak hours	1.45	1.06	1.22	1.17
Business hours	1.47	1.07	1.20	1.16
Other	1.43	1.09	1.20	1.19
All hours	**1.46**	**1.07**	**1.21**	**1.17**

Source: Estimated by TfNSW based on vehicle occupancy weighted by number of trips, Household Travel Survey (HTS) 5 year pooled data 2009/010-2013/14.

Table 8 Vehicle Composition

Hours	Private Car (%)	Business Car (%)	Commercial (%)	
			Light	Heavy
Peak hours	71%	10%	15%	4%
Business hours	67%	11%	14%	8%
Other	68%	9%	17%	6%
All hours	**69%**	**10%**	**15%**	**6%**

Source: Estimated by TfNSW based on the number of trips weighted by the average trip length, Household Travel Survey (HTS) 5 year pooled data 2009/010-2013/14 (BTS data request 15155).

Table 9 provides the weighted travel time values for all vehicles (car, LCV, heavy vehicles) by time of day. This is a weighted average derived from peak and off-peak values. The higher value in business hours is mainly due to a higher proportion of business vehicles during business hours than in other hours. A higher value in off-peak than peak hours is due to higher proportion of commercial vehicles in off-peak hours compared to peak hours.

Table 9 Average hourly value for travel time per vehicle - Urban

Period	Time + Freight Value ($) per vehicle (urban)	Default yearly hours	Proportion of peak hourly volume
No flow	0	660	0.00
Off peak	$29.66	1,000	0.11
Medium off peak	$29.66	1,650	0.28
Medium business peak	$30.91	1,650	0.53
Business peak	$30.91	1,800	0.70
AM peak shoulder	$29.35	400	0.75
AM peak	$29.35	600	1.00
PM peak shoulder	$29.35	400	0.75
PM peak	$29.35	600	1.00
Total		**8,760**	
Average hourly value ($/vehicle-hr)			

Light vehicle (Car & LCV)	**$28.81**
Heavy vehicle (HCV, excluding Bus)	**$53.00**
Bus (include driver and average 20 passengers)	**$357.84**
Average vehicle (excluding Bus)	**$30.12**
Average vehicle (including Bus)	**$31.96**

Source: Estimated by the Economic Evaluations, TfNSW. Light vehicle refers to car and LCV. Heavy vehicle refers to rigid and articulated trucks and combination vehicles. Bus value includes driver value of time and average of 20 passengers. Average vehicle refers to the average of car, LCV and HCV weighted by vehicle composition on roads and traffic volumes by hour of a day and day of a week.

1. 7 Value of travel time of vehicles in rural

Table 10 presents the value of travel time by vehicle type on rural roads. Vehicle composition and the proportion of private and business car are estimated using the 2014 ABS Survey of Motor Vehicle Use for NSW. Private car accounts for 80% and business car 20% of car trips. Heavy commercial vehicles include rigid trucks and articulated trucks (4 axle, 5 axle and 6 axle). Combination vehicles include road trains.

Table 10 Average hourly value by vehicle type - Rural

Vehicle type	% of vehicle type in vehicle fleet	Occupancy	Value of Travel Time for Occupants		Value of Travel Time for Freight ($/veh-hr)	Total Value of Travel Time ($/veh-hr)
			$/person-hr	$/veh-hr		
Private car	63.86%	1.7	16.26	27.65		27.65
Business car	9.07%	1.3	52.76	68.59		68.59
Utility vehicle (Light commercial/courier van utility and 4WD mid-size petrol)	16.06%	1-1.5	27.57	33.32		33.32
Heavy commercial (rigid + articulated trucks)	7.36%	1-1.3	28.58	30.10	12.55	42.66
Combination vehicles (B-Double + Road Trains)	2.90%	1	29.55	29.55	32.25	61.80
Bus	0.75%	21	27.90 (driver) 16.26 (passenger)	353.15		353.15
Average hourly value ($/vehicle-hr)						
Light vehicle[1] (Car & utility)						**$32.84**
Heavy vehicle (HCV & B-double, excluding bus)						**$48.07**
Overall average (excluding bus)						**$34.16**
Overall average (including bus)						**$36.80**

Source: Estimated by the Economic Evaluations, TfNSW; Vehicle composition data was sourced from ABS Survey of Motor Vehicle Use 2014.

[1] Proportion of vehicle composition has changed compared to the last ABS SMVU particularly business cars and heavy vehicles which result in a lower weighted average values.

2. Road vehicle operating cost

Three types of vehicle operating costs (VOC) are presented in this section:

- **Resource cost**: Include all resource costs of fuel, oil, tyre, vehicle capital cost, repair and maintenance. Costs of taxes, fuel excise and GST are removed. The resource cost should be used in economic evaluation.

- **Perceived cost**: This is the cost perceived by drivers which is typically the fuel cost including taxes such as fuel excise and GST. However since the perceived cost of one driver maybe different to another, the perceived cost can cover the range reported in Table 13 (i.e. fuel cost including taxes only) up until the full financial cost in Table 14 and outlined below. The perceived costs should be used for travel demand modelling and modal choice modelling.

- **Full financial cost**: Include all resource costs, taxes, fuel excise, GST and all sunk costs. The full financial costs are recommended for financial analysis.

2.1 Urban vehicle operating cost

The urban stop-start model is used for predicting the effects of average journey speed on vehicle operating cost in stop-start operations where average speeds are less than 60 km/h. The freeway model predicts the effects of average journey speeds on vehicle operating costs for operations over freeways and high quality arterials where average travel speeds are typically in excess of 60 km/h. The structures of the two models are set out below:

Urban Stop-Start Model:

$$c = A + B / V$$

Freeway Model:

$$c = C_0 + C_1V + C_2V^2$$

Where:

- **c** represents vehicle operating cost (cents/km)

- **V** represents journey speed (km/h)

- **A, B, C_0, C_1** and **C_2** are model coefficients, which were updated in the ATC National Guidelines[73]. Coefficient A represents the constant fixed cost. Coefficient B represents the relationship between speed and VOC for the urban stop-start model. Under urban operations, the VOC generally decreases when speed increases. The coefficients C_1 and C_2 represent the relationship between speed and VOC for the freeway model. Under the freeway condition, VOC initially decreases as speed increases (depicted by C_1). Beyond a certain speed threshold, VOC increases when speed increases.

The values of the model coefficients by vehicle types are given in Table 11.

[73] Transport and Infrastructure Council, 2015 National Guidelines for Transport System Management in Australia, Road Parameter Values

Table 11 Coefficients for urban stop-start and freeway vehicle operating models

Vehicle Type	Stop-start		Free-flow		
	A	B	C_0	C_1	C_2
Car (all types)					
Small car	12.5242	838.2969	25.7952	-0.1253	0.0010
Medium car	12.6514	1,315.5178	35.0470	-0.1751	0.0012
Large car	14.4297	1,838.4754	46.1765	-0.2221	0.0014
Utility vehicles					
Courier van utility	15.9354	1,357.1233	38.4920	-0.1840	0.0014
4WD mid-size Petrol	21.0481	1,328.7944	40.5580	-0.1540	0.0013
Rigid trucks					
Light Rigid	33.9697	1,543.5546	51.5092	-0.2481	0.0025
Medium Rigid	35.8038	2,259.9048	62.6793	-0.3002	0.0026
Heavy Rigid	57.1600	2,556.0769	82.2900	-0.5525	0.0053
Bus - heavy bus	64.5569	4,632.1535	124.7014	-0.6467	0.0047
Articulated trucks					
4 axle	84.5711	3,323.0102	111.6621	-0.7240	0.0072
5 axle	91.1303	3,688.6095	119.8994	-0.6800	0.0066
6 axle	98.6903	3,991.2764	128.6879	-0.6878	0.0066
Combination vehicles					
Rigid + 5 Axle Dog	122.5511	3,729.8458	136.1620	-0.6403	0.0065
B-Double	122.9920	4,592.1836	151.4716	-0.7228	0.0068
Twin steer + 5 Axle Dog	127.1973	4,379.9716	149.9310	-0.6911	0.0067
A-Double	143.9930	5,692.0036	183.5354	-0.8330	0.0074
B-Triple	149.4138	7,134.4573	214.1429	-0.9878	0.0081
A B combination	170.3213	6,257.8473	208.7075	-0.9017	0.0080
A-Triple	190.6482	7,134.9278	237.0682	-1.0131	0.0086
Double B-Double	199.5704	6,976.3148	238.7248	-0.9882	0.0086

Note: Coefficient values are in June 2013. National Guidelines advises that the VOC values are indexed rather than coefficients.

The VOCs estimated from the Urban Stop Start Model and Freeway Models are presented in Tables 12 to 14.

The VOC values from Urban Stop Start Model and Freeway Model have been calculated for different speeds and indexed to March 2016. These are presented in Table 12.

Table 12 Urban vehicle operating costs: resource cost (cents/km)

	Urban stop-start model					Free flow model				
	20	30	40	50	60	70	80	90	100	110
Car (all types)										
Small car	52.4	38.9	32.2	28.2	25.5	21.1	21.3	21.8	22.4	23.2
Medium car	75.5	54.4	43.8	37.5	33.3	27.6	27.6	27.9	28.4	29.2
Large car	102.3	72.8	58.1	49.3	43.4	36.1	36.0	36.1	36.5	37.2
Utility vehicles										
Courier van utility	80.6	58.9	48.0	41.4	37.1	31.2	31.5	32.0	32.8	33.9
4WD mid-size	84.2	62.9	52.2	45.8	41.6	34.8	35.2	35.8	36.7	37.9
Rigid trucks										
Light Rigid	111.6	85.7	72.8	65.1	59.9	46.6	47.8	49.6	51.9	54.7
Medium Rigid	149.4	111.6	92.7	81.3	73.7	54.6	55.5	56.9	58.9	61.4
Heavy Rigid	185.7	142.9	121.5	108.7	100.1	69.9	72.3	75.8	80.3	86.0
Bus - heavy bus	297.3	219.8	181.0	157.8	142.3	102.9	103.4	105.0	107.4	110.9

Articulated trucks										
4 axle	251.7	196.1	168.3	151.6	140.5	96.6	100.2	105.2	111.7	119.6
5 axle	276.6	214.9	184.0	165.5	153.2	105.0	108.1	112.6	118.3	125.4
6 axle	299.4	232.6	199.2	179.2	165.8	113.3	116.3	120.7	126.4	133.4
Combination vehicles										
Rigid + 5 Axle	310.2	247.8	216.6	197.9	185.4	123.7	127.0	131.7	137.7	144.9
B-Double	353.9	277.1	238.7	215.7	200.3	134.7	137.7	142.0	147.8	154.8
Twin steer + 5 Axle Dog	347.5	274.2	237.6	215.6	201.0	134.9	138.0	142.5	148.4	155.6
A-Double	430.2	335.0	287.4	258.8	239.8	162.1	164.9	169.1	174.9	182.1
B-Triple	508.1	388.7	329.0	293.2	269.3	185.4	187.7	191.6	197.1	204.3
A B combination	485.1	380.4	328.0	296.6	275.7	185.5	188.5	193.1	199.3	207.1
A-Triple	549.5	430.1	370.4	334.6	310.7	209.1	211.9	216.4	222.6	230.6
Double B-Double	550.5	433.8	375.4	340.4	317.0	212.5	215.5	220.3	226.8	235.0

Source: Estimated by the Economics Evaluations, TfNSW based on the updated National Guidelines for Transport System Management Australia (NGTSM), 2015. The calculated values based on the NGSTM coefficients have been indexed by Sydney CPI Private motoring from June 2013 to March 2016. Values for commercial vehicles have been indexed from June 2013 to March 2016 using Producer Price Index (PPI, Table 21), road freight transport section.

The Perceived cost values in Table 13 have been calculated separately for light vehicle and heavy vehicle at 50km/hr and 90km/hr and then weighted resulting in a factor for light vehicle and another factor for heavy vehicle. The factors are then applied to the resource costs in Table 12. Similarly, factors have been applied to the resource cost to obtain the financial cost values in Table 14, which include the most recent RMS vehicle registration associated insurance costs, taxes and have been adjusted to reflect recent heavy vehicle registration costs.

Table 13 Urban vehicle operating costs: perceived cost (cents/km)

	Urban stop-start model					Free flow model				
	20	30	40	50	60	70	80	90	100	110
Car (all types)										
Small car	28.81	21.41	17.72	15.50	14.02	11.60	11.73	11.97	12.31	12.76
Medium car	41.50	29.90	24.10	20.62	18.30	15.17	15.20	15.35	15.63	16.04
Large car	56.28	40.07	31.96	27.09	23.85	19.84	19.77	19.86	20.09	20.47
Utility vehicles										
Courier van utility	44.34	32.37	26.39	22.80	20.40	17.18	17.32	17.61	18.04	18.62
4WD Mid Size Petrol	46.30	34.58	28.72	25.20	22.86	19.13	19.35	19.70	20.19	20.82
Rigid trucks										
Light Rigid	70.29	54.02	45.89	41.01	37.75	29.34	30.14	31.26	32.69	34.45
Medium Rigid	94.10	70.28	58.37	51.23	46.46	34.41	34.97	35.87	37.10	38.65
Heavy Rigid	116.97	90.03	76.56	68.48	63.09	44.01	45.54	47.74	50.62	54.16
Bus - heavy bus	187.29	138.47	114.06	99.41	89.65	64.80	65.17	66.13	67.69	69.84
Articulated trucks										
4 axle	158.56	123.53	106.02	95.51	88.51	60.88	63.13	66.29	70.36	75.35
5 axle	174.26	135.39	115.95	104.28	96.51	66.17	68.13	70.93	74.56	79.02
6 axle	188.62	146.55	125.51	112.89	104.48	71.39	73.30	76.04	79.62	84.04
Combination vehicles										
Rigid + 5 Axle Dog	195.44	156.13	136.47	124.68	116.81	77.91	80.02	82.96	86.72	91.31
B-Double	222.98	174.58	150.38	135.86	126.18	84.87	86.74	89.48	93.08	97.54
Twin steer + 5 Axle Dog	218.93	172.77	149.69	135.84	126.60	84.98	86.97	89.80	93.48	98.01
A-Double	271.04	211.05	181.05	163.05	151.05	102.12	103.88	106.56	110.19	114.75
B-Triple	320.08	244.88	207.29	184.73	169.69	116.80	118.23	120.69	124.18	128.69

A B combination	305.58	239.63	206.65	186.86	173.67	116.86	118.75	121.64	125.56	130.48
A-Triple	346.17	270.97	233.37	210.81	195.77	131.72	133.47	136.31	140.24	145.25
Double B-Double	346.80	273.27	236.50	214.44	199.74	133.87	135.78	138.78	142.86	148.03

Source: Estimated by the Economics Evaluations, TfNSW by applying a factor to resource costs for light vehicle and heavy vehicle calculated based on fuel cost and taxes only. Values have been indexed by Sydney CPI Private motoring from June 2013 to March 2016. Values for commercial vehicles have been indexed from June 2013 to March 2016 using Producer Price Index (PPI, Table 21), road freight transport section.

Table 14 Urban vehicle operating costs: full financial cost (cents/km)

	Urban stop-start model					Free flow model				
	20	30	40	50	60	70	80	90	100	110
Car (all types)										
Small car	92.19	68.53	56.70	49.60	44.87	37.13	37.54	38.30	39.40	40.83
Medium car	132.81	95.68	77.12	65.98	58.55	48.55	48.63	49.12	50.02	51.32
Large car	180.10	128.21	102.27	86.70	76.32	63.48	63.28	63.55	64.29	65.51
Utility vehicles										
Courier van utility	141.89	103.59	84.44	72.95	65.29	54.99	55.43	56.34	57.73	59.59
4WD Mid Size	148.15	110.65	91.90	80.65	73.15	61.21	61.91	63.04	64.62	66.63
Rigid trucks										
Light Rigid	185.21	142.34	120.91	108.05	99.47	77.30	79.42	82.37	86.15	90.76
Medium Rigid	247.95	185.19	153.80	134.98	122.42	90.66	92.15	94.52	97.75	101.84
Heavy Rigid	308.21	237.22	201.73	180.43	166.23	115.95	119.99	125.80	133.37	142.71
Bus - heavy bus	493.51	364.86	300.54	261.95	236.22	170.74	171.71	174.24	178.35	184.02
Articulated										
4 axle	417.78	325.50	279.35	251.67	233.21	160.40	166.34	174.67	185.40	198.53
5 axle	459.17	356.73	305.51	274.78	254.29	174.36	179.53	186.89	196.46	208.22
6 axle	496.99	386.14	330.72	297.47	275.30	188.10	193.13	200.37	209.80	221.44
Combination										
Rigid + 5 Axle	514.97	411.38	359.59	328.51	307.80	205.28	210.85	218.60	228.51	240.58
B-Double	587.55	460.01	396.25	357.99	332.48	223.61	228.57	235.78	245.27	257.02
Twin steer + 5 Axle Dog	576.87	455.23	394.41	357.92	333.59	223.93	229.16	236.62	246.32	258.25
A-Double	714.18	556.10	477.06	429.63	398.02	269.09	273.70	280.78	290.33	302.35
B-Triple	843.39	645.25	546.18	486.74	447.11	307.75	311.53	318.02	327.20	339.09
A B combination	805.19	631.40	544.50	492.36	457.60	307.92	312.89	320.52	330.83	343.80
A-Triple	912.14	713.98	614.91	555.46	515.83	347.08	351.69	359.17	369.52	382.73
Double B- Double	913.79	720.04	623.17	565.04	526.30	352.75	357.77	365.67	376.43	390.06

Source: Estimated by the Economics Evaluations, TfNSW by applying a factor to resource costs for light vehicle and heavy vehicle calculated based on registration and associated insurance costs and taxes. Values have been indexed by Sydney CPI Private motoring from June 2013 to March 2016. Values for commercial vehicles have been indexed from June 2013 to March 2016 using Producer Price Index (PPI, Table 21), road freight transport section.

Vehicle operating costs per stop in urban roads are provided in Tables 15 and 16.

Table 15 Vehicle operating cost parameters for cars

1	Fuel cost/litre	63.8	(Cents/L)
2	VOC per km (excluding fuel and VOC for stops)	29.59	(Cents/km)
3	VOC per stop (excluding fuel)	4.19	(Cents/Stop)
4	Fuel used per stop	0.04	(litres)
5	Fuel consumption	8.0 to 18.0	(L/100 km)

Notes

1. Based on 2015 to March 2016 average fuel price excluding GST and fuel excise, Exxon Mobil TGP.
2. Estimated based on medium car at 50km/hr using Table 12 and fuel consumption parameters provided by 2015 National Guidelines for Transport System Management Australia (NGTSM)Table 5.13.
3. Calculated from Sydney Coordinated Adaptive Traffic System (SCATS) Computer Aided Traffic Engineering System (SCATES) model, indexed by private motoring (excluding automotive fuel) component of ABS CPI.
4. Based on SCATES values.
5. Based on 2015 National Guidelines for Transport System Management Australia (NGTSM), medium car.

Table 16 Vehicle operating cost per stop

	Vehicle	VOC/Stop (excl. fuel) (cents) 2014	Fuel consumption per stop (Litres) (1)	Fuel cost (Cents/L) (2)	VOC/Stop (incl. fuel) (cents)
1	Car	4.2	0.04	63.75	6.56
2	Light Truck	9.7	0.22	58.70	22.84
3	Heavy Truck	17.7	0.72	58.70	59.89

1. Based on RTA estimate of 0.42 stops per km of travel based on SCATES data
2. Based on 2015 to March 2016 average fuel price excluding GST and fuel excise, Exxon Mobil TGP. Diesel fuel price for Light and Heavy truck.

2.2 Urban road congestion cost

Average congestion cost

Congestion imposes significant social costs by interrupting traffic flow, lengthening average journey times, making trip travel times more unreliable and vehicle engine operation less efficient. Urban congestion has the following negative impacts:

- Extra travel time: Additional vehicle travel time compared to travel time under free flow speeds
- Extra travel time variability: Congestion can result in trip time becoming more uncertain, leading to travellers having to allow for an even greater amount of buffer time in order to avoid being late at their destination
- Increased vehicle operating costs: higher rates of fuel consumption
- Poorer air quality: vehicle under congested conditions emitting higher rates of noxious pollutants than under freely flowing conditions, leading to even higher health costs.

Table 17 presents Bureau of Infrastructure Transport and Regional Economics (BITRE) estimates[74] of the average avoidable social costs of congestion in Australian capital cities. The congestion cost in Sydney was estimated at $3.53 billion in 2005 and projected to increase to $7.76 billion in 2020. The total congestion costs of all Australian capital cities were estimated at $9.39 billion in 2005, which is projected to increase to $20.36 billion in 2020. Indexed to March 2016, Sydney congestion cost is $8.47 billion, and would increase to $10.17 billion in 2020. The congestion costs in Australian capital cities are $22.28 billion in 2016, and would increase to $26.67 billion in 2020.

Table 17 Average congestion costs: Sydney and Australian Capital Cities

Projected congestion cost	Sydney		Australian capital cities	
	Total Congestion Cost ($ Billion)	Unit Cost of congestion (cents/PCU km)	Total Congestion Cost ($ Billion)	Unit Cost of congestion (cents/PCU km)
Original estimate in 2005 dollars				
2005	$3.53	8.0	$9.39	$6.80
2010	$4.87	9.6	$12.85	$8.20
2015	$6.19	11.1	$16.29	$9.40
2016	$6.46	11.3	$17.01	$9.70
2020	$7.76	12.7	$20.36	$10.80
Indexed to March 2016				
2005	$4.62	10.48	$12.30	$8.91
2010	$6.38	12.58	$16.84	$10.74

[74] Estimating urban traffic and congestion cost trends for Australian cities, Bureau of Transport and Regional Economics, working paper No. 71, 2007

2015	$8.11	$14.54	$21.34	$12.31
2016	**$8.47**	**$14.80**	**$22.28**	**$12.71**
2020	$10.17	16.64	$26.67	$14.15

Source: Bureau of Infrastructure Transport and Regional Economics (BITRE) (2007) Estimating urban traffic and congestion cost trends for Australian cities, Working Paper No 71. Values were indexed to March 2016 using CPI, All Groups. (For consistency, Australian CPI was applied for both Sydney and Australian congestion costs.)

Marginal congestion cost

In economic appraisals, congestion costs can be evaluated by unit costs of vehicle kilometre travelled. Two indicators of unit costs are average congestion costs and marginal congestion costs. The average congestion cost is the total congestion costs divided by the total vehicle kilometre travelled (vkt). As the impacts of cars, freight vehicles and buses are different, vkt has been converted into Passenger Car Equivalent Units (PCU) kilometre travelled (PCU-km). The PCE factors of buses and trucks are presented in Table 18.

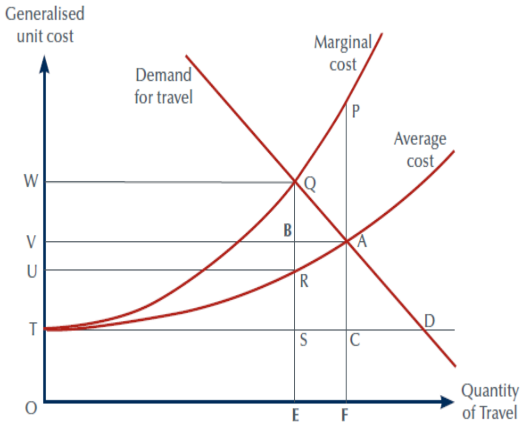


Figure 1 Average & marginal congestion costs

A literature review was undertaken to determine the passenger car equivalency (PCE) factors of various vehicle types. The main factors in determining PCE include terrain type (flat, rolling or mountainous), grade severity, length of grade, traffic volume and percentage of heavy vehicles. All these factors have an effect on the performance of heavy vehicles and their subsequent effects on traffic flow. In addition, PCE factors have been used for different purposes. For example, NTC uses the PCE for determining heavy vehicle access charges, while in traffic analysis, PCE factors are used to represent the effects on road congestion and highway capacity. Table 18 presents the PCE factors in representative literatures and recommended PCE factors. The recommended values can be adjusted using the PCE range provided considering terrain type, grade length, grade severity and traffic mix.

The marginal congestion cost is higher than average cost. The marginal cost is the additional congestion cost imposed to all vehicles by entering traffic. Marginal cost varies at different levels of congestion in various links of the city. If the volume to capacity ratio is low, marginal cost is close to average cost. As the volume to capacity ratio increases and roads become more congested, marginal cost is higher than average cost as shown in Figure 1.

Table 19 presents the marginal congestion cost in Sydney estimated by BITRE:

Table 19 Marginal Congestion Cost by Road Type in Sydney

Road category	**Marginal congestion cost (cents/vkt) (in 1996 dollars)**	**Marginal congestion cost (cents/vkt) (indexed to March 2016)**
Freeways	13	21.1
CBD streets	62	100.6
Arterial roads (inner)	21	34.1
Arterial roads (outer)	7	11.4

Source: Traffic congestion and road user charges in Australian capital cities, Report 92, Bureau of Transport and Communications Economics, 1996.

An examination of changes in congestion cost between two years provides a proxy method for estimating the marginal congestion cost.[75] Using BITRE forecast of the social cost of congestion and projections of total metropolitan vehicle kilometres travelled in passenger car unit equivalents (PCU) from 1990-2020[76], the marginal congestion cost can be estimated taking into account the following factors:

- •Extra travel time (excess travel time above free flow conditions)
- •Extra travel time variability (uncertainty in trip times)
- •Increased vehicle operating costs
- •Poorer air quality due to vehicle emissions

Total metropolitan vehicle kilometres are represented in PCUs to take into account the impact of differing vehicle class such as cars, light commercial vehicles, rigid trucks and articulated trucks.

The marginal social cost of congestion is calculated by dividing the change in the social cost of congestion between 2 consecutive years by the change in PCU kilometres travelled. This value is then indexed from 2005/06 to 2016 dollars using Sydney CPI. The estimated marginal congestion cost is $0.36 per vkt as shown in Table 20. This is a marginal value representing the social cost of congestion imposed by each additional passenger car to all other vehicles on the road.

[75] This method was originally developed by PWC economics team in Sydney.
[76] BITRE (2007) Estimating urban traffic and congestion cost trends in Australian cities. Working paper 71, Bureau of Infrastructure, Transport and Regional Economics

Table 18 Passenger car equivalency (PCE) factors

Vehicle Class	NTC[1]	ARRB[2]		Mainroads Western Australia[3]			USA[4]	DFT UK[5]	National Guidelines[6]	TfNSW	
		Urban*	Rural**	Flat Terrain	Rolling Terrain	Mountainous Terrain				Range	Recommended
Passenger vehicles & LCVs	1.0			1.0	1.3	2.0	1.0	1.0	0.99-1.12	1.0 -2.0	1.0
Rigid trucks	2.0	4.9	1.4 - 7.9	1.2 - 2.0	1.7 - 5.0	3.0 - 8.0	1.5	1.9	1.23-1.56	1.2 - 8.0	3.0
Trailers	2.0 - 3.0	6.5 - 8.7	1.7 - 13.0				2.0			1.7 - 13.0	6.0
Articulated trucks	3.0			2.5	5.0	10.0		2.9	1.78-1.89	2.5 - 10.0	5.0
B doubles	4.0	8.8 - 22.3	1.9 - 15.6	4.0	10.0	16.0			2.22	1.9 - 16.0	8.0
Double Road Train	4.0			4.0	10.0	16.0			2.75-2.9	4.0- 16.0	8.0
Triple Road Trains	5.0	9.7 - 24.0	4.2 - 25.7	9.0	22.0	35.0			2.82-3.38	4.2 - 35.0	10.0
2 axle buses	1.0 - 2.0			1.2	1.7	3.0				1.0 - 3.0	2.0
3 axle buses	3.0			1.7	3.5	6.0			1.59	1.7 - 6.0	3.0

* The PCU presented are for 5% heavy vehicles on urban 3-lane road, for unimpeded car speed 70 km/h, for grades 4% and 8% and grade length of 1000metres.
** The PCU presented are for 14% heavy vehicles on rural roads, for speed 70 km/h, for grades 0%, 4% and 8% and grade length of 5kms at traffic volume of 291 per lane hour. PCU for rigid truck is only for 8% grade.

Source:

1. National Transport Commission (NTC), Heavy vehicle charges - Report to the Standing Council of Transport and Infrastructure, February 2012.
2. ARRB Consulting, Review of passenger car equivalency factors for heavy vehicles, October 2007.
3. Mainroads Western Australia, Policy and guidelines for overtaking lanes, December 2011.
4. US Highway Capacity Manual & Al-Kaisy, A. (2006) Passenger car equivalents for heavy vehicles at freeways and multilane highways: some critical issues, ITE Journal, March 2006.
5. UK Department for Transport, Transport Analysis Guidance (TAG).
6. National Guidelines for Transport System Management Australia (NGTSM) update 2015

Table 20 Marginal Congestion Cost, Sydney-wide

	2010/11	2011/12	2012/13	2013/14	2014/15	2016
Social Cost ($ billion)	5.133	5.392	5.649	5.915	6.189	6.463
Change in Social Cost ($ billion)		0.259	0.257	0.266	0.274	0.274
Billion pcu-km	51.91	52.96	53.96	54.98	55.99	56.97
Change in pcu-km		1.05	1.00	1.02	1.01	0.98
MSC in 2016 dollar ($/pcu-km)						**$0.36**

Source: Economic Evaluations, TfNSW.

Recommended marginal congestion costs in Sydney

Based on research and analysis undertaken by the Evaluation & Benefits, Finance and Investment, TfNSW recommends the marginal congestion cost being used in economic evaluation in Sydney as shown in Table 21.

Table 21 Marginal road congestion cost in Sydney

Vehicle type	Passenger car equivalency (PCE) factors	Marginal Congestion Cost in Sydney (Cents / VKT)
Passenger vehicles & LCVs	1	36
Rigid trucks	3	108
Trailers	6	216
Articulated trucks	5	180
B doubles	8	288
Double Road Train	8	288
Triple Road Trains	10	360
2 axle buses	2	72
3 axle buses	3	108

Source: Economic Evaluations, TfNSW.

2.3 Rural vehicle operating cost: light vehicle

Vehicle operating costs are a function of vehicle class, average vehicle speed, road surface and pavement conditions, horizontal alignment, grading and road Volume Capacity Ratio. The VOCs for rural roads are estimated based on coefficients and equations provided by National Guidelines for Transport System and Management (NGTSM) 2015 update.

Two measures of pavement condition are the International Roughness Index (IRI) and NAASRA Roughness Meter (NRM). At low values the road surface is characterised as good-very good at low values with little surface imperfections. A fair road is characterised with surface imperfections; poor roads with frequent minor depressions and very poor roads with frequent shallow depressions or deep shallow depressions.[77]

The road surface conditions presented in VOC tables are provided in Table 22.

[77] Sayers, Michael, et.al. Guidelines for Conducting and Calibrating Road Roughness Measurements, 1986 World Bank Technical Paper 46

Table 22 Description of road surface conditions

	Sealed road				
Pavement condition	**Very Poor**	**Poor**	**Fair**	**Good**	**Very Good**
International Roughness Index (IRI)	8+	6-7	4-5	3	0-2
Roughness (NRM) Count[78]	≥ 200	150 - 199	100 - 149	50 - 99	0 - 49

Table 23 provides the percentages of heavy vehicles in urban and rural areas used to calculate the heavy vehicle operating costs.

Table 23 Mix of heavy vehicles

Vehicle type	% Urban	% Regional	% Overall
Cars (all types)	**79.72%**	**72.93%**	**78.06%**
Cars	79.72%	72.93%	78.06%
Utility vehicles	**14.26%**	**16.06%**	**14.70%**
Courier van utility	8.31%	9.36%	8.56%
4WD Mid Size Petrol	5.95%	6.71%	6.14%
Rigid trucks	**4.00%**	**3.90%**	**3.98%**
Light Rigid (previously LCV 2 axle-4tyre)	0.93%	0.91%	0.92%
Medium Rigid (previously 2 axle-6 tyre)	0.69%	0.67%	0.68%
Heavy Rigid (previously 3 axle)	2.38%	2.32%	2.37%
Articulated trucks	**0.65%**	**3.46%**	**1.34%**
4 axle	0.04%	0.04%	0.04%
5 axle	0.06%	0.35%	0.13%
6 axle	0.55%	3.07%	1.16%
Combination vehicles	**0.52%**	**2.90%**	**1.10%**
Rigid + 5 Axle Dog	0.01%	0.03%	0.01%
B-Double	0.49%	2.74%	1.04%
Twin steer + 5 Axle Dog	0.01%	0.03%	0.01%
A-Double	0.01%	0.03%	0.01%
B-Triple	0.00%	0.02%	0.01%
A B combination	0.00%	0.02%	0.01%
A-Triple	0.00%	0.02%	0.01%
Double B-Double	0.00%	0.02%	0.01%
Buses	**0.85%**	**0.75%**	**0.82%**
Heavy Bus	0.85%	0.75%	0.82%

Source: Estimated by Economic Evaluations, TfNSW from ABS Survey of Motor Vehicle Use 2014.

VOC Adjustments for traffic volume, vertical grades and horizontal curvature

Tables 24 – 39 presents the VOC for rural (uninterrupted travel or free flow) travel for each vehicle type by speed for each road surface condition (very good, good, fair, poor), gradient (0%, 4%,6%,8%) and road curvature (straight, curvy, very curvy).

These vehicle operating costs have been calculated based on modelling and coefficients provided by the National Guidelines for Transport System Management Australia (NGTSM) 2015 update at an assumed payload of 75%.

The VOC equation used to produce the values in Table 24-39 is provided below:

$$VOC = BaseVOC * (k_1 + k_2/V + k_3*V^2 + k_4*IRI + k_5*IRI^2 + k_6*GVM$$

[78] National Association of Australian State Road Authorities (NAASRA) Roughness Counts per kilometre.

where:
VOC = vehicle operating cost (cents/km)
Base VOC = lowest VOC point in curve from raw HDM-4 output
V = vehicle speed (km/hr)
IRI = International Roughness Index (m/km)
GVM = gross vehicle mass (tonnes)
k_1 to k_6 = model coefficients

The VOC also increases as the vehicle operates in slope road sections. This is because additional power is needed to climb a slope and extra braking is needed to control the vehicle in falling slope. The curvature adjustment is made by the reduced designed speed as the curvature increases. The speed is reduced when driving on curve road sections. The relationship between the speed reduction and curvature can be estimated from engineering design.

Table 40 presents the fuel consumption for a typical road with very good road surface condition and 4% gradient at varying levels of curvature (straight, curvy, very curvy) based on National Guidelines coefficients and modelling. The fuel consumption equation is outlined below:

$$\textit{Fuel consumption} = \textit{BaseFuel} * (k_1 + k_2/V + k_3V^2 + k_4*IRI + k_5*GVM)$$

where:
Fuel consumption is in L/km
BaseFuel=lowest fuel consumption point in curve from raw HDM-4 output
V = vehicle speed (km/hr)
IRI = International Roughness Index (m/km)
GVM = gross vehicle mass (tonnes)
k_1 to k_5 = model coefficients

For 100% and 125% payload, please email EconomicAppraisal.EPSP@transport.nsw.gov.au for VOC value calculations. More details regarding the full range of model coefficients can be found in the National Guidelines for Transport System Management Australia (NGTSM) 2015 update, now called Australian Transport Assessment and Planning (ATAP)- Road Parameter Values.

Table 24 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)
Gradient = 0%
Curvature = Straight (20 degree/km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	24.9	22.1	20.8	20.2	20.0	20.1	20.3	20.7	21.3	21.9
Medium Car	34.7	30.2	28.2	27.1	26.6	26.5	26.5	26.8	27.2	27.8
Large Car	46.6	40.4	37.5	35.9	35.0	34.6	34.5	34.7	35.0	35.4
Courier Van-Utility	35.8	31.9	30.2	29.3	29.0	29.1	29.3	29.8	30.4	31.1
4WD Mid Size Petrol	38.6	34.9	33.2	32.4	32.2	32.2	32.5	33.0	33.7	34.5
Light Rigid	47.8	44.2	42.8	42.5	42.9	43.7	44.8	46.3	48.0	50.1
Medium Rigid	62.5	55.8	53.0	51.8	51.5	51.9	52.8	54.0	55.6	57.5
Heavy Rigid	77.1	67.0	63.0	61.6	61.8	63.1	65.2	68.0	71.5	75.5
Heavy Bus	120.6	106.0	99.3	95.8	94.0	93.3	93.4	94.1	95.3	96.8
Artic 4 Axle	101.9	90.2	85.7	84.4	85.1	87.2	90.3	94.4	99.3	105.0
Artic 5 Axle	112.3	99.5	94.5	92.9	93.2	95.0	97.8	101.6	106.2	111.5
Artic 6 Axle	121.0	107.6	102.2	100.3	100.5	102.2	105.0	108.7	113.2	118.5
Rigid + 5 Axle Dog	128.1	116.0	111.3	110.0	110.6	112.6	115.7	119.7	124.5	130.1
B-Double	142.0	127.5	121.5	119.4	119.4	120.9	123.6	127.3	131.8	137.1
Twin steer + 5 Axle	141.2	127.4	121.8	119.9	120.1	121.7	124.5	128.3	132.9	138.3
A-Double	171.0	153.9	146.6	143.7	143.1	144.2	146.5	149.9	154.1	159.2
B Triple	199.7	178.6	169.3	165.0	163.5	163.8	165.5	168.2	171.8	176.3
A B Combination	193.0	174.9	167.2	164.0	163.3	164.3	166.6	170.0	174.2	179.3
A-Triple	218.3	198.2	189.5	185.7	184.6	185.3	187.4	190.6	194.7	199.7
Double B-Double	219.5	200.1	191.7	188.2	187.3	188.2	190.4	193.8	198.1	203.2

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)
Gradient = 0%
Curvature = Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	24.9	22.1	20.8	20.2	20.1	20.1	20.3	20.7	21.2	21.8
Medium Car	34.6	30.2	28.2	27.2	26.6	26.5	26.5	26.8	27.2	27.7
Large Car	46.5	40.4	37.5	36.0	35.1	34.7	34.5	34.6	34.9	35.3
Courier Van-Utility	35.8	31.9	30.2	29.4	29.1	29.1	29.4	29.9	30.6	31.4
4WD Mid Size Petrol	38.6	34.9	33.2	32.5	32.2	32.3	32.6	33.2	33.9	34.7
Light Rigid	47.8	44.2	42.9	42.6	42.9	43.7	44.8	46.3	48.0	50.0
Medium Rigid	62.6	55.8	53.0	51.9	51.8	52.4	53.4	54.9	56.8	59.0
Heavy Rigid	77.3	67.0	63.0	61.8	62.2	63.9	66.4	69.7	73.6	78.3
Heavy Bus	120.8	106.0	99.3	95.9	94.4	94.0	94.5	95.6	97.3	99.4
Artic 4 Axle	101.9	90.3	86.0	84.9	85.9	88.3	91.8	96.3	101.7	107.9
Artic 5 Axle	112.0	99.5	94.6	93.2	93.7	95.6	98.6	102.6	107.4	113.0
Artic 6 Axle	120.7	107.5	102.3	100.6	101.0	102.8	105.8	109.7	114.5	120.0
Rigid + 5 Axle Dog	128.1	116.0	111.5	110.4	111.4	113.9	117.5	122.1	127.7	134.1
B-Double	141.9	127.4	121.7	119.8	120.2	122.2	125.4	129.7	134.9	141.0
Twin steer + 5 Axle	141.2	127.4	122.0	120.4	121.0	123.2	126.6	131.0	136.4	142.6
A-Double	171.1	153.9	146.8	144.2	144.3	146.0	149.2	153.4	158.7	164.9
B Triple	199.7	178.6	169.5	165.6	164.6	165.5	168.0	171.5	176.2	181.7
A B Combination	193.3	175.1	167.6	164.9	165.0	166.9	170.3	174.9	180.6	187.3
A-Triple	218.7	198.5	190.1	186.9	186.6	188.4	191.7	196.2	201.9	208.6
Double B-Double	219.9	200.4	192.4	189.4	189.4	191.4	195.0	199.8	205.8	212.8

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)
Gradient = 0%
Curvature = Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	24.8	22.1	20.9	20.3	20.1	20.2	20.4	20.8	21.2	21.8
Medium Car	34.5	30.2	28.3	27.3	26.8	26.6	26.6	26.8	27.2	27.7
Large Car	46.3	40.4	37.6	36.1	35.2	34.8	34.6	34.6	34.8	35.2
Courier Van-Utility	35.7	31.9	30.2	29.5	29.3	29.5	30.0	30.7	31.5	32.5
4WD Mid Size Petrol	38.6	34.8	33.3	32.6	32.5	32.8	33.3	34.0	35.0	36.1
Light Rigid	47.7	44.2	43.0	42.8	43.2	44.2	45.5	47.2	49.1	51.3
Medium Rigid	62.8	55.9	53.3	52.8	53.5	55.1	57.4	60.4	63.8	67.8
Heavy Rigid	77.5	67.0	63.5	63.3	65.1	68.5	73.1	78.8	85.5	93.1
Heavy Bus	120.7	105.8	99.6	97.1	96.9	98.0	100.3	103.5	107.6	112.3
Artic 4 Axle	102.1	90.4	87.1	87.7	91.0	96.1	103.0	111.3	120.9	131.9
Artic 5 Axle	111.9	99.5	95.4	95.1	97.2	101.1	106.4	113.0	120.8	129.6
Artic 6 Axle	120.6	107.5	103.0	102.6	104.7	108.6	114.0	120.7	128.6	137.6
Rigid + 5 Axle Dog	128.2	116.0	112.6	113.5	117.2	122.9	130.4	139.5	150.1	162.0
B-Double	142.0	127.4	122.8	122.9	126.1	131.4	138.6	147.4	157.8	169.5
Twin steer + 5 Axle	141.4	127.4	123.2	123.7	127.2	132.9	140.5	149.7	160.5	172.8
A-Double	171.3	153.8	148.3	148.4	152.0	158.4	166.9	177.3	189.5	203.4
B Triple	199.7	178.4	170.9	169.8	172.5	178.0	185.8	195.7	207.3	220.6
A B Combination	193.8	175.0	169.4	170.2	175.0	182.9	193.3	206.0	220.8	237.6
A-Triple	219.4	198.5	192.3	193.2	198.6	207.3	218.9	232.9	249.4	268.0
Double B-Double	220.7	200.4	194.6	196.0	201.8	211.0	223.2	237.9	255.0	274.4

Table 25 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)
Gradient = 4%
Curvature = Straight (20 degree/km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	25.2	22.3	21.1	20.5	20.3	20.3	20.5	20.9	21.4	22.0
Medium Car	35.0	30.6	28.5	27.5	26.9	26.8	26.8	27.1	27.4	28.0
Large Car	47.0	40.9	37.9	36.3	35.5	35.0	34.9	35.0	35.2	35.6
Courier Van-Utility	37.3	33.3	31.5	30.6	30.1	30.0	30.1	30.3	30.8	31.3
4WD Mid Size Petrol	39.4	35.6	34.0	33.2	32.8	32.8	33.1	33.5	34.0	34.7
Light Rigid	51.3	47.1	45.5	44.9	45.0	45.5	46.4	47.6	49.0	50.6
Medium Rigid	69.9	62.9	59.7	58.1	57.3	57.2	57.4	58.0	58.8	59.8
Heavy Rigid	100.8	90.3	85.4	82.7	81.4	80.8	80.7	81.0	81.6	82.6
Heavy Bus	138.7	125.1	118.1	113.6	110.4	107.8	105.5	103.5	101.6	99.7
Artic 4 Axle	136.1	122.3	116.2	113.5	112.7	113.1	114.4	116.5	119.2	122.4
Artic 5 Axle	151.9	137.7	131.3	128.3	127.1	127.1	127.9	129.5	131.6	134.3
Artic 6 Axle	163.4	148.8	142.1	138.8	137.3	136.9	137.4	138.5	140.2	142.4
Rigid + 5 Axle Dog	188.8	175.2	169.1	166.1	164.9	164.8	165.4	166.8	168.6	170.9
B-Double	205.9	190.2	182.9	178.9	176.7	175.7	175.4	175.7	176.4	177.6
Twin steer + 5 Axle	207.1	191.9	184.9	181.3	179.6	179.1	179.4	180.3	181.8	183.8
A-Double	255.5	237.3	228.3	222.8	219.2	216.6	214.6	213.1	211.9	210.9
B Triple	288.2	266.4	255.2	248.0	242.9	238.8	235.3	232.1	229.1	226.3
A B Combination	299.9	280.0	269.7	263.3	258.7	255.1	252.0	249.4	246.9	244.5
A-Triple	344.6	321.8	310.0	302.4	297.0	292.6	288.8	285.3	282.0	278.9
Double B-Double	350.4	327.9	316.4	309.2	304.1	300.1	296.7	293.8	291.0	288.5

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)
Gradient = 4%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	25.1	22.3	21.1	20.5	20.3	20.3	20.5	20.9	21.4	22.0
Medium Car	35.0	30.6	28.6	27.5	27.0	26.8	26.8	27.0	27.4	27.9
Large Car	46.9	40.9	38.0	36.4	35.5	35.1	34.9	34.9	35.2	35.5
Courier Van-Utility	37.3	33.3	31.5	30.6	30.1	30.0	30.1	30.3	30.7	31.2
4WD Mid Size Petrol	39.4	35.6	34.0	33.2	32.9	32.9	33.2	33.6	34.2	34.9
Light Rigid	51.1	47.1	45.5	44.9	45.0	45.4	46.1	47.1	48.4	49.9
Medium Rigid	69.8	63.0	59.9	58.3	57.5	57.3	57.4	57.9	58.6	59.5
Heavy Rigid	100.7	90.4	85.5	82.9	81.5	80.9	80.8	81.1	81.7	82.5
Heavy Bus	138.7	125.1	118.1	113.7	110.5	107.9	105.7	103.8	102.0	100.2
Artic 4 Axle	135.8	122.8	116.9	114.0	112.9	112.8	113.4	114.7	116.5	118.8
Artic 5 Axle	151.7	138.3	132.1	129.0	127.6	127.1	127.5	128.4	129.8	131.6
Artic 6 Axle	163.2	149.4	143.0	139.6	137.9	137.2	137.2	137.7	138.7	140.1
Rigid + 5 Axle Dog	188.9	175.8	169.9	167.0	165.9	165.8	166.5	167.9	169.8	172.1
B-Double	206.0	190.7	183.6	179.9	178.0	177.2	177.3	178.0	179.2	180.8
Twin steer + 5 Axle	207.3	192.5	185.7	182.3	180.8	180.4	180.9	182.1	183.8	185.9
A-Double	255.7	237.9	229.2	224.1	220.9	218.8	217.4	216.5	215.9	215.7
B Triple	288.4	267.0	256.1	249.2	244.4	240.6	237.5	234.7	232.2	229.9
A B Combination	300.0	280.7	270.8	264.6	260.2	256.8	254.0	251.5	249.2	247.0
A-Triple	344.7	322.7	311.2	303.8	298.4	294.0	290.2	286.7	283.3	280.0
Double B-Double	350.5	328.8	317.7	310.7	305.8	301.9	298.6	295.8	293.1	290.6

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)
Gradient = 4%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	**Speed**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	25.0	22.3	21.1	20.6	20.4	20.4	20.6	20.9	21.4	21.9
Medium Car	34.8	30.6	28.6	27.6	27.1	26.8	26.9	27.0	27.3	27.8
Large Car	46.7	40.9	38.1	36.5	35.6	35.1	34.9	34.9	35.1	35.3
Courier Van-Utility	37.2	33.3	31.5	30.7	30.3	30.2	30.4	30.8	31.2	31.9
4WD Mid Size Petrol	39.3	35.6	34.0	33.3	33.1	33.3	33.7	34.4	35.2	36.1
Light Rigid	51.0	47.2	45.7	45.1	45.1	45.5	46.2	47.1	48.3	49.6
Medium Rigid	69.6	63.2	60.3	58.8	58.2	58.1	58.4	58.9	59.7	60.7
Heavy Rigid	100.5	90.7	86.1	83.7	82.4	81.8	81.8	82.1	82.7	83.6
Heavy Bus	138.7	125.2	118.4	114.3	111.4	109.3	107.7	106.3	105.1	104.1
Artic 4 Axle	135.6	123.3	117.8	115.1	114.0	113.9	114.5	115.6	117.2	119.3
Artic 5 Axle	151.3	139.0	133.2	130.1	128.5	127.8	127.8	128.2	129.0	130.2
Artic 6 Axle	162.9	150.1	144.0	140.8	139.0	138.2	138.0	138.2	138.8	139.8
Rigid + 5 Axle Dog	188.9	176.3	170.8	168.5	168.0	168.6	170.1	172.3	175.1	178.5
B-Double	206.0	191.2	184.6	181.4	180.2	180.2	181.0	182.6	184.8	187.5
Twin steer + 5 Axle	207.2	193.0	186.8	183.9	183.0	183.2	184.4	186.3	188.8	191.9
A-Double	255.7	238.4	230.3	226.0	223.7	222.7	222.6	223.2	224.2	225.8
B Triple	288.3	267.5	257.2	251.0	247.0	244.1	241.9	240.3	239.0	238.0
A B Combination	299.8	281.3	272.0	266.4	262.6	259.8	257.6	255.9	254.5	253.2
A-Triple	344.5	323.5	312.6	305.7	300.5	296.4	292.8	289.6	286.5	283.4
Double B-Double	350.3	329.7	319.1	312.6	308.0	304.5	301.6	299.1	296.9	294.8

Table 26 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)										
Gradient = 6%										
Curvature = Straight (20 degree/km)										
Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	25.6	22.8	21.5	20.9	20.6	20.7	20.8	21.2	21.6	22.1
Medium Car	35.6	31.2	29.1	28.0	27.5	27.2	27.2	27.4	27.7	28.1
Large Car	47.5	41.4	38.5	36.9	36.0	35.6	35.4	35.4	35.6	35.9
Courier Van-Utility	39.0	35.3	33.5	32.5	31.9	31.5	31.2	31.1	31.0	31.0
4WD Mid Size Petrol	41.2	37.3	35.5	34.6	34.1	34.0	34.0	34.2	34.6	35.1
Light Rigid	55.0	50.9	49.1	48.3	48.1	48.2	48.6	49.2	50.1	51.0
Medium Rigid	77.1	70.0	66.7	65.0	64.2	64.0	64.1	64.5	65.2	66.1
Heavy Rigid	120.8	110.1	104.9	101.9	100.0	98.8	98.0	97.5	97.3	97.2
Heavy Bus	153.8	140.7	133.5	128.5	124.5	120.8	117.4	113.9	110.4	106.7
Artic 4 Axle	164.1	150.0	143.2	139.3	136.9	135.5	134.6	134.2	134.1	134.3
Artic 5 Axle	184.5	170.1	163.2	159.5	157.4	156.2	155.8	155.9	156.3	157.1
Artic 6 Axle	199.3	184.4	177.2	173.3	171.0	169.7	169.1	169.0	169.3	169.9
Rigid + 5 Axle Dog	237.6	223.1	216.2	212.6	210.6	209.8	209.6	210.0	210.8	212.0
B-Double	258.0	241.3	233.1	228.5	225.6	223.8	222.7	222.1	221.9	221.9
Twin steer + 5 Axle	260.9	244.7	236.9	232.8	230.4	229.2	228.8	229.0	229.6	230.6
A-Double	322.6	302.1	291.7	285.4	281.1	277.9	275.4	273.3	271.5	269.9
B Triple	358.2	333.6	320.7	312.3	306.2	301.1	296.7	292.6	288.6	284.7
A B Combination	382.0	358.5	347.8	342.6	340.3	339.9	340.8	342.9	345.8	349.5
A-Triple	440.5	414.0	403.3	399.5	399.7	402.7	407.8	414.7	423.2	433.2
Double B-Double	449.8	424.1	414.2	411.4	412.9	417.4	424.2	433.1	443.7	456.1

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)										
Gradient = 6%										
Curvature =Curvy / Hilly / Winding (120 degree /km)										
Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	25.6	22.8	21.5	20.9	20.7	20.7	20.8	21.1	21.6	22.1
Medium Car	35.6	31.2	29.1	28.0	27.5	27.2	27.2	27.3	27.6	28.0
Large Car	47.5	41.4	38.6	37.0	36.1	35.6	35.4	35.4	35.5	35.8
Courier Van-Utility	38.9	35.3	33.5	32.5	31.9	31.5	31.2	31.0	30.9	30.9
4WD Mid Size Petrol	41.1	37.3	35.5	34.6	34.1	34.0	34.1	34.3	34.6	35.1
Light Rigid	54.9	50.9	49.2	48.4	48.1	48.1	48.4	48.9	49.5	50.3
Medium Rigid	77.0	70.1	66.9	65.2	64.4	64.0	64.0	64.3	64.9	65.6
Heavy Rigid	120.9	110.2	105.0	102.1	100.3	99.2	98.6	98.2	98.2	98.3
Heavy Bus	153.8	140.7	133.5	128.4	124.4	120.7	117.3	113.8	110.2	106.6
Artic 4 Axle	164.3	150.8	144.4	140.8	138.7	137.5	137.0	136.9	137.1	137.6
Artic 5 Axle	184.9	170.8	164.3	161.0	159.3	158.7	158.8	159.5	160.7	162.3
Artic 6 Axle	199.7	185.1	178.3	174.8	173.0	172.3	172.4	173.1	174.2	175.8
Rigid + 5 Axle Dog	238.0	224.0	217.6	214.4	212.9	212.5	212.9	213.9	215.4	217.3
B-Double	258.3	242.2	234.5	230.2	227.8	226.4	225.8	225.8	226.2	226.9
Twin steer + 5 Axle	261.3	245.6	238.4	234.6	232.8	232.1	232.3	233.2	234.5	236.4
A-Double	322.9	303.3	293.5	287.6	283.6	280.8	278.7	277.0	275.7	274.6
B Triple	358.5	334.8	322.4	314.4	308.5	303.6	299.4	295.4	291.6	287.9
A B Combination	382.5	360.0	350.2	345.7	344.3	344.9	346.9	350.1	354.3	359.4
A-Triple	441.2	416.1	406.5	403.9	405.4	410.0	416.8	425.6	436.3	448.6
Double B-Double	450.5	426.1	417.5	416.2	419.2	425.5	434.4	445.6	458.8	474.0

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)									
Gradient = 6%									
Curvature =Very Curvy or Very Winding (300-320 degree /km)									
Speed (km/hr)									
20	30	40	50	60	70	80	90	100	110
25.5	22.8	21.5	21.0	20.7	20.7	20.9	21.2	21.6	22.1
35.5	31.2	29.2	28.1	27.6	27.3	27.3	27.4	27.6	28.0
47.3	41.4	38.6	37.1	36.2	35.7	35.5	35.4	35.5	35.8
38.9	35.3	33.6	32.6	32.0	31.6	31.4	31.2	31.1	31.1
41.1	37.3	35.5	34.7	34.3	34.3	34.4	34.8	35.3	35.9
54.8	51.1	49.4	48.6	48.2	48.2	48.3	48.7	49.1	49.7
76.8	70.3	67.3	65.7	64.8	64.4	64.4	64.6	65.0	65.6
121.0	110.5	105.6	102.9	101.5	100.9	100.8	101.1	101.7	102.6
153.8	140.7	133.7	128.9	125.0	121.7	118.5	115.4	112.3	109.0
164.3	151.5	145.6	142.5	140.9	140.2	140.2	140.7	141.6	142.9
184.9	171.4	165.4	162.6	161.5	161.6	162.5	164.1	166.3	168.9
199.8	185.7	179.4	176.5	175.4	175.5	176.5	178.2	180.4	183.2
238.0	224.7	218.9	216.4	215.7	216.3	217.7	219.9	222.8	226.1
258.3	242.9	235.8	232.3	230.6	230.1	230.5	231.5	233.1	235.1
261.3	246.4	239.8	236.8	235.8	236.2	237.5	239.5	242.3	245.6
322.8	304.3	295.1	289.7	286.3	283.9	282.3	281.2	280.4	280.0
358.4	335.9	324.1	316.5	310.7	306.0	301.9	298.0	294.2	290.5
382.7	361.4	352.6	349.1	348.8	350.5	353.9	358.6	364.5	371.4
441.6	418.0	409.7	408.6	411.9	418.3	427.4	438.6	452.0	467.2
451.0	428.1	421.0	421.4	426.5	435.1	446.6	460.7	477.2	496.0

Table 27 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)										
Gradient = 8%										
Curvature = Straight (20 degree/km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	26.6	23.7	22.4	21.8	21.4	21.4	21.4	21.6	21.9	22.3
Medium Car	36.9	32.5	30.4	29.2	28.5	28.2	28.0	28.0	28.1	28.3
Large Car	49.0	42.9	39.9	38.2	37.2	36.6	36.3	36.1	36.2	36.3
Courier Van-Utility	40.9	37.5	35.7	34.6	33.9	33.3	32.8	32.4	32.0	31.6
4WD Mid Size Petrol	43.2	39.5	37.7	36.7	36.1	35.7	35.5	35.4	35.3	35.4
Light Rigid	59.4	55.3	53.4	52.4	51.9	51.7	51.7	51.8	52.1	52.5
Medium Rigid	84.8	77.9	74.6	72.8	71.8	71.3	71.1	71.1	71.4	71.8
Heavy Rigid	143.8	132.4	126.7	123.2	120.9	119.3	118.1	117.1	116.3	115.7
Heavy Bus	170.6	157.5	149.9	144.1	139.0	134.1	129.1	123.9	118.3	112.4
Artic 4 Axle	196.0	180.2	172.4	167.9	165.1	163.2	162.0	161.2	160.7	160.5
Artic 5 Axle	221.0	205.3	197.7	193.4	190.8	189.3	188.4	188.1	188.2	188.5
Artic 6 Axle	239.7	223.4	215.5	211.0	208.3	206.6	205.6	205.0	204.9	205.0
Rigid + 5 Axle Dog	292.5	276.0	268.5	264.8	263.2	262.9	263.6	265.1	267.2	269.8
B-Double	316.3	297.3	288.3	283.5	280.9	279.7	279.5	279.9	280.9	282.4
Twin steer + 5 Axle	321.5	303.1	294.6	290.3	288.3	287.6	287.9	289.1	290.8	293.2
A-Double	397.3	373.8	363.8	359.7	358.9	360.3	363.4	367.9	373.5	380.3
B Triple	435.7	407.7	395.5	390.1	388.5	389.4	392.2	396.4	402.0	408.7
A B Combination	473.4	449.3	442.7	444.5	451.7	463.1	477.9	495.9	516.8	540.5
A-Triple	548.9	524.2	521.3	529.6	545.5	567.6	595.2	627.8	665.1	707.0
Double B-Double	562.7	539.2	537.7	547.6	565.6	590.0	620.3	655.9	696.6	742.3

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)										
Gradient = 8%										
Curvature =Curvy / Hilly / Winding (120 degree /km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	26.5	23.7	22.4	21.8	21.4	21.3	21.4	21.6	21.8	22.2
Medium Car	36.8	32.5	30.4	29.2	28.5	28.2	28.0	27.9	27.9	28.1
Large Car	48.9	42.9	39.9	38.2	37.2	36.6	36.3	36.1	36.0	36.1
Courier Van-Utility	40.8	37.5	35.7	34.7	33.9	33.3	32.8	32.4	32.0	31.6
4WD Mid Size Petrol	43.2	39.5	37.8	36.8	36.1	35.7	35.5	35.4	35.3	35.3
Light Rigid	59.3	55.4	53.5	52.5	52.0	51.7	51.5	51.6	51.7	51.9
Medium Rigid	84.8	78.0	74.8	73.0	71.9	71.3	71.0	70.9	71.0	71.3
Heavy Rigid	143.9	132.5	126.9	123.6	121.4	119.9	118.8	118.0	117.4	117.0
Heavy Bus	170.5	157.5	149.9	144.1	139.0	134.1	129.0	123.8	118.2	112.3
Artic 4 Axle	196.5	181.7	174.4	170.2	167.4	165.6	164.3	163.4	162.8	162.4
Artic 5 Axle	221.4	206.5	199.4	195.5	193.3	192.1	191.6	191.6	192.0	192.8
Artic 6 Axle	240.1	224.6	217.2	213.2	210.9	209.6	209.1	209.1	209.5	210.3
Rigid + 5 Axle Dog	293.1	277.5	270.7	267.6	266.7	267.1	268.6	270.9	273.9	277.6
B-Double	316.8	298.8	290.6	286.4	284.4	283.8	284.2	285.4	287.2	289.6
Twin steer + 5 Axle	322.1	304.7	296.9	293.3	291.8	291.8	292.9	294.8	297.4	300.7
A-Double	398.1	376.0	367.1	364.0	364.4	367.1	371.6	377.7	385.2	393.9
B Triple	436.5	410.1	399.1	394.9	394.6	397.0	401.4	407.5	415.1	424.0
A B Combination	474.7	452.4	447.5	451.4	460.9	475.0	492.8	514.2	538.9	566.7
A-Triple	550.7	528.4	527.9	539.0	558.2	584.1	615.9	653.3	696.0	743.8
Double B-Double	564.5	543.5	544.5	557.4	578.9	607.3	642.1	682.8	729.2	781.2

IRI = 1, NRM = 25 (Road Surface Condition: Very Good)									
Gradient = 8%									
Curvature =Very Curvy or Very Winding (300-320 degree /km)									
Speed (km/hr)									
20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
26.4	23.7	22.5	21.8	21.5	21.3	21.3	21.5	21.7	21.9
36.6	32.5	30.4	29.3	28.6	28.2	27.9	27.8	27.7	27.8
48.7	42.9	40.0	38.3	37.3	36.6	36.2	35.9	35.8	35.7
40.8	37.5	35.8	34.7	34.0	33.4	33.0	32.6	32.3	32.0
43.1	39.6	37.8	36.9	36.3	36.0	35.8	35.7	35.7	35.8
59.2	55.5	53.7	52.7	52.1	51.7	51.4	51.3	51.2	51.3
84.6	78.2	75.0	73.3	72.2	71.5	71.1	70.9	70.8	70.9
143.9	132.9	127.7	124.7	123.0	122.0	121.5	121.4	121.5	121.9
170.5	157.6	150.1	144.4	139.4	134.6	129.7	124.7	119.3	113.6
196.5	182.9	176.2	172.3	169.8	168.2	167.1	166.4	166.0	165.7
221.4	207.4	200.9	197.6	195.9	195.3	195.5	196.2	197.4	199.0
240.1	225.5	218.8	215.4	213.7	213.2	213.5	214.4	215.8	217.6
293.3	278.7	272.7	270.5	270.4	271.8	274.4	277.9	282.3	287.4
316.9	300.1	292.6	289.2	287.9	288.2	289.5	291.7	294.6	298.2
322.2	306.0	299.1	296.2	295.6	296.6	298.8	301.9	305.8	310.5
398.4	377.7	370.0	368.2	369.9	374.2	380.4	388.4	397.9	408.9
436.9	412.1	402.5	399.6	400.8	404.9	411.1	419.3	429.1	440.5
475.5	455.2	452.5	458.9	471.4	488.9	510.7	536.5	566.0	599.3
552.0	532.4	534.9	549.7	573.2	604.1	641.7	685.5	735.5	791.3
565.9	547.7	551.9	568.7	594.7	628.5	669.4	717.0	771.1	831.5

Table 28 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 0%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr) 20	30	40	50	60	70	80	90	100	110
Small Car	26.3	23.4	22.1	21.6	21.4	21.4	21.7	22.1	22.6	23.2
Medium Car	36.4	31.9	29.8	28.8	28.3	28.1	28.2	28.5	28.9	29.5
Large Car	48.6	42.4	39.5	37.9	37.0	36.6	36.5	36.6	37.0	37.4
Courier Van-Utility	38.8	34.9	33.2	32.4	32.1	32.1	32.3	32.8	33.4	34.2
4WD Mid Size Petrol	41.5	37.8	36.1	35.3	35.1	35.1	35.4	35.9	36.6	37.4
Light Rigid	52.3	48.6	47.3	47.0	47.4	48.1	49.3	50.8	52.5	54.5
Medium Rigid	67.1	60.4	57.6	56.4	56.2	56.6	57.4	58.6	60.2	62.1
Heavy Rigid	87.8	77.8	73.7	72.3	72.5	73.8	75.9	78.7	82.2	86.2
Heavy Bus	134.8	120.2	113.4	109.9	108.1	107.4	107.5	108.2	109.4	111.0
Artic 4 Axle	117.3	105.5	101.0	99.8	100.5	102.5	105.7	109.8	114.7	120.3
Artic 5 Axle	128.7	116.0	110.9	109.3	109.7	111.4	114.3	118.0	122.6	128.0
Artic 6 Axle	139.0	125.6	120.2	118.4	118.6	120.2	123.0	126.7	131.3	136.6
Rigid + 5 Axle Dog	146.0	134.0	129.3	127.9	128.6	130.6	133.6	137.7	142.5	148.1
B-Double	164.3	149.8	143.9	141.7	141.7	143.3	146.0	149.6	154.1	159.4
Twin steer + 5 Axle	162.2	148.3	142.7	140.8	141.0	142.7	145.5	149.2	153.8	159.2
A-Double	199.5	182.4	175.1	172.1	171.6	172.7	175.0	178.4	182.6	187.6
B Triple	233.6	212.5	203.2	198.9	197.4	197.7	199.4	202.1	205.7	210.2
A B Combination	225.7	207.6	199.9	196.7	196.0	197.0	199.3	202.7	206.9	212.0
A-Triple	255.5	235.4	226.7	222.9	221.8	222.5	224.6	227.8	231.9	236.9
Double B-Double	257.0	237.6	229.2	225.7	224.8	225.7	227.9	231.3	235.6	240.7

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat) (highlighted)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km) (highlighted)	Curvy (100-299°/km) (highlighted)	Very Curvy (300°+/km) (highlighted)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good) (highlighted)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99 (highlighted)	100-149	150-199

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 0%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr) 20	30	40	50	60	70	80	90	100	110
Small Car	26.2	23.4	22.2	21.6	21.4	21.5	21.7	22.1	22.6	23.2
Medium Car	36.3	31.9	29.9	28.9	28.3	28.2	28.2	28.5	28.9	29.4
Large Car	48.5	42.4	39.5	38.0	37.1	36.7	36.6	36.7	36.9	37.3
Courier Van-Utility	38.8	34.9	33.2	32.4	32.1	32.2	32.5	33.0	33.6	34.4
4WD Mid Size Petrol	41.5	37.8	36.1	35.4	35.1	35.2	35.5	36.1	36.8	37.6
Light Rigid	52.2	48.7	47.3	47.1	47.4	48.2	49.3	50.8	52.5	54.5
Medium Rigid	67.2	60.5	57.7	56.6	56.4	57.0	58.1	59.5	61.4	63.6
Heavy Rigid	88.0	77.7	73.7	72.5	72.9	74.5	77.1	80.4	84.3	89.0
Heavy Bus	134.9	120.1	113.4	110.0	108.5	108.1	108.6	109.8	111.4	113.6
Artic 4 Axle	117.3	105.7	101.3	100.3	101.3	103.7	107.2	111.7	117.1	123.3
Artic 5 Axle	128.6	116.1	111.2	109.7	110.2	112.2	115.2	119.2	124.0	129.6
Artic 6 Axle	138.9	125.7	120.5	118.8	119.2	121.0	124.0	127.9	132.7	138.2
Rigid + 5 Axle Dog	146.1	134.0	129.5	128.5	129.5	131.9	135.5	140.2	145.7	152.1
B-Double	164.4	149.9	144.1	142.2	142.7	144.6	147.9	152.1	157.4	163.4
Twin steer + 5 Axle	162.2	148.4	143.0	141.4	142.0	144.2	147.6	152.0	157.4	163.6
A-Double	199.6	182.4	175.4	172.8	172.8	174.6	177.7	182.0	187.3	193.5
B Triple	233.7	212.6	203.5	199.6	198.6	199.6	202.0	205.6	210.2	215.7
A B Combination	226.0	207.7	200.3	197.6	197.6	199.6	203.0	207.6	213.3	219.9
A-Triple	255.8	235.6	227.2	224.0	223.7	225.5	228.8	233.3	239.0	245.7
Double B-Double	257.3	237.8	229.8	226.8	226.8	228.8	232.3	237.2	243.1	250.1

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 0%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr) 20	30	40	50	60	70	80	90	100	110
Small Car	26.2	23.5	22.3	21.7	21.5	21.6	21.8	22.1	22.6	23.2
Medium Car	36.2	32.0	30.0	29.0	28.5	28.3	28.4	28.6	28.9	29.4
Large Car	48.3	42.5	39.7	38.2	37.3	36.9	36.7	36.7	36.9	37.3
Courier Van-Utility	38.8	35.0	33.3	32.6	32.4	32.6	33.1	33.7	34.6	35.6
4WD Mid Size Petrol	41.5	37.8	36.2	35.6	35.5	35.7	36.2	37.0	37.9	39.0
Light Rigid	52.2	48.7	47.5	47.3	47.7	48.7	50.0	51.6	53.6	55.8
Medium Rigid	67.5	60.5	58.0	57.5	58.2	59.8	62.1	65.0	68.5	72.5
Heavy Rigid	88.4	77.8	74.3	74.1	76.0	79.3	83.9	89.6	96.3	103.9
Heavy Bus	135.1	120.2	113.9	111.5	111.2	112.3	114.6	117.8	121.9	126.6
Artic 4 Axle	117.7	106.0	102.6	103.3	106.5	111.7	118.5	126.8	136.5	147.4
Artic 5 Axle	128.7	116.3	112.2	111.9	114.0	117.9	123.2	129.8	137.6	146.4
Artic 6 Axle	139.0	125.9	121.5	121.1	123.2	127.1	132.5	139.2	147.1	156.1
Rigid + 5 Axle Dog	146.5	134.3	130.9	131.8	135.4	141.2	148.7	157.8	168.3	180.3
B-Double	164.7	150.1	145.5	145.7	148.8	154.1	161.3	170.2	180.5	192.2
Twin steer + 5 Axle	162.6	148.6	144.5	145.0	148.5	154.2	161.8	171.0	181.8	194.1
A-Double	200.2	182.6	177.1	177.2	180.9	187.2	195.7	206.1	218.4	232.3
B Triple	234.1	212.8	205.3	204.2	206.9	212.4	220.3	230.1	241.7	255.0
A B Combination	226.8	207.9	202.4	203.2	208.0	215.9	226.3	239.0	253.7	270.5
A-Triple	256.8	235.9	229.7	230.6	236.0	244.7	256.3	270.4	286.8	305.4
Double B-Double	258.4	238.1	232.3	233.6	239.5	248.7	260.9	275.6	292.7	312.1

Table 29 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 3, NRM = 78 (Road Surface Condition: Good)										
Gradient = 4%										
Curvature = Straight (20 degree/km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	26.5	23.7	22.4	21.8	21.6	21.6	21.9	22.2	22.7	23.3
Medium Car	36.7	32.3	30.2	29.2	28.6	28.4	28.5	28.7	29.1	29.6
Large Car	49.0	42.8	39.9	38.3	37.5	37.0	36.9	37.0	37.2	37.6
Courier Van-Utility	40.3	36.3	34.5	33.5	33.1	33.0	33.1	33.3	33.7	34.3
4WD Mid Size Petrol	42.3	38.5	36.8	36.0	35.7	35.7	36.0	36.4	36.9	37.6
Light Rigid	55.6	51.5	49.9	49.3	49.4	49.9	50.8	51.9	53.3	55.0
Medium Rigid	74.4	67.4	64.2	62.6	61.9	61.7	61.9	62.5	63.3	64.3
Heavy Rigid	111.3	100.8	95.8	93.2	91.9	91.2	91.2	91.5	92.1	93.1
Heavy Bus	152.9	139.3	132.3	127.8	124.6	122.0	119.7	117.7	115.8	113.9
Artic 4 Axle	151.6	137.8	131.8	129.1	128.2	128.6	130.0	132.0	134.7	138.0
Artic 5 Axle	168.8	154.5	148.1	145.1	143.9	143.9	144.8	146.3	148.5	151.2
Artic 6 Axle	181.9	167.3	160.6	157.3	155.8	155.4	155.9	157.0	158.7	160.9
Rigid + 5 Axle Dog	207.1	193.5	187.4	184.4	183.2	183.1	183.8	185.1	186.9	189.3
B-Double	228.6	213.0	205.6	201.6	199.5	198.4	198.1	198.4	199.2	200.3
Twin steer + 5 Axle	228.6	213.3	206.3	202.8	201.1	200.5	200.8	201.8	203.3	205.2
A-Double	284.3	266.2	257.1	251.7	248.0	245.4	243.5	241.9	240.7	239.7
B Triple	322.5	300.7	289.5	282.3	277.1	273.0	269.5	266.4	263.4	260.5
A B Combination	332.6	312.7	302.4	296.0	291.4	287.8	284.8	282.1	279.6	277.2
A-Triple	381.7	359.0	347.1	339.6	334.1	329.7	325.9	322.5	319.2	316.0
Double B-Double	387.7	365.3	353.8	346.6	341.5	337.5	334.1	331.1	328.4	325.8

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 3, NRM = 78 (Road Surface Condition: Good)										
Gradient = 4%										
Curvature =Curvy / Hilly / Winding (120 degree /km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	26.5	23.7	22.4	21.8	21.6	21.7	21.9	22.2	22.7	23.3
Medium Car	36.7	32.3	30.3	29.2	28.7	28.5	28.5	28.7	29.1	29.6
Large Car	49.0	42.9	40.0	38.4	37.5	37.1	36.9	37.0	37.2	37.5
Courier Van-Utility	40.3	36.3	34.5	33.6	33.1	33.0	33.1	33.3	33.7	34.2
4WD Mid Size Petrol	42.3	38.5	36.9	36.1	35.8	35.8	36.1	36.5	37.1	37.8
Light Rigid	55.5	51.6	49.9	49.4	49.4	49.8	50.5	51.6	52.8	54.3
Medium Rigid	74.3	67.5	64.4	62.8	62.0	61.8	62.0	62.4	63.1	64.0
Heavy Rigid	111.2	100.8	96.0	93.4	92.0	91.4	91.2	91.5	92.1	93.0
Heavy Bus	152.9	139.3	132.3	127.9	124.7	122.1	119.9	118.0	116.2	114.4
Artic 4 Axle	151.3	138.2	132.3	129.5	128.3	128.2	128.9	130.1	131.9	134.2
Artic 5 Axle	168.4	155.0	148.8	145.7	144.2	143.8	144.2	145.1	146.4	148.2
Artic 6 Axle	181.5	167.7	161.3	157.9	156.2	155.5	155.5	156.0	157.0	158.4
Rigid + 5 Axle Dog	207.0	193.8	187.9	185.1	184.0	183.9	184.6	186.0	187.9	190.2
B-Double	228.5	213.2	206.1	202.4	200.5	199.7	199.8	200.5	201.6	203.3
Twin steer + 5 Axle	228.4	213.6	206.9	203.5	202.0	201.6	202.1	203.2	204.9	207.1
A-Double	284.2	266.4	257.7	252.6	249.4	247.3	245.9	245.0	244.5	244.3
B Triple	322.4	301.0	290.1	283.2	278.4	274.6	271.5	268.7	266.2	263.9
A B Combination	332.4	313.1	303.2	297.0	292.6	289.2	286.4	283.9	281.6	279.5
A-Triple	381.5	359.5	348.1	340.7	335.3	330.9	327.1	323.6	320.2	316.9
Double B-Double	387.6	365.9	354.8	347.8	342.9	339.0	335.7	332.9	330.2	327.7

IRI = 3, NRM = 78 (Road Surface Condition: Good)										
Gradient = 4%										
Curvature =Very Curvy or Very Winding (300-320 degree /km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	26.4	23.7	22.5	21.9	21.7	21.8	22.0	22.3	22.8	23.3
Medium Car	36.6	32.3	30.4	29.3	28.8	28.6	28.6	28.8	29.1	29.5
Large Car	48.8	42.9	40.1	38.6	37.7	37.2	37.0	37.0	37.1	37.4
Courier Van-Utility	40.2	36.4	34.6	33.7	33.4	33.3	33.5	33.8	34.3	34.9
4WD Mid Size Petrol	42.3	38.6	37.0	36.3	36.1	36.3	36.7	37.3	38.1	39.1
Light Rigid	55.4	51.7	50.1	49.5	49.6	49.9	50.6	51.6	52.7	54.1
Medium Rigid	74.1	67.7	64.8	63.4	62.8	62.6	62.9	63.4	64.2	65.2
Heavy Rigid	111.0	101.2	96.6	94.1	92.9	92.3	92.2	92.6	93.2	94.1
Heavy Bus	152.9	139.4	132.6	128.5	125.6	123.5	121.9	120.5	119.3	118.3
Artic 4 Axle	151.0	138.7	133.2	130.5	129.4	129.2	129.8	131.0	132.6	134.7
Artic 5 Axle	168.0	155.6	149.8	146.8	145.2	144.5	144.4	144.9	145.7	146.8
Artic 6 Axle	181.1	168.3	162.3	159.1	157.3	156.4	156.2	156.5	157.1	158.0
Rigid + 5 Axle Dog	206.8	194.2	188.8	186.5	185.9	186.6	188.0	190.2	193.1	196.5
B-Double	228.4	213.6	207.0	203.8	202.6	202.5	203.4	205.0	207.2	209.9
Twin steer + 5 Axle	228.2	214.1	207.8	205.0	204.0	204.3	205.4	207.3	209.9	212.9
A-Double	284.1	266.8	258.7	254.4	252.1	251.1	251.0	251.6	252.7	254.2
B Triple	322.2	301.5	291.1	285.0	280.9	278.0	275.9	274.2	273.0	272.0
A B Combination	332.2	313.7	304.4	298.7	294.9	292.1	290.0	288.3	286.8	285.6
A-Triple	381.3	360.3	349.4	342.5	337.3	333.2	329.6	326.4	323.3	320.2
Double B-Double	387.4	366.7	356.1	349.6	345.0	341.5	338.6	336.1	333.9	331.8

Table 30 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 6%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.0	24.1	22.8	22.2	22.0	22.0	22.2	22.5	22.9	23.5
Medium Car	37.3	32.9	30.8	29.7	29.1	28.9	28.9	29.1	29.4	29.8
Large Car	49.5	43.4	40.5	39.0	38.1	37.6	37.4	37.4	37.6	37.9
Courier Van-Utility	42.0	38.3	36.5	35.5	34.9	34.5	34.2	34.1	34.1	34.1
4WD Mid Size Petrol	44.0	40.1	38.3	37.4	37.0	36.8	36.9	37.1	37.5	37.9
Light Rigid	59.4	55.3	53.5	52.7	52.5	52.6	53.0	53.7	54.5	55.5
Medium Rigid	81.7	74.5	71.3	69.6	68.8	68.5	68.6	69.1	69.8	70.6
Heavy Rigid	131.3	120.7	115.4	112.4	110.5	109.3	108.5	108.1	107.8	107.8
Heavy Bus	168.1	155.0	147.8	142.8	138.8	135.2	131.7	128.2	124.7	121.0
Artic 4 Axle	180.4	166.4	159.5	155.7	153.3	151.9	151.0	150.6	150.5	150.7
Artic 5 Axle	202.2	187.8	180.9	177.2	175.1	173.9	173.5	173.6	174.0	174.8
Artic 6 Axle	218.6	203.7	196.6	192.7	190.4	189.1	188.5	188.4	188.7	189.3
Rigid + 5 Axle Dog	256.9	242.4	235.5	231.9	229.9	229.1	228.9	229.3	230.1	231.3
B-Double	281.7	265.0	256.8	252.2	249.3	247.5	246.4	245.8	245.6	245.7
Twin steer + 5 Axle	283.5	267.2	259.5	255.3	253.0	251.8	251.4	251.5	252.2	253.2
A-Double	352.7	332.2	321.8	315.5	311.2	308.0	305.5	303.4	301.6	300.0
B Triple	393.8	369.2	356.3	347.9	341.8	336.7	332.3	328.2	324.2	320.3
A B Combination	416.3	392.8	382.2	376.9	374.6	374.2	375.2	377.2	380.1	383.8
A-Triple	479.6	453.2	442.4	438.6	438.8	441.8	446.9	453.8	462.3	472.3
Double B-Double	489.2	463.5	453.6	450.8	452.3	456.8	463.6	472.5	483.2	495.5

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 6%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	26.9	24.1	22.8	22.3	22.0	22.0	22.2	22.5	22.9	23.4
Medium Car	37.3	32.9	30.8	29.8	29.2	28.9	28.9	29.1	29.3	29.7
Large Car	49.5	43.5	40.6	39.0	38.1	37.6	37.4	37.4	37.6	37.8
Courier Van-Utility	41.9	38.3	36.6	35.6	34.9	34.5	34.2	34.1	34.0	34.0
4WD Mid Size Petrol	44.0	40.2	38.4	37.5	37.0	36.9	36.9	37.1	37.5	38.0
Light Rigid	59.3	55.4	53.6	52.8	52.5	52.6	52.8	53.3	54.0	54.7
Medium Rigid	81.5	74.6	71.4	69.7	68.9	68.6	68.6	68.9	69.4	70.1
Heavy Rigid	131.4	120.7	115.5	112.6	110.8	109.7	109.1	108.7	108.7	108.8
Heavy Bus	168.1	155.0	147.8	142.8	138.7	135.1	131.6	128.1	124.6	120.9
Artic 4 Axle	180.3	166.9	160.4	156.8	154.7	153.6	153.0	152.9	153.1	153.6
Artic 5 Axle	202.2	188.1	181.6	178.3	176.6	176.0	176.1	176.8	178.0	179.6
Artic 6 Axle	218.7	204.1	197.3	193.8	192.0	191.3	191.4	192.0	193.2	194.7
Rigid + 5 Axle Dog	256.9	242.9	236.5	233.3	231.8	231.4	231.8	232.8	234.3	236.2
B-Double	281.6	265.5	257.8	253.6	251.1	249.8	249.2	249.1	249.5	250.2
Twin steer + 5 Axle	283.4	267.8	260.5	256.8	254.9	254.3	254.5	255.3	256.7	258.5
A-Double	352.6	333.0	323.1	317.2	313.3	310.5	308.4	306.7	305.4	304.3
B Triple	393.7	370.0	357.6	349.6	343.7	338.8	334.6	330.6	326.8	323.1
A B Combination	416.4	393.9	384.1	379.6	378.2	378.8	380.8	384.0	388.2	393.3
A-Triple	479.8	454.7	445.1	442.5	444.1	448.6	455.4	464.3	474.9	487.2
Double B-Double	489.5	465.1	456.5	455.1	458.2	464.5	473.4	484.5	497.8	512.9

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	26.9	24.1	22.9	22.3	22.1	22.1	22.3	22.5	23.0	23.5
Medium Car	37.2	32.9	30.9	29.9	29.3	29.0	29.0	29.1	29.4	29.7
Large Car	49.4	43.5	40.7	39.2	38.3	37.8	37.5	37.5	37.6	37.9
Courier Van-Utility	41.9	38.4	36.7	35.7	35.1	34.7	34.4	34.3	34.2	34.2
4WD Mid Size Petrol	44.0	40.2	38.5	37.6	37.3	37.2	37.4	37.7	38.2	38.8
Light Rigid	59.2	55.5	53.8	53.0	52.7	52.6	52.8	53.1	53.6	54.2
Medium Rigid	81.3	74.8	71.8	70.2	69.3	69.0	68.9	69.1	69.5	70.1
Heavy Rigid	131.4	120.9	116.0	113.4	112.0	111.3	111.2	111.5	112.1	113.0
Heavy Bus	168.1	155.1	148.0	143.2	139.4	136.0	132.8	129.7	126.6	123.4
Artic 4 Axle	180.2	167.4	161.5	158.4	156.8	156.1	156.1	156.6	157.5	158.8
Artic 5 Axle	202.1	188.6	182.6	179.8	178.7	178.8	179.7	181.3	183.5	186.1
Artic 6 Axle	218.6	204.5	198.3	195.3	194.2	194.3	195.3	197.0	199.3	202.0
Rigid + 5 Axle Dog	256.8	243.5	237.7	235.2	234.5	235.1	236.5	238.7	241.5	244.9
B-Double	281.5	266.1	259.1	255.5	253.8	253.3	253.7	254.7	256.3	258.3
Twin steer + 5 Axle	283.3	268.4	261.8	258.8	257.8	258.2	259.5	261.6	264.3	267.7
A-Double	352.4	333.8	324.7	319.3	315.8	313.5	311.9	310.8	310.0	309.5
B Triple	393.5	371.0	359.2	351.5	345.8	341.1	337.0	333.1	329.3	325.6
A B Combination	416.5	395.2	386.3	382.9	382.5	384.3	387.7	392.4	398.2	405.2
A-Triple	480.1	456.5	448.2	447.1	450.4	456.8	465.8	477.1	490.5	505.7
Double B-Double	489.8	466.9	459.9	460.2	465.3	473.9	485.4	499.5	516.0	534.8

Table 31 Vehicle Operating Costs for Rural Roads (Cents/KM)

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 8%
Curvature = Straight (20 degree/km)

	20	30	40	50	60	70	80	90	100	110
Small Car	27.9	25.0	23.7	23.1	22.8	22.7	22.7	22.9	23.2	23.6
Medium Car	38.5	34.1	32.0	30.9	30.2	29.8	29.7	29.6	29.7	29.9
Large Car	51.0	44.8	41.9	40.2	39.2	38.6	38.3	38.1	38.1	38.3
Courier Van-Utility	43.9	40.5	38.8	37.7	36.9	36.3	35.8	35.4	35.0	34.7
4WD Mid Size Petrol	46.1	42.4	40.6	39.6	39.0	38.6	38.4	38.3	38.2	38.3
Light Rigid	63.8	59.8	57.9	56.9	56.4	56.2	56.2	56.3	56.6	57.0
Medium Rigid	89.4	82.4	79.1	77.3	76.3	75.8	75.6	75.7	75.9	76.3
Heavy Rigid	154.3	142.9	137.2	133.7	131.5	129.8	128.6	127.6	126.8	126.2
Heavy Bus	185.1	172.1	164.5	158.7	153.6	148.6	143.6	138.4	132.9	127.0
Artic 4 Axle	213.4	197.5	189.8	185.2	182.4	180.5	179.3	178.5	178.0	177.8
Artic 5 Axle	239.6	223.9	216.3	212.0	209.4	207.9	207.1	206.7	206.8	207.1
Artic 6 Axle	260.0	243.8	235.9	231.4	228.6	226.9	225.9	225.4	225.2	225.4
Rigid + 5 Axle Dog	313.2	296.6	289.1	285.4	283.8	283.5	284.2	285.7	287.8	290.4
B-Double	341.4	322.4	313.4	308.6	306.0	304.8	304.6	305.0	306.0	307.5
Twin steer + 5 Axle	345.6	327.2	318.7	314.4	312.3	311.7	312.0	313.2	314.9	317.2
A-Double	429.3	405.8	395.8	391.7	390.9	392.3	395.4	399.8	405.5	412.3
B Triple	473.3	445.3	433.1	427.7	426.1	427.0	429.7	434.0	439.6	446.3
A B Combination	510.0	485.9	479.2	481.1	488.3	499.7	514.5	532.5	553.4	577.1
A-Triple	590.6	566.0	563.1	571.3	587.3	609.4	637.0	669.5	706.8	748.8
Double B-Double	604.8	581.4	579.8	589.8	607.7	632.2	662.5	698.1	738.8	784.4

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 8%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.9	25.1	23.8	23.1	22.8	22.7	22.7	22.9	23.1	23.5
Medium Car	38.5	34.1	32.1	30.9	30.2	29.8	29.6	29.6	29.6	29.8
Large Car	50.9	44.9	41.9	40.3	39.2	38.6	38.3	38.1	38.0	38.1
Courier Van-Utility	43.9	40.5	38.8	37.7	36.9	36.3	35.9	35.4	35.0	34.7
4WD Mid Size Petrol	46.1	42.4	40.7	39.7	39.0	38.7	38.4	38.3	38.2	38.2
Light Rigid	63.8	59.9	58.0	57.0	56.4	56.1	56.0	56.0	56.1	56.4
Medium Rigid	89.3	82.5	79.3	77.5	76.4	75.8	75.5	75.4	75.5	75.8
Heavy Rigid	154.3	143.0	137.4	134.1	131.9	130.4	129.3	128.5	127.9	127.4
Heavy Bus	185.1	172.1	164.4	158.7	153.5	148.6	143.6	138.3	132.8	126.9
Artic 4 Axle	213.3	198.6	191.3	187.0	184.3	182.4	181.1	180.2	179.7	179.3
Artic 5 Axle	239.5	224.6	217.5	213.6	211.4	210.2	209.7	209.8	210.2	211.0
Artic 6 Axle	259.9	244.5	237.1	233.0	230.7	229.5	228.9	228.9	229.4	230.1
Rigid + 5 Axle Dog	313.2	297.6	290.8	287.7	286.8	287.2	288.7	291.0	294.0	297.6
B-Double	341.4	323.4	315.1	311.0	309.0	308.4	308.8	310.0	311.8	314.2
Twin steer + 5 Axle	345.6	328.2	320.5	316.8	315.3	315.3	316.4	318.3	321.0	324.2
A-Double	429.5	407.4	398.5	395.4	395.8	398.5	403.0	409.1	416.6	425.3
B Triple	473.5	447.1	436.1	431.9	431.6	434.0	438.4	444.5	452.1	461.0
A B Combination	510.6	488.3	483.5	487.3	496.9	510.9	528.8	550.2	574.8	602.7
A-Triple	591.8	569.5	569.0	580.1	599.3	625.2	657.0	694.4	737.1	784.9
Double B-Double	606.0	585.0	586.0	598.9	620.3	648.8	683.6	724.3	770.7	822.6

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 8%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.8	25.1	23.8	23.2	22.8	22.7	22.7	22.8	23.0	23.3
Medium Car	38.4	34.2	32.2	31.0	30.3	29.9	29.6	29.5	29.4	29.5
Large Car	50.8	44.9	42.1	40.4	39.4	38.7	38.2	38.0	37.8	37.8
Courier Van-Utility	43.9	40.5	38.8	37.8	37.0	36.5	36.0	35.7	35.3	35.0
4WD Mid Size Petrol	46.0	42.5	40.8	39.8	39.2	38.9	38.7	38.6	38.6	38.7
Light Rigid	63.7	60.0	58.2	57.2	56.5	56.1	55.9	55.8	55.7	55.7
Medium Rigid	89.1	82.7	79.6	77.8	76.7	76.0	75.6	75.4	75.4	75.4
Heavy Rigid	154.3	143.3	138.0	135.1	133.4	132.4	131.9	131.7	131.9	132.3
Heavy Bus	185.0	172.1	164.6	158.9	154.0	149.1	144.3	139.2	133.8	128.1
Artic 4 Axle	213.2	199.6	192.9	189.0	186.6	184.9	183.8	183.1	182.7	182.5
Artic 5 Axle	239.4	225.4	218.9	215.6	213.9	213.3	213.5	214.2	215.4	217.0
Artic 6 Axle	259.8	245.2	238.5	235.1	233.4	232.9	233.2	234.1	235.5	237.3
Rigid + 5 Axle Dog	313.3	298.7	292.6	290.4	290.3	291.8	294.3	297.9	302.2	307.3
B-Double	341.4	324.5	317.0	313.6	312.4	312.6	314.0	316.1	319.1	322.6
Twin steer + 5 Axle	345.6	329.4	322.4	319.6	319.0	320.0	322.2	325.3	329.2	333.9
A-Double	429.7	409.0	401.3	399.5	401.2	405.4	411.7	419.6	429.2	440.1
B Triple	473.8	449.0	439.3	436.5	437.7	441.7	448.0	456.1	466.0	477.4
A B Combination	511.3	491.0	488.3	494.7	507.2	524.7	546.5	572.3	601.8	635.1
A-Triple	592.9	573.3	575.9	590.6	614.1	645.0	682.6	726.4	776.4	832.2
Double B-Double	607.2	589.0	593.2	610.0	636.0	669.8	710.7	758.3	812.4	872.8

Table 32 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 0%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.7	24.9	23.6	23.0	22.8	22.9	23.1	23.5	24.1	24.7
Medium Car	38.2	33.8	31.7	30.7	30.2	30.0	30.1	30.4	30.8	31.4
Large Car	50.9	44.7	41.7	40.2	39.3	38.9	38.8	38.9	39.2	39.7
Courier Van-Utility	42.4	38.6	36.8	36.0	35.7	35.7	36.0	36.4	37.1	37.8
4WD Mid Size Petrol	45.0	41.2	39.6	38.8	38.5	38.6	38.9	39.4	40.0	40.9
Light Rigid	57.4	53.8	52.5	52.2	52.5	53.3	54.5	55.9	57.7	59.7
Medium Rigid	72.5	65.8	63.0	61.8	61.5	61.9	62.8	64.0	65.6	67.4
Heavy Rigid	98.7	88.6	84.5	83.2	83.3	84.6	86.7	89.6	93.0	97.0
Heavy Bus	149.7	135.1	128.4	124.9	123.1	122.4	122.5	123.2	124.4	125.9
Artic 4 Axle	132.8	121.1	116.6	115.3	116.0	118.1	121.2	125.3	130.2	135.9
Artic 5 Axle	145.4	132.7	127.7	126.0	126.4	128.2	131.0	134.8	139.4	144.7
Artic 6 Axle	157.4	143.9	138.5	136.7	136.9	138.6	141.4	145.1	149.6	154.9
Rigid + 5 Axle Dog	164.1	152.0	147.4	146.0	146.6	148.6	151.7	155.7	160.6	166.2
B-Double	186.8	172.3	166.3	164.2	164.2	165.8	168.4	172.1	176.6	181.9
Twin steer + 5 Axle	183.3	169.4	163.8	161.9	162.1	163.8	166.6	170.3	174.9	180.3
A-Double	228.1	211.0	203.7	200.7	200.2	201.3	203.6	207.0	211.2	216.2
B Triple	268.0	246.9	237.6	233.3	231.8	232.1	233.7	236.5	240.1	244.6
A B Combination	258.3	240.3	232.6	229.3	228.7	229.7	232.0	235.3	239.6	244.6
A-Triple	292.7	272.6	263.9	260.1	259.0	259.7	261.8	265.0	269.1	274.1
Double B-Double	294.3	274.9	266.5	263.0	262.1	263.0	265.2	268.6	272.9	278.0

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	**0%-2% (Flat)**	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	**Straight (0-99°/km)**	**Curvy (100-299°/km)**	**Very Curvy (300°+/km)**	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	**5-6 (Fair)**	7-8 (Poor)
Roughness (NRM)	0-49	50-99	**100-149**	150-199

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 0%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.7	24.9	23.6	23.1	22.9	22.9	23.2	23.5	24.1	24.7
Medium Car	38.2	33.8	31.8	30.7	30.2	30.1	30.1	30.4	30.8	31.3
Large Car	50.8	44.7	41.8	40.3	39.4	39.0	38.9	38.9	39.2	39.6
Courier Van-Utility	42.4	38.6	36.9	36.1	35.8	35.8	36.1	36.6	37.3	38.1
4WD Mid Size Petrol	45.0	41.2	39.6	38.8	38.6	38.7	39.0	39.5	40.2	41.1
Light Rigid	57.4	53.8	52.5	52.2	52.6	53.3	54.5	55.9	57.7	59.7
Medium Rigid	72.5	65.8	63.0	61.9	61.8	62.3	63.4	64.9	66.7	68.9
Heavy Rigid	98.8	88.5	84.5	83.3	83.8	85.4	87.9	91.2	95.2	99.8
Heavy Bus	149.9	135.1	128.4	125.0	123.5	123.1	123.6	124.7	126.4	128.5
Artic 4 Axle	132.8	121.2	116.9	115.8	116.8	119.2	122.7	127.2	132.6	138.8
Artic 5 Axle	145.4	132.9	128.0	126.5	127.0	129.0	132.0	136.0	140.8	146.4
Artic 6 Axle	157.3	144.1	138.9	137.2	137.6	139.4	142.4	146.3	151.1	156.6
Rigid + 5 Axle Dog	164.2	152.1	147.6	146.5	147.5	150.0	153.6	158.3	163.8	170.2
B-Double	186.9	172.4	166.6	164.8	165.2	167.2	170.4	174.7	179.9	185.9
Twin steer + 5 Axle	183.4	169.5	164.1	162.5	163.1	165.3	168.7	173.2	178.5	184.8
A-Double	228.2	211.0	204.0	201.4	201.4	203.2	206.3	210.6	215.9	222.1
B Triple	268.1	247.0	237.9	234.0	233.0	234.0	236.4	240.0	244.6	250.1
A B Combination	258.5	240.3	232.8	230.2	230.2	232.1	235.5	240.2	245.8	252.5
A-Triple	292.8	272.7	264.3	261.1	260.8	262.5	265.8	270.4	276.1	282.8
Double B-Double	294.5	275.0	266.9	264.0	264.0	266.0	269.5	274.4	280.3	287.3

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 0%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.7	24.9	23.7	23.2	23.0	23.0	23.3	23.6	24.1	24.7
Medium Car	38.1	33.9	31.9	30.9	30.4	30.2	30.3	30.5	30.8	31.3
Large Car	50.7	44.8	42.0	40.5	39.6	39.2	39.0	39.1	39.3	39.6
Courier Van-Utility	42.5	38.6	37.0	36.3	36.1	36.3	36.7	37.4	38.2	39.3
4WD Mid Size Petrol	45.0	41.3	39.7	39.1	38.9	39.2	39.7	40.5	41.4	42.5
Light Rigid	57.4	53.9	52.6	52.4	52.9	53.8	55.2	56.8	58.8	61.0
Medium Rigid	72.8	65.9	63.3	62.8	63.6	65.2	67.5	70.4	73.8	77.8
Heavy Rigid	99.2	88.7	85.2	85.0	86.8	90.2	94.8	100.5	107.1	114.8
Heavy Bus	150.1	135.2	129.0	126.5	126.2	127.4	129.7	132.9	136.9	141.7
Artic 4 Axle	133.3	121.6	118.2	118.9	122.1	127.3	134.1	142.4	152.1	163.0
Artic 5 Axle	145.6	133.2	129.1	128.8	131.0	134.8	140.2	146.7	154.5	163.4
Artic 6 Axle	157.6	144.5	140.0	139.6	141.7	145.6	151.0	157.7	165.6	174.6
Rigid + 5 Axle Dog	164.7	152.4	149.1	150.0	153.6	159.4	166.9	176.0	186.5	198.5
B-Double	187.4	172.7	168.2	168.3	171.4	176.8	184.0	192.8	203.1	214.9
Twin steer + 5 Axle	183.9	169.9	165.7	166.2	169.7	175.4	183.0	192.3	203.1	215.3
A-Double	228.9	211.4	205.9	206.0	209.7	216.0	224.5	234.9	247.1	261.0
B Triple	268.7	247.4	239.9	238.8	241.5	247.0	254.9	264.7	276.3	289.6
A B Combination	259.5	240.6	235.1	235.9	240.7	248.6	259.0	271.7	286.4	303.2
A-Triple	294.0	273.1	266.9	267.8	273.2	281.9	293.5	307.5	324.0	342.6
Double B-Double	295.7	275.4	269.6	271.0	276.8	286.0	298.2	312.9	330.0	349.4

Table 33 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 4%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	28.0	25.1	23.9	23.3	23.1	23.1	23.3	23.7	24.2	24.8
Medium Car	38.6	34.1	32.1	31.0	30.5	30.3	30.4	30.6	31.0	31.5
Large Car	51.3	45.1	42.2	40.6	39.7	39.3	39.2	39.2	39.5	39.9
Courier Van-Utility	43.9	39.9	38.1	37.1	36.7	36.6	36.7	36.9	37.3	37.9
4WD Mid Size Petrol	45.8	42.0	40.3	39.5	39.2	39.2	39.4	39.8	40.4	41.1
Light Rigid	60.7	56.6	54.9	54.4	54.5	55.0	55.9	57.0	58.4	60.1
Medium Rigid	79.7	72.7	69.5	67.9	67.1	67.0	67.2	67.8	68.6	69.6
Heavy Rigid	122.0	111.5	106.5	103.9	102.6	101.9	101.9	102.2	102.8	103.8
Heavy Bus	167.9	154.3	147.3	142.8	139.6	137.0	134.7	132.7	130.8	128.9
Artic 4 Axle	167.4	153.5	147.5	144.8	144.0	144.4	145.7	147.8	150.4	153.7
Artic 5 Axle	185.9	171.6	165.2	162.2	161.0	161.0	161.9	163.4	165.6	168.2
Artic 6 Axle	200.6	185.9	179.3	175.9	174.4	174.1	174.6	175.7	177.4	179.5
Rigid + 5 Axle Dog	225.4	211.8	205.7	202.7	201.5	201.4	202.0	203.4	205.2	207.5
B-Double	251.4	235.7	228.4	224.4	222.2	221.2	220.9	221.2	221.9	223.1
Twin steer + 5 Axle	250.0	234.8	227.8	224.2	222.5	222.0	222.3	223.2	224.7	226.7
A-Double	313.1	294.9	285.9	280.4	276.8	274.2	272.2	270.7	269.5	268.5
B Triple	357.1	335.3	324.0	316.9	311.7	307.6	304.1	300.9	297.9	295.1
A B Combination	365.1	345.2	334.9	328.5	323.9	320.3	317.3	314.6	312.1	309.7
A-Triple	418.7	395.9	384.1	376.5	371.1	366.7	362.9	359.4	356.1	353.0
Double B-Double	424.8	402.3	390.8	383.6	378.5	374.5	371.1	368.2	365.4	362.9

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 4%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	28.0	25.1	23.9	23.3	23.1	23.1	23.4	23.7	24.2	24.8
Medium Car	38.6	34.2	32.1	31.1	30.6	30.4	30.4	30.6	31.0	31.5
Large Car	51.2	45.2	42.3	40.7	39.8	39.4	39.2	39.2	39.5	39.8
Courier Van-Utility	43.9	39.9	38.1	37.2	36.8	36.6	36.7	37.0	37.3	37.8
4WD Mid Size Petrol	45.8	42.0	40.3	39.6	39.3	39.3	39.5	40.0	40.5	41.3
Light Rigid	60.6	56.7	55.0	54.5	54.5	54.9	55.6	56.7	57.9	59.4
Medium Rigid	79.6	72.8	69.6	68.1	67.3	67.1	67.2	67.7	68.4	69.2
Heavy Rigid	121.9	111.5	106.6	104.0	102.7	102.0	101.9	102.2	102.8	103.7
Heavy Bus	167.9	154.3	147.3	142.8	139.6	137.1	134.9	133.0	131.2	129.4
Artic 4 Axle	166.9	153.8	147.9	145.1	143.9	143.8	144.5	145.8	147.6	149.8
Artic 5 Axle	185.3	171.9	165.7	162.6	161.2	160.8	161.1	162.0	163.4	165.2
Artic 6 Axle	200.0	186.2	179.8	176.4	174.7	174.0	174.0	174.6	175.5	176.9
Rigid + 5 Axle Dog	225.1	211.9	206.0	203.2	202.1	202.0	202.7	204.1	206.0	208.3
B-Double	251.1	235.8	228.6	224.9	223.0	222.3	222.4	223.0	224.2	225.8
Twin steer + 5 Axle	249.7	234.9	228.1	224.8	223.2	222.9	223.4	224.5	226.2	228.3
A-Double	312.8	295.0	286.2	281.2	278.0	275.9	274.5	273.6	273.0	272.8
B Triple	356.7	335.4	324.4	317.6	312.7	309.0	305.8	303.1	300.6	298.2
A B Combination	364.7	345.4	335.5	329.3	324.9	321.5	318.7	316.2	313.9	311.8
A-Triple	418.3	396.3	384.8	377.4	372.0	367.6	363.8	360.3	356.9	353.6
Double B-Double	424.4	402.7	391.6	384.6	379.7	375.8	372.5	369.7	367.0	364.5

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 4%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	27.9	25.2	24.0	23.4	23.2	23.3	23.5	23.8	24.3	24.8
Medium Car	38.5	34.2	32.3	31.2	30.7	30.5	30.5	30.7	31.0	31.4
Large Car	51.1	45.3	42.5	40.9	40.0	39.5	39.3	39.3	39.5	39.7
Courier Van-Utility	43.9	40.0	38.2	37.4	37.0	36.9	37.1	37.4	37.9	38.6
4WD Mid Size Petrol	45.8	42.0	40.4	39.8	39.6	39.7	40.2	40.8	41.6	42.5
Light Rigid	60.5	56.8	55.2	54.7	54.7	55.1	55.7	56.7	57.8	59.2
Medium Rigid	79.4	73.0	70.1	68.6	68.0	67.9	68.1	68.7	69.5	70.5
Heavy Rigid	121.6	111.8	107.2	104.8	103.5	102.9	102.9	103.2	103.8	104.7
Heavy Bus	167.9	154.4	147.6	143.4	140.6	138.5	136.8	135.5	134.3	133.3
Artic 4 Axle	166.5	154.2	148.7	146.0	144.9	144.7	145.3	146.5	148.1	150.2
Artic 5 Axle	184.8	172.4	166.6	163.6	162.0	161.3	161.3	161.7	162.5	163.7
Artic 6 Axle	199.5	186.7	180.7	177.5	175.7	174.9	174.6	174.9	175.5	176.4
Rigid + 5 Axle Dog	224.8	212.2	206.8	204.5	203.9	204.5	206.0	208.2	211.0	214.4
B-Double	250.8	236.0	229.4	226.2	225.0	225.0	225.8	227.4	229.6	232.3
Twin steer + 5 Axle	249.4	235.2	229.0	226.1	225.1	225.4	226.6	228.5	231.0	234.1
A-Double	312.6	295.3	287.1	282.8	280.6	279.6	279.5	280.0	281.1	282.7
B Triple	356.4	335.7	325.4	319.2	315.1	312.2	310.1	308.5	307.2	306.2
A B Combination	364.4	345.9	336.6	330.9	327.1	324.3	322.2	320.5	319.0	317.8
A-Triple	418.0	397.0	386.1	379.1	374.0	369.8	366.3	363.0	359.9	356.8
Double B-Double	424.1	403.4	392.9	386.3	381.7	378.2	375.3	372.8	370.6	368.5

Table 34 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 6%
Curvature = Straight (20 degree/km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	28.4	25.6	24.3	23.7	23.4	23.5	23.6	24.0	24.4	25.0
Medium Car	39.2	34.8	32.7	31.6	31.0	30.8	30.8	30.9	31.3	31.7
Large Car	51.8	45.7	42.8	41.2	40.3	39.9	39.7	39.7	39.9	40.2
Courier Van-Utility	45.6	41.9	40.2	39.1	38.5	38.1	37.9	37.7	37.7	37.7
4WD Mid Size Petrol	47.5	43.6	41.8	40.9	40.4	40.3	40.3	40.5	40.9	41.4
Light Rigid	64.5	60.4	58.7	57.9	57.6	57.8	58.2	58.8	59.6	60.6
Medium Rigid	87.0	79.8	76.6	74.9	74.1	73.8	74.0	74.4	75.1	76.0
Heavy Rigid	142.1	131.4	126.2	123.2	121.3	120.1	119.3	118.8	118.6	118.5
Heavy Bus	183.2	170.1	162.9	158.0	153.9	150.3	146.8	143.4	139.8	136.1
Artic 4 Axle	196.8	182.7	175.9	172.0	169.6	168.2	167.3	166.9	166.8	167.0
Artic 5 Axle	219.9	205.5	198.6	194.9	192.7	191.6	191.2	191.3	191.7	192.5
Artic 6 Axle	238.0	223.1	215.9	212.0	209.7	208.4	207.8	207.7	208.0	208.7
Rigid + 5 Axle Dog	275.9	261.4	254.5	250.9	248.9	248.0	247.9	248.3	249.1	250.3
B-Double	305.3	288.5	280.4	275.7	272.8	271.0	269.9	269.3	269.1	269.2
Twin steer + 5 Axle	305.8	289.6	281.9	277.7	275.4	274.2	273.7	273.9	274.5	275.5
A-Double	382.4	361.9	351.6	345.3	341.0	337.8	335.2	333.2	331.4	329.8
B Triple	429.4	404.7	391.8	383.5	377.3	372.3	367.9	363.8	359.8	355.9
A B Combination	450.1	426.6	415.9	410.7	408.4	408.0	408.9	411.0	413.9	417.6
A-Triple	518.0	491.6	480.9	477.1	477.3	480.3	485.4	492.3	500.8	510.7
Double B-Double	527.9	502.2	492.3	489.5	491.0	495.5	502.3	511.2	521.8	534.2

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 6%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	28.4	25.6	24.3	23.7	23.5	23.5	23.7	24.0	24.4	24.9
Medium Car	39.2	34.8	32.7	31.6	31.1	30.8	30.8	30.9	31.2	31.6
Large Car	51.8	45.8	42.9	41.3	40.4	39.9	39.7	39.7	39.8	40.1
Courier Van-Utility	45.6	42.0	40.2	39.2	38.5	38.1	37.9	37.7	37.6	37.6
4WD Mid Size Petrol	47.4	43.6	41.8	40.9	40.5	40.3	40.4	40.6	40.9	41.4
Light Rigid	64.5	60.5	58.8	58.0	57.7	57.7	58.0	58.4	59.1	59.9
Medium Rigid	86.8	79.9	76.7	75.0	74.2	73.8	73.9	74.2	74.7	75.4
Heavy Rigid	142.1	131.4	126.3	123.3	121.5	120.4	119.8	119.5	119.4	119.5
Heavy Bus	183.2	170.1	162.9	157.9	153.8	150.2	146.7	143.2	139.7	136.0
Artic 4 Axle	196.4	182.9	176.5	172.9	170.8	169.6	169.1	168.9	169.2	169.7
Artic 5 Axle	219.6	205.5	199.0	195.7	194.0	193.4	193.5	194.2	195.4	197.0
Artic 6 Axle	237.7	223.1	216.3	212.8	211.0	210.3	210.4	211.1	212.2	213.8
Rigid + 5 Axle Dog	275.6	261.6	255.2	252.0	250.5	250.1	250.5	251.5	253.0	254.9
B-Double	304.9	288.7	281.0	276.8	274.3	273.0	272.4	272.3	272.7	273.4
Twin steer + 5 Axle	305.5	289.8	282.6	278.8	277.0	276.3	276.5	277.4	278.7	280.5
A-Double	382.0	362.4	352.6	346.7	342.8	340.0	337.8	336.2	334.8	333.7
B Triple	429.0	405.3	392.9	384.9	379.0	374.1	369.9	365.9	362.1	358.3
A B Combination	449.9	427.4	417.5	413.1	411.7	412.2	414.3	417.5	421.7	426.8
A-Triple	518.0	492.9	483.3	480.7	482.2	486.8	493.6	502.4	513.1	525.3
Double B-Double	527.9	503.5	494.8	493.5	496.5	502.8	511.7	522.9	536.1	551.3

IRI = 5, NRM = 131 (Road Surface Condition: Fair)
Gradient = 6%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	28.4	25.6	24.4	23.8	23.6	23.6	23.7	24.0	24.4	24.9
Medium Car	39.1	34.8	32.8	31.8	31.2	31.0	30.9	31.0	31.3	31.6
Large Car	51.7	45.8	43.0	41.5	40.6	40.1	39.9	39.8	39.9	40.2
Courier Van-Utility	45.5	42.0	40.3	39.3	38.7	38.3	38.0	37.9	37.8	37.8
4WD Mid Size Petrol	47.4	43.6	41.9	41.1	40.7	40.7	40.8	41.2	41.6	42.3
Light Rigid	64.3	60.6	59.0	58.1	57.8	57.7	57.9	58.2	58.7	59.3
Medium Rigid	86.6	80.1	77.1	75.5	74.6	74.2	74.2	74.4	74.8	75.4
Heavy Rigid	142.0	131.5	126.6	124.0	122.6	122.0	121.9	122.2	122.8	123.7
Heavy Bus	183.2	170.2	163.1	158.3	154.5	151.1	148.0	144.8	141.7	138.5
Artic 4 Axle	196.1	183.4	177.4	174.3	172.7	172.0	172.0	172.5	173.4	174.7
Artic 5 Axle	219.3	205.9	199.9	197.1	196.0	196.1	197.0	198.6	200.7	203.4
Artic 6 Axle	237.5	223.4	217.2	214.2	213.1	213.2	214.2	215.9	218.1	220.9
Rigid + 5 Axle Dog	275.3	262.0	256.3	253.7	253.1	253.6	255.1	257.2	260.1	263.5
B-Double	304.6	289.2	282.1	278.6	276.9	276.4	276.8	277.8	279.4	281.4
Twin steer + 5 Axle	305.2	290.3	283.7	280.7	279.7	280.1	281.4	283.5	286.2	289.5
A-Double	381.7	363.2	354.0	348.6	345.2	342.8	341.2	340.1	339.3	338.9
B Triple	428.6	406.1	394.3	386.7	381.0	376.3	372.1	368.2	364.5	360.7
A B Combination	449.8	428.5	419.7	416.2	415.9	417.6	421.0	425.7	431.6	438.5
A-Triple	518.1	494.5	486.2	485.1	488.4	494.8	503.8	515.1	528.5	543.7
Double B-Double	528.0	505.1	498.0	498.4	503.5	512.1	523.6	537.7	554.2	572.9

Table 35 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 5, NRM = 131 (Road Surface Condition: Fair)										
Gradient = 8%										
Curvature = Straight (20 degree/km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	29.3	26.5	25.2	24.5	24.2	24.1	24.2	24.4	24.7	25.1
Medium Car	40.4	36.0	33.9	32.7	32.1	31.7	31.5	31.5	31.6	31.8
Large Car	53.2	47.1	44.1	42.5	41.5	40.9	40.5	40.4	40.4	40.5
Courier Van-Utility	47.5	44.1	42.4	41.3	40.6	40.0	39.5	39.1	38.7	38.3
4WD Mid Size Petrol	49.5	45.9	44.1	43.1	42.5	42.1	41.9	41.7	41.7	41.7
Light Rigid	69.0	65.0	63.1	62.1	61.6	61.3	61.3	61.5	61.8	62.2
Medium Rigid	94.7	87.7	84.4	82.6	81.6	81.1	80.9	81.0	81.2	81.6
Heavy Rigid	165.1	153.7	148.0	144.5	142.2	140.6	139.4	138.4	137.6	137.0
Heavy Bus	200.4	187.4	179.8	174.0	168.9	164.0	158.9	153.7	148.2	142.3
Artic 4 Axle	230.4	214.6	206.8	202.3	199.4	197.6	196.3	195.5	195.1	194.9
Artic 5 Axle	258.0	242.3	234.7	230.4	227.8	226.3	225.5	225.1	225.2	225.5
Artic 6 Axle	280.1	263.9	256.0	251.5	248.7	247.0	246.0	245.4	245.3	245.4
Rigid + 5 Axle Dog	333.1	316.6	309.1	305.4	303.8	303.5	304.2	305.7	307.8	310.4
B-Double	366.0	347.0	338.0	333.3	330.7	329.5	329.2	329.6	330.6	332.1
Twin steer + 5 Axle	369.2	350.8	342.3	338.0	335.9	335.2	335.6	336.7	338.5	340.8
A-Double	460.6	437.1	427.1	422.9	422.1	423.5	426.6	431.1	436.8	443.5
B Triple	510.4	482.5	470.3	464.9	463.3	464.2	466.9	471.2	476.7	483.4
A B Combination	545.6	521.5	514.8	516.6	523.9	535.2	550.1	568.1	589.0	612.6
A-Triple	631.2	606.6	603.7	611.9	627.9	650.0	677.6	710.1	747.5	789.4
Double B-Double	645.7	622.3	620.7	630.7	648.6	673.1	703.3	738.9	779.7	825.3

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 5, NRM = 131 (Road Surface Condition: Fair)											IRI = 5, NRM = 131 (Road Surface Condition: Fair)									
Gradient = 8%											**Gradient = 8%**									
Curvature =Curvy / Hilly / Winding (120 degree /km)											**Curvature =Very Curvy or Very Winding (300-320 degree /km)**									
Vehicle Class	**Speed (km/hr)**										**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	29.3	26.5	25.2	24.6	24.2	24.1	24.2	24.3	24.6	24.9	29.3	26.6	25.3	24.7	24.3	24.2	24.2	24.3	24.5	24.7
Medium Car	40.3	36.0	33.9	32.8	32.1	31.7	31.5	31.4	31.5	31.6	40.3	36.1	34.1	32.9	32.2	31.8	31.5	31.4	31.3	31.4
Large Car	53.2	47.1	44.2	42.5	41.5	40.9	40.5	40.3	40.3	40.4	53.1	47.2	44.4	42.7	41.7	41.0	40.5	40.3	40.1	40.1
Courier Van-Utility	47.5	44.2	42.4	41.3	40.6	40.0	39.5	39.1	38.7	38.3	47.5	44.2	42.5	41.4	40.7	40.1	39.7	39.3	39.0	38.7
4WD Mid Size Petrol	49.5	45.9	44.1	43.1	42.5	42.1	41.9	41.7	41.7	41.7	49.5	45.9	44.2	43.3	42.7	42.3	42.2	42.1	42.1	42.2
Light Rigid	68.9	65.0	63.2	62.2	61.6	61.3	61.2	61.2	61.3	61.5	68.8	65.1	63.3	62.3	61.7	61.3	61.0	60.9	60.9	60.9
Medium Rigid	94.6	87.8	84.6	82.7	81.7	81.1	80.8	80.7	80.8	81.0	94.4	87.9	84.8	83.0	82.0	81.3	80.9	80.7	80.6	80.7
Heavy Rigid	165.0	153.7	148.1	144.8	142.6	141.1	140.0	139.2	138.6	138.1	164.9	153.9	148.6	145.7	144.0	143.0	142.5	142.4	142.5	142.9
Heavy Bus	200.4	187.4	179.7	174.0	168.8	163.9	158.9	153.6	148.1	142.2	200.3	187.4	179.9	174.2	169.2	164.4	159.6	154.5	149.1	143.4
Artic 4 Axle	230.0	215.2	208.0	203.7	201.0	199.1	197.8	196.9	196.3	196.0	229.8	216.2	209.5	205.6	203.1	201.5	200.4	199.7	199.2	199.0
Artic 5 Axle	257.6	242.7	235.6	231.7	229.5	228.3	227.8	227.8	228.2	229.0	257.3	243.3	236.8	233.5	231.8	231.2	231.4	232.1	233.3	234.9
Artic 6 Axle	279.6	264.2	256.8	252.7	250.4	249.2	248.6	248.6	249.1	249.8	279.3	264.7	258.0	254.6	253.0	252.4	252.7	253.6	255.0	256.9
Rigid + 5 Axle Dog	332.8	317.2	310.4	307.3	306.4	306.8	308.3	310.6	313.6	317.2	332.7	318.1	312.1	309.8	309.8	311.2	313.8	317.3	321.7	326.8
B-Double	365.7	347.7	339.4	335.2	333.2	332.6	333.0	334.2	336.0	338.4	365.4	348.6	341.1	337.7	336.5	336.7	338.0	340.2	343.1	346.7
Twin steer + 5 Axle	368.8	351.4	343.6	339.9	338.5	338.5	339.6	341.5	344.1	347.4	368.6	352.4	345.4	342.6	342.0	343.0	345.1	348.3	352.2	356.9
A-Double	460.3	438.2	429.3	426.2	426.6	429.3	433.8	439.9	447.4	456.1	460.4	439.7	432.0	430.2	431.9	436.1	442.4	450.3	459.9	470.8
B Triple	510.3	483.8	472.9	468.7	468.4	470.8	475.2	481.2	488.8	497.7	510.4	485.5	475.9	473.1	474.3	478.3	484.5	492.7	502.5	514.0
A B Combination	545.7	523.4	518.6	522.4	532.0	546.0	563.9	585.3	609.9	637.8	546.2	525.9	523.3	529.6	542.1	559.6	581.4	607.2	636.8	670.0
A-Triple	631.9	609.7	609.2	620.2	639.5	665.3	697.2	734.6	777.3	825.1	632.8	613.2	615.8	630.5	654.0	684.9	722.5	766.4	816.3	872.1
Double B-Double	646.4	625.4	626.4	639.3	660.7	689.2	724.0	764.7	811.1	863.0	647.4	629.2	633.5	650.2	676.2	710.0	750.9	798.5	852.6	913.0

Table 36 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 0%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	29.3	26.5	25.2	24.6	24.4	24.5	24.8	25.2	25.7	26.3
Medium Car	40.3	35.9	33.8	32.8	32.3	32.1	32.2	32.5	32.9	33.5
Large Car	53.4	47.2	44.3	42.7	41.9	41.5	41.4	41.5	41.8	42.3
Courier Van-Utility	46.7	42.8	41.1	40.3	40.0	40.0	40.2	40.7	41.3	42.1
4WD Mid Size Petrol	49.0	45.3	43.6	42.8	42.6	42.6	42.9	43.4	44.1	44.9
Light Rigid	63.3	59.6	58.3	58.0	58.3	59.1	60.3	61.8	63.5	65.5
Medium Rigid	78.5	71.9	69.1	67.9	67.6	68.0	68.8	70.1	71.7	73.5
Heavy Rigid	109.6	99.5	95.5	94.1	94.3	95.6	97.7	100.5	104.0	108.0
Heavy Bus	165.5	151.0	144.2	140.7	138.9	138.2	138.3	139.0	140.2	141.8
Artic 4 Axle	148.5	136.8	132.3	131.0	131.7	133.8	136.9	141.0	145.9	151.6
Artic 5 Axle	162.5	149.8	144.7	143.1	143.5	145.2	148.1	151.8	156.4	161.7
Artic 6 Axle	176.0	162.6	157.2	155.3	155.6	157.2	160.0	163.7	168.3	173.6
Rigid + 5 Axle Dog	182.3	170.2	165.5	164.2	164.8	166.8	169.9	173.9	178.7	184.4
B-Double	209.4	194.9	189.0	186.8	186.8	188.4	191.1	194.7	199.2	204.5
Twin steer + 5 Axle	204.6	190.7	185.1	183.2	183.4	185.1	187.9	191.6	196.2	201.6
A-Double	256.8	239.6	232.4	229.4	228.9	230.0	232.3	235.6	239.9	244.9
B Triple	302.8	281.7	272.4	268.1	266.6	266.9	268.6	271.3	274.9	279.4
A B Combination	290.9	272.8	265.1	261.9	261.2	262.2	264.5	267.9	272.1	277.2
A-Triple	329.8	309.7	301.0	297.2	296.1	296.8	298.9	302.1	306.2	311.2
Double B-Double	331.4	312.0	303.6	300.1	299.2	300.1	302.3	305.7	310.0	315.1

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 0%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	29.3	26.5	25.3	24.7	24.5	24.5	24.8	25.2	25.7	26.3
Medium Car	40.3	35.9	33.9	32.8	32.3	32.2	32.2	32.5	32.9	33.4
Large Car	53.4	47.3	44.4	42.8	42.0	41.6	41.4	41.5	41.8	42.2
Courier Van-Utility	46.7	42.8	41.1	40.3	40.0	40.1	40.4	40.8	41.5	42.3
4WD Mid Size Petrol	49.0	45.3	43.6	42.9	42.6	42.7	43.0	43.6	44.3	45.1
Light Rigid	63.2	59.6	58.3	58.0	58.4	59.2	60.3	61.8	63.5	65.5
Medium Rigid	78.6	71.9	69.1	68.0	67.9	68.4	69.5	71.0	72.8	75.0
Heavy Rigid	109.8	99.5	95.5	94.2	94.7	96.3	98.8	102.1	106.1	110.7
Heavy Bus	165.7	150.9	144.2	140.8	139.3	138.9	139.4	140.5	142.2	144.3
Artic 4 Axle	148.5	136.8	132.5	131.5	132.5	134.9	138.4	142.9	148.3	154.5
Artic 5 Axle	162.4	149.9	145.0	143.5	144.1	146.0	149.0	153.0	157.8	163.4
Artic 6 Axle	176.0	162.8	157.5	155.8	156.2	158.0	161.0	164.9	169.7	175.3
Rigid + 5 Axle Dog	182.3	170.2	165.7	164.7	165.7	168.1	171.7	176.4	181.9	188.3
B-Double	209.5	195.0	189.2	187.4	187.8	189.8	193.0	197.3	202.5	208.5
Twin steer + 5 Axle	204.6	190.8	185.4	183.8	184.4	186.6	190.0	194.4	199.8	206.0
A-Double	256.9	239.7	232.6	230.0	230.0	231.8	234.9	239.2	244.5	250.7
B Triple	302.9	281.8	272.7	268.8	267.8	268.8	271.2	274.8	279.4	284.9
A B Combination	291.0	272.8	265.3	262.6	262.7	264.6	268.0	272.6	278.3	285.0
A-Triple	329.9	309.7	301.3	298.1	297.8	299.6	302.8	307.4	313.1	319.8
Double B-Double	331.5	311.9	303.9	301.0	301.0	303.0	306.5	311.3	317.3	324.3

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 0%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	29.3	26.5	25.3	24.8	24.6	24.7	24.9	25.2	25.7	26.3
Medium Car	40.2	36.0	34.0	33.0	32.5	32.3	32.4	32.6	32.9	33.4
Large Car	53.2	47.4	44.6	43.1	42.2	41.8	41.6	41.6	41.8	42.2
Courier Van-Utility	46.7	42.9	41.2	40.5	40.3	40.5	41.0	41.6	42.5	43.5
4WD Mid Size Petrol	49.0	45.3	43.7	43.1	43.0	43.2	43.7	44.5	45.4	46.6
Light Rigid	63.2	59.7	58.4	58.3	58.7	59.7	61.0	62.6	64.6	66.8
Medium Rigid	78.9	71.9	69.4	68.9	69.6	71.2	73.5	76.4	79.9	83.9
Heavy Rigid	110.1	99.6	96.1	95.9	97.7	101.1	105.7	111.4	118.1	125.7
Heavy Bus	165.9	151.0	144.8	142.3	142.0	143.2	145.5	148.7	152.7	157.5
Artic 4 Axle	148.9	137.2	133.9	134.5	137.8	143.0	149.8	158.1	167.7	178.7
Artic 5 Axle	162.7	150.3	146.1	145.9	148.0	151.9	157.2	163.8	171.5	180.4
Artic 6 Axle	176.2	163.1	158.7	158.3	160.3	164.3	169.6	176.3	184.2	193.3
Rigid + 5 Axle Dog	182.8	170.6	167.2	168.1	171.7	177.5	185.0	194.1	204.6	216.6
B-Double	210.0	195.3	190.7	190.9	194.0	199.4	206.6	215.4	225.7	237.5
Twin steer + 5 Axle	205.2	191.1	187.0	187.5	191.0	196.7	204.3	213.5	224.3	236.6
A-Double	257.5	240.0	234.5	234.6	238.3	244.6	253.1	263.5	275.7	289.7
B Triple	303.5	282.2	274.7	273.6	276.3	281.8	289.7	299.5	311.1	324.4
A B Combination	291.9	273.0	267.5	268.3	273.1	281.0	291.4	304.1	318.9	335.6
A-Triple	331.0	310.0	303.9	304.8	310.1	318.9	330.4	344.5	360.9	379.5
Double B-Double	332.7	312.3	306.6	307.9	313.7	323.0	335.1	349.8	366.9	386.3

Table 37 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 7, NRM = 184 (Road Surface Condition: Poor)										
Gradient = 4%										
Curvature = Straight (20 degree/km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	29.6	26.7	25.5	24.9	24.7	24.7	24.9	25.3	25.8	26.4
Medium Car	40.7	36.2	34.2	33.1	32.6	32.4	32.5	32.7	33.1	33.6
Large Car	53.9	47.7	44.8	43.2	42.3	41.9	41.7	41.8	42.1	42.5
Courier Van-Utility	48.1	44.1	42.3	41.4	40.9	40.8	40.9	41.1	41.5	42.1
4WD Mid Size Petrol	49.8	46.0	44.3	43.5	43.2	43.2	43.4	43.8	44.4	45.1
Light Rigid	66.5	62.4	60.7	60.2	60.2	60.8	61.6	62.8	64.2	65.9
Medium Rigid	85.8	78.7	75.5	73.9	73.2	73.0	73.2	73.8	74.6	75.7
Heavy Rigid	132.9	122.4	117.5	114.8	113.5	112.9	112.8	113.1	113.7	114.7
Heavy Bus	183.7	170.1	163.1	158.6	155.3	152.7	150.5	148.5	146.5	144.7
Artic 4 Axle	183.3	169.5	163.4	160.7	159.9	160.3	161.6	163.7	166.4	169.6
Artic 5 Axle	203.2	188.9	182.6	179.5	178.3	178.3	179.2	180.8	182.9	185.6
Artic 6 Axle	219.5	204.8	198.2	194.8	193.3	193.0	193.5	194.6	196.3	198.4
Rigid + 5 Axle Dog	243.7	230.1	223.9	221.0	219.7	219.6	220.3	221.6	223.4	225.8
B-Double	274.1	258.5	251.1	247.2	245.0	243.9	243.7	244.0	244.7	245.9
Twin steer + 5 Axle	271.5	256.3	249.3	245.7	244.0	243.5	243.8	244.7	246.2	248.2
A-Double	341.8	323.6	314.6	309.1	305.5	302.9	300.9	299.4	298.2	297.2
B Triple	391.9	370.1	358.8	351.7	346.5	342.4	338.9	335.7	332.8	329.9
A B Combination	397.3	377.4	367.2	360.8	356.2	352.6	349.5	346.8	344.3	342.0
A-Triple	455.4	432.6	420.8	413.3	407.8	403.4	399.6	396.1	392.9	389.7
Double B-Double	461.4	439.0	427.5	420.3	415.1	411.1	407.8	404.8	402.1	399.5

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 7, NRM = 184 (Road Surface Condition: Poor)										
Gradient = 4%										
Curvature =Curvy / Hilly / Winding (120 degree /km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	29.6	26.7	25.5	24.9	24.7	24.7	25.0	25.3	25.8	26.4
Medium Car	40.6	36.3	34.2	33.2	32.6	32.4	32.5	32.7	33.1	33.5
Large Car	53.8	47.7	44.8	43.2	42.4	41.9	41.7	41.8	42.0	42.4
Courier Van-Utility	48.1	44.1	42.3	41.4	41.0	40.8	40.9	41.2	41.6	42.1
4WD Mid Size Petrol	49.8	46.0	44.4	43.6	43.3	43.3	43.5	44.0	44.6	45.3
Light Rigid	66.4	62.4	60.8	60.2	60.3	60.7	61.4	62.4	63.7	65.2
Medium Rigid	85.6	78.8	75.7	74.1	73.3	73.1	73.2	73.7	74.4	75.3
Heavy Rigid	132.8	122.4	117.5	114.9	113.5	112.9	112.8	113.1	113.7	114.6
Heavy Bus	183.7	170.1	163.1	158.6	155.4	152.9	150.7	148.7	146.9	145.2
Artic 4 Axle	182.7	169.6	163.7	160.9	159.7	159.6	160.3	161.6	163.4	165.6
Artic 5 Axle	202.5	189.1	182.9	179.8	178.3	177.9	178.3	179.2	180.5	182.3
Artic 6 Axle	218.8	205.0	198.5	195.2	193.4	192.7	192.7	193.3	194.3	195.6
Rigid + 5 Axle Dog	243.2	230.0	224.1	221.3	220.2	220.1	220.8	222.2	224.1	226.4
B-Double	273.7	258.4	251.3	247.6	245.7	244.9	245.0	245.7	246.8	248.5
Twin steer + 5 Axle	271.0	256.2	249.5	246.1	244.6	244.2	244.7	245.9	247.5	249.7
A-Double	341.3	323.5	314.8	309.7	306.5	304.4	303.0	302.1	301.6	301.4
B Triple	391.4	370.0	359.1	352.3	347.4	343.6	340.5	337.8	335.2	332.9
A B Combination	396.8	377.5	367.6	361.4	357.0	353.6	350.8	348.3	346.1	343.9
A-Triple	454.8	432.8	421.4	414.0	408.6	404.2	400.4	396.8	393.5	390.2
Double B-Double	460.9	439.2	428.1	421.1	416.2	412.3	409.0	406.2	403.5	401.0

IRI = 7, NRM = 184 (Road Surface Condition: Poor)										
Gradient = 4%										
Curvature =Very Curvy or Very Winding (300-320 degree /km)										
Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	29.5	26.8	25.6	25.0	24.8	24.9	25.1	25.4	25.9	26.4
Medium Car	40.6	36.3	34.4	33.3	32.8	32.6	32.6	32.8	33.1	33.5
Large Car	53.7	47.8	45.0	43.5	42.6	42.1	41.9	41.9	42.0	42.3
Courier Van-Utility	48.1	44.2	42.4	41.6	41.2	41.1	41.3	41.7	42.1	42.8
4WD Mid Size Petrol	49.8	46.1	44.5	43.8	43.6	43.8	44.2	44.8	45.6	46.6
Light Rigid	66.3	62.5	61.0	60.4	60.4	60.8	61.5	62.5	63.6	65.0
Medium Rigid	85.4	79.0	76.0	74.6	74.0	73.9	74.1	74.7	75.5	76.4
Heavy Rigid	132.4	122.6	118.0	115.6	114.3	113.7	113.7	114.0	114.6	115.5
Heavy Bus	183.6	170.2	163.3	159.2	156.3	154.2	152.6	151.2	150.1	149.0
Artic 4 Axle	182.1	169.9	164.4	161.7	160.5	160.4	161.0	162.2	163.8	165.8
Artic 5 Axle	201.8	189.4	183.6	180.6	179.0	178.3	178.3	178.7	179.5	180.7
Artic 6 Axle	218.1	205.3	199.3	196.0	194.3	193.4	193.2	193.4	194.1	195.0
Rigid + 5 Axle Dog	242.8	230.2	224.7	222.4	221.9	222.5	224.0	226.2	229.0	232.4
B-Double	273.3	258.5	251.9	248.7	247.5	247.5	248.3	249.9	252.1	254.8
Twin steer + 5 Axle	270.6	256.4	250.2	247.3	246.3	246.6	247.8	249.7	252.2	255.3
A-Double	341.0	323.7	315.6	311.3	309.0	308.0	307.9	308.5	309.5	311.1
B Triple	391.0	370.2	359.9	353.7	349.7	346.8	344.6	343.0	341.8	340.7
A B Combination	396.4	377.9	368.6	362.9	359.1	356.3	354.2	352.5	351.0	349.8
A-Triple	454.4	433.4	422.5	415.5	410.4	406.3	402.7	399.4	396.3	393.3
Double B-Double	460.5	439.8	429.3	422.7	418.1	414.6	411.7	409.2	407.0	404.9

Table 38 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 6%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr) 20	30	40	50	60	70	80	90	100	110
Small Car	30.0	27.2	25.9	25.3	25.0	25.0	25.2	25.6	26.0	26.5
Medium Car	41.3	36.8	34.8	33.7	33.1	32.9	32.9	33.0	33.3	33.8
Large Car	54.4	48.3	45.4	43.8	42.9	42.4	42.2	42.3	42.4	42.8
Courier Van-Utility	49.8	46.2	44.4	43.4	42.7	42.4	42.1	42.0	41.9	41.9
4WD Mid Size Petrol	51.5	47.6	45.8	44.8	44.4	44.2	44.3	44.5	44.9	45.3
Light Rigid	70.4	66.3	64.5	63.7	63.5	63.6	64.0	64.6	65.5	66.4
Medium Rigid	93.0	85.9	82.6	81.0	80.2	79.9	80.0	80.5	81.1	82.0
Heavy Rigid	153.1	142.4	137.2	134.2	132.3	131.1	130.3	129.8	129.6	129.5
Heavy Bus	199.1	186.0	178.9	173.9	169.8	166.2	162.7	159.3	155.7	152.1
Artic 4 Axle	213.0	199.0	192.1	188.3	185.9	184.5	183.6	183.2	183.1	183.3
Artic 5 Axle	237.6	223.2	216.3	212.5	210.4	209.3	208.9	209.0	209.4	210.2
Artic 6 Axle	257.3	242.4	235.2	231.3	229.0	227.7	227.1	227.0	227.3	227.9
Rigid + 5 Axle Dog	294.6	280.1	273.2	269.6	267.6	266.7	266.6	267.0	267.8	269.0
B-Double	328.6	311.9	303.7	299.0	296.2	294.4	293.3	292.7	292.5	292.5
Twin steer + 5 Axle	328.0	311.7	304.0	299.8	297.5	296.3	295.9	296.0	296.7	297.7
A-Double	411.9	391.4	381.0	374.7	370.4	367.2	364.7	362.6	360.8	359.2
B Triple	465.0	440.3	427.4	419.1	412.9	407.9	403.4	399.3	395.4	391.5
A B Combination	483.3	459.8	449.1	443.9	441.6	441.2	442.1	444.2	447.1	450.8
A-Triple	555.9	529.5	518.8	515.0	515.2	518.1	523.3	530.2	538.7	548.6
Double B-Double	565.8	540.1	530.2	527.4	528.9	533.4	540.2	549.1	559.8	572.1

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 6%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr) 20	30	40	50	60	70	80	90	100	110
Small Car	30.0	27.2	25.9	25.3	25.1	25.1	25.2	25.6	26.0	26.5
Medium Car	41.2	36.9	34.8	33.7	33.1	32.9	32.9	33.0	33.3	33.7
Large Car	54.3	48.3	45.4	43.9	43.0	42.5	42.3	42.2	42.4	42.7
Courier Van-Utility	49.8	46.2	44.4	43.4	42.8	42.4	42.1	41.9	41.8	41.8
4WD Mid Size Petrol	51.4	47.6	45.8	44.9	44.4	44.3	44.4	44.6	44.9	45.4
Light Rigid	70.3	66.3	64.6	63.8	63.5	63.5	63.8	64.3	64.9	65.7
Medium Rigid	92.9	86.0	82.8	81.1	80.2	79.9	79.9	80.2	80.7	81.4
Heavy Rigid	153.1	142.4	137.2	134.3	132.5	131.4	130.8	130.4	130.4	130.5
Heavy Bus	199.1	186.0	178.8	173.8	169.7	166.1	162.6	159.1	155.6	151.9
Artic 4 Axle	212.5	199.0	192.6	189.0	186.9	185.7	185.2	185.0	185.3	185.8
Artic 5 Axle	237.1	223.1	216.6	213.2	211.5	210.9	211.0	211.7	212.9	214.5
Artic 6 Axle	256.8	242.2	235.4	231.9	230.1	229.4	229.5	230.2	231.3	232.9
Rigid + 5 Axle Dog	294.1	280.1	273.7	270.5	269.0	268.6	269.0	270.0	271.5	273.4
B-Double	328.0	311.9	304.2	299.9	297.5	296.1	295.5	295.5	295.8	296.6
Twin steer + 5 Axle	327.4	311.7	304.5	300.8	298.9	298.3	298.5	299.3	300.7	302.5
A-Double	411.3	391.7	381.9	376.0	372.0	369.2	367.1	365.4	364.1	363.0
B Triple	464.3	440.6	428.3	420.3	414.3	409.5	405.2	401.3	397.5	393.7
A B Combination	482.9	460.4	450.6	446.1	444.7	445.3	447.3	450.5	454.7	459.8
A-Triple	555.7	530.6	521.0	518.4	519.9	524.4	531.3	540.1	550.7	563.0
Double B-Double	565.6	541.2	532.6	531.2	534.3	540.6	549.5	560.6	573.9	589.0

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 6%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr) 20	30	40	50	60	70	80	90	100	110
Small Car	29.9	27.2	26.0	25.4	25.2	25.2	25.3	25.6	26.0	26.5
Medium Car	41.2	36.9	34.9	33.8	33.3	33.0	33.0	33.1	33.4	33.7
Large Car	54.2	48.4	45.6	44.0	43.1	42.6	42.4	42.4	42.5	42.7
Courier Van-Utility	49.8	46.2	44.5	43.5	42.9	42.5	42.3	42.1	42.1	42.0
4WD Mid Size Petrol	51.4	47.6	45.9	45.1	44.7	44.6	44.8	45.1	45.6	46.2
Light Rigid	70.1	66.4	64.8	63.9	63.6	63.5	63.7	64.0	64.5	65.1
Medium Rigid	92.6	86.1	83.1	81.5	80.6	80.2	80.2	80.4	80.8	81.4
Heavy Rigid	152.9	142.4	137.5	134.9	133.5	132.8	132.7	133.0	133.6	134.5
Heavy Bus	199.1	186.1	179.0	174.2	170.4	167.0	163.8	160.7	157.6	154.4
Artic 4 Axle	212.0	199.3	193.4	190.3	188.6	188.0	188.0	188.5	189.4	190.6
Artic 5 Axle	236.7	223.2	217.2	214.4	213.3	213.4	214.3	215.9	218.1	220.7
Artic 6 Axle	256.4	242.4	236.1	233.2	232.1	232.2	233.2	234.8	237.1	239.9
Rigid + 5 Axle Dog	293.7	280.3	274.6	272.1	271.4	271.9	273.4	275.6	278.4	281.8
B-Double	327.6	312.2	305.1	301.5	299.9	299.4	299.7	300.8	302.3	304.4
Twin steer + 5 Axle	327.0	312.0	305.5	302.5	301.5	301.8	303.1	305.2	308.0	311.3
A-Double	410.8	392.2	383.1	377.7	374.2	371.9	370.3	369.2	368.4	367.9
B Triple	463.9	441.4	429.6	421.9	416.2	411.5	407.3	403.5	399.7	396.0
A B Combination	482.7	461.4	452.5	449.1	448.7	450.5	453.9	458.6	464.4	471.4
A-Triple	555.6	532.0	523.7	522.6	525.9	532.3	541.3	552.6	566.0	581.2
Double B-Double	565.5	542.7	535.6	536.0	541.0	549.6	561.1	575.2	591.7	610.5

Table 39 Vehicle Operating Costs for Rural Roads (Cents/KM)

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 8%
Curvature = Straight (20 degree/km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	30.9	28.1	26.8	26.1	25.8	25.7	25.8	26.0	26.3	26.6
Medium Car	42.4	38.0	35.9	34.8	34.1	33.7	33.6	33.6	33.7	33.9
Large Car	55.8	49.6	46.7	45.0	44.0	43.4	43.1	42.9	42.9	43.1
Courier Van-Utility	51.8	48.4	46.6	45.6	44.8	44.2	43.7	43.3	42.9	42.6
4WD Mid Size Petrol	53.6	49.9	48.1	47.1	46.5	46.1	45.9	45.7	45.7	45.7
Light Rigid	74.9	70.9	69.0	68.0	67.5	67.2	67.2	67.4	67.7	68.1
Medium Rigid	100.8	93.8	90.5	88.7	87.7	87.2	87.0	87.0	87.3	87.7
Heavy Rigid	176.1	164.7	159.0	155.6	153.3	151.6	150.4	149.4	148.7	148.0
Heavy Bus	216.5	203.5	195.8	190.1	185.0	180.0	175.0	169.8	164.3	158.4
Artic 4 Axle	247.2	231.4	223.6	219.1	216.2	214.4	213.1	212.3	211.9	211.6
Artic 5 Axle	276.2	260.5	252.9	248.6	246.0	244.5	243.7	243.3	243.4	243.7
Artic 6 Axle	299.9	283.7	275.8	271.3	268.5	266.8	265.8	265.3	265.1	265.2
Rigid + 5 Axle Dog	352.5	336.0	328.4	324.8	323.2	322.9	323.6	325.0	327.1	329.8
B-Double	390.2	371.2	362.2	357.4	354.8	353.6	353.3	353.8	354.8	356.3
Twin steer + 5 Axle	392.2	373.8	365.3	361.0	358.9	358.3	358.6	359.8	361.5	363.8
A-Double	491.1	467.6	457.6	453.5	452.7	454.1	457.2	461.7	467.3	474.1
B Triple	547.2	519.2	507.0	501.6	500.0	500.9	503.7	507.9	513.5	520.2
A B Combination	580.2	556.0	549.4	551.2	558.5	569.8	584.7	602.7	623.6	647.2
A-Triple	670.7	646.1	643.1	651.4	667.4	689.5	717.0	749.6	786.9	828.9
Double B-Double	685.4	661.9	660.4	670.3	688.3	712.7	743.0	778.6	819.3	864.9

Use this page to look up VOC values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 8%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	30.9	28.1	26.8	26.1	25.8	25.7	25.8	25.9	26.2	26.5
Medium Car	42.4	38.1	36.0	34.8	34.2	33.8	33.6	33.5	33.6	33.7
Large Car	55.7	49.7	46.7	45.1	44.0	43.4	43.1	42.9	42.8	42.9
Courier Van-Utility	51.8	48.4	46.7	45.6	44.8	44.2	43.7	43.3	42.9	42.6
4WD Mid Size Petrol	53.5	49.9	48.1	47.1	46.5	46.1	45.9	45.7	45.7	45.7
Light Rigid	74.8	70.9	69.0	68.0	67.5	67.2	67.0	67.1	67.2	67.4
Medium Rigid	100.6	93.9	90.6	88.8	87.7	87.1	86.8	86.8	86.9	87.1
Heavy Rigid	176.0	164.7	159.1	155.8	153.6	152.1	151.0	150.2	149.6	149.1
Heavy Bus	216.4	203.4	195.8	190.0	184.9	180.0	174.9	169.7	164.1	158.2
Artic 4 Axle	246.5	231.8	224.5	220.2	217.5	215.6	214.4	213.5	212.9	212.5
Artic 5 Axle	275.5	260.6	253.5	249.6	247.4	246.2	245.7	245.8	246.2	247.0
Artic 6 Axle	299.2	283.7	276.3	272.3	270.0	268.7	268.2	268.2	268.6	269.4
Rigid + 5 Axle Dog	351.9	336.3	329.5	326.4	325.5	325.9	327.4	329.7	332.7	336.3
B-Double	389.6	371.6	363.3	359.1	357.1	356.5	356.9	358.1	359.9	362.3
Twin steer + 5 Axle	391.5	374.2	366.4	362.7	361.3	361.3	362.3	364.3	366.9	370.1
A-Double	490.6	468.5	459.6	456.5	456.9	459.6	464.1	470.2	477.6	486.3
B Triple	546.8	520.3	509.4	505.2	504.9	507.3	511.7	517.8	525.3	534.3
A B Combination	580.0	557.7	552.9	556.7	566.2	580.3	598.2	619.5	644.2	672.0
A-Triple	671.1	648.9	648.4	659.5	678.7	704.6	736.4	773.8	816.5	864.3
Double B-Double	685.7	664.7	665.7	678.6	700.0	728.5	763.3	804.0	850.4	902.4

IRI = 7, NRM = 184 (Road Surface Condition: Poor)
Gradient = 8%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	Speed (km/hr)									
	20	30	40	50	60	70	80	90	100	110
Small Car	30.8	28.1	26.9	26.2	25.9	25.8	25.8	25.9	26.1	26.3
Medium Car	42.3	38.1	36.1	35.0	34.3	33.8	33.6	33.4	33.4	33.4
Large Car	55.6	49.8	46.9	45.2	44.2	43.5	43.1	42.8	42.6	42.6
Courier Van-Utility	51.8	48.4	46.7	45.6	44.9	44.4	43.9	43.5	43.2	42.9
4WD Mid Size Petrol	53.5	49.9	48.2	47.3	46.7	46.3	46.2	46.1	46.1	46.2
Light Rigid	74.7	71.0	69.2	68.2	67.5	67.1	66.9	66.8	66.7	66.7
Medium Rigid	100.4	94.0	90.8	89.1	88.0	87.3	86.9	86.7	86.6	86.7
Heavy Rigid	175.8	164.8	159.5	156.6	154.9	153.9	153.4	153.2	153.4	153.8
Heavy Bus	216.3	203.5	195.9	190.3	185.3	180.5	175.6	170.5	165.2	159.5
Artic 4 Axle	246.1	232.5	225.8	221.9	219.5	217.8	216.7	216.0	215.6	215.4
Artic 5 Axle	275.1	261.1	254.6	251.3	249.6	249.0	249.2	249.9	251.1	252.7
Artic 6 Axle	298.7	284.1	277.4	274.0	272.3	271.8	272.1	273.0	274.4	276.2
Rigid + 5 Axle Dog	351.6	337.0	331.0	328.8	328.7	330.1	332.7	336.2	340.6	345.7
B-Double	389.1	372.3	364.8	361.4	360.1	360.4	361.7	363.9	366.8	370.4
Twin steer + 5 Axle	391.2	374.9	368.0	365.2	364.6	365.6	367.7	370.9	374.8	379.5
A-Double	490.5	469.8	462.1	460.3	462.0	466.2	472.5	480.4	490.0	501.0
B Triple	546.7	521.8	512.2	509.4	510.6	514.6	520.9	529.0	538.8	550.3
A B Combination	580.3	560.0	557.4	563.7	576.2	593.7	615.5	641.3	670.9	704.1
A-Triple	671.7	652.2	654.7	669.4	692.9	723.9	761.4	805.3	855.2	911.0
Double B-Double	686.5	668.3	672.6	689.3	715.3	749.1	790.0	837.6	891.7	952.1

Table 40 Fuel Consumption for Rural Roads (L/100KM)

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 4%
Curvature = Straight (20 degree/km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	8.4	7.2	6.9	6.8	7.0	7.4	7.9	8.5	9.2	10.0
Medium Car	10.7	9.1	8.4	8.3	8.4	8.7	9.1	9.7	10.4	11.3
Large Car	13.9	11.7	10.7	10.4	10.4	10.6	11.0	11.6	12.3	13.1
Courier Van-Utility	12.8	10.5	9.5	9.1	9.1	9.3	9.7	10.2	10.9	11.7
4WD Mid Size Petrol	14.4	12.2	11.4	11.1	11.1	11.4	11.9	12.5	13.3	14.2
Light Rigid	13.0	11.1	10.6	10.6	11.1	11.9	12.9	14.2	15.7	17.4
Medium Rigid	23.4	21.6	21.1	21.2	21.7	22.6	23.7	25.1	26.6	28.4
Heavy Rigid	51.9	47.2	45.3	44.6	44.6	45.1	46.0	47.2	48.7	50.5
Heavy Bus	48.6	44.6	42.7	41.7	41.2	40.9	40.8	40.9	41.1	41.4
Artic 4 Axle	66.0	60.4	58.6	58.5	59.4	61.2	63.6	66.6	70.1	74.0
Artic 5 Axle	75.3	70.1	68.3	68.2	69.0	70.6	72.9	75.6	78.8	82.5
Artic 6 Axle	81.1	76.2	74.5	74.4	75.2	76.7	78.7	81.3	84.3	87.7
Rigid + 5 Axle Dog	104.4	99.5	97.8	97.6	98.3	99.6	101.5	103.9	106.7	109.9
B-Double	110.5	105.9	104.3	104.0	104.5	105.6	107.1	109.1	111.4	114.1
Twin steer + 5 Axle	111.8	107.1	105.5	105.3	106.0	107.3	109.1	111.4	114.1	117.2
A-Double	136.0	131.3	129.5	129.1	129.6	130.6	132.2	134.1	136.4	139.1
B Triple	142.3	137.4	135.7	135.3	135.8	136.9	138.5	140.5	142.9	145.6
A B Combination	166.9	161.2	159.4	159.6	160.8	163.0	165.9	169.4	173.5	178.2
A-Triple	191.7	185.5	184.0	184.8	187.1	190.6	195.2	200.6	206.8	213.9
Double B-Double	197.8	191.6	190.2	191.2	193.8	197.6	202.4	208.3	215.0	222.6

Use this page to look up fuel consumption values for the following yellow highlighted road conditions

Gradient (Rise & Fall)	0%-2% (Flat)	3%-4%	5%-6%	7%-8% (Very steep)
Curvature (Terrain type)	Straight (0-99°/km)	Curvy (100-299°/km)	Very Curvy (300°+/km)	
Roughness (IRI)	1-2 (Very good)	3-4 (Good)	5-6 (Fair)	7-8 (Poor)
Roughness (NRM)	0-49	50-99	100-149	150-199

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 4%
Curvature =Curvy / Hilly / Winding (120 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	8.4	7.2	6.9	6.9	7.1	7.4	7.9	8.5	9.2	10.1
Medium Car	10.7	9.1	8.5	8.3	8.4	8.7	9.2	9.8	10.5	11.3
Large Car	13.9	11.7	10.8	10.4	10.5	10.7	11.1	11.7	12.4	13.2
Courier Van-Utility	12.8	10.5	9.5	9.2	9.1	9.3	9.7	10.3	10.9	11.7
4WD Mid Size Petrol	14.4	12.2	11.4	11.1	11.2	11.5	12.0	12.7	13.5	14.4
Light Rigid	13.0	11.1	10.6	10.7	11.1	11.8	12.8	13.9	15.3	16.9
Medium Rigid	23.3	21.6	21.2	21.4	21.9	22.8	23.9	25.2	26.7	28.4
Heavy Rigid	51.8	47.2	45.3	44.7	44.7	45.2	46.1	47.3	48.8	50.5
Heavy Bus	48.6	44.6	42.7	41.8	41.3	41.1	41.2	41.4	41.7	42.2
Artic 4 Axle	65.7	60.7	59.0	58.6	59.2	60.4	62.1	64.3	66.8	69.8
Artic 5 Axle	75.0	70.4	68.8	68.5	69.1	70.3	72.0	74.2	76.7	79.6
Artic 6 Axle	80.9	76.5	75.0	74.8	75.4	76.5	78.1	80.1	82.5	85.3
Rigid + 5 Axle Dog	104.3	99.6	98.0	97.9	98.6	100.0	101.9	104.2	107.0	110.2
B-Double	110.5	106.0	104.5	104.3	105.1	106.4	108.3	110.6	113.3	116.4
Twin steer + 5 Axle	111.8	107.3	105.7	105.7	106.5	107.9	109.9	112.3	115.2	118.4
A-Double	136.1	131.2	129.7	129.6	130.5	132.2	134.4	137.2	140.4	144.1
B Triple	142.3	137.4	135.9	135.8	136.8	138.5	140.8	143.6	146.9	150.7
A B Combination	166.9	161.2	159.7	160.3	162.2	165.2	169.0	173.6	179.0	185.0
A-Triple	191.8	185.5	184.4	185.8	189.0	193.5	199.1	205.9	213.7	222.5
Double B-Double	197.9	191.6	190.6	192.2	195.6	200.5	206.6	213.8	222.1	231.4

IRI = 3, NRM = 78 (Road Surface Condition: Good)
Gradient = 4%
Curvature =Very Curvy or Very Winding (300-320 degree /km)

Vehicle Class	**Speed (km/hr)**									
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Small Car	8.3	7.3	6.9	6.9	7.2	7.6	8.1	8.8	9.5	10.4
Medium Car	10.7	9.1	8.5	8.4	8.6	8.9	9.5	10.1	10.9	11.8
Large Car	13.9	11.7	10.9	10.6	10.7	11.0	11.5	12.1	12.9	13.8
Courier Van-Utility	12.8	10.5	9.6	9.3	9.4	9.7	10.2	10.9	11.7	12.7
4WD Mid Size Petrol	14.4	12.2	11.5	11.3	11.5	12.0	12.8	13.7	14.8	16.0
Light Rigid	12.9	11.2	10.7	10.8	11.3	12.0	13.0	14.2	15.6	17.1
Medium Rigid	23.2	21.8	21.6	21.9	22.7	23.8	25.2	26.8	28.6	30.7
Heavy Rigid	51.7	47.4	45.8	45.3	45.5	46.2	47.3	48.7	50.4	52.3
Heavy Bus	48.7	44.6	43.0	42.4	42.4	42.8	43.6	44.6	45.8	47.3
Artic 4 Axle	65.5	61.0	59.4	59.3	60.0	61.3	63.1	65.3	68.0	71.0
Artic 5 Axle	74.8	70.7	69.4	69.3	70.0	71.3	73.1	75.3	77.8	80.8
Artic 6 Axle	80.7	76.9	75.7	75.7	76.5	77.9	79.8	82.1	84.8	87.8
Rigid + 5 Axle Dog	104.3	99.7	98.5	98.9	100.3	102.5	105.4	108.9	113.0	117.6
B-Double	110.5	106.1	105.0	105.4	107.0	109.3	112.3	115.9	120.0	124.8
Twin steer + 5 Axle	111.8	107.4	106.3	106.7	108.2	110.5	113.5	117.0	121.2	125.8
A-Double	136.3	131.3	130.2	131.1	133.3	136.6	140.7	145.7	151.4	157.8
B Triple	142.5	137.5	136.4	137.4	139.7	143.1	147.4	152.5	158.3	165.0
A B Combination	167.1	161.3	160.5	162.2	165.7	170.6	176.7	184.0	192.2	201.6
A-Triple	191.8	185.7	185.3	188.1	193.0	199.7	207.9	217.5	228.6	241.0
Double B-Double	198.0	191.8	191.6	194.6	199.8	206.9	215.6	225.8	237.5	250.5

The fuel consumption in other road conditions is available upon request.

2.4 SWIDE

The REVS uses the economic parameters specified in SWIDE file. The estimated SWIDE parameters are provided in Table 41.

Table 41 SWIDE (Updated to March 2016)

Parameters	Identifier	Units	Car	2x-4ty Truck	2x-6ty Truck	3 Axle Truck	4 Axle Truck	5 Axle Semi	6 Axle Semi	B-Double	B-Triple	Quad Group Semi
ROAD USER COST PARAMETERS:												
Petrol price	PETROL	¢/Litre	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8
Diesel price	DIESEL	¢/Litre	58.7	58.7	58.7	58.7	58.7	58.7	58.7	58.7	58.7	58.7
Oil price	OIL	¢/Litre	734	445	445	445	445	445	445	445	445	445
New tyre price	TYRE	$/Litre	130	163	361	698	647	661	658	626	555	577
Retread tyre price	RETRED	$/Litre	64	82	184	234	234	226	232	237	263	243
Repair & servicing cost	REPAIR	¢/Km	6.64	7.06	10.12	14.76	20.14	23.41	24.04	27.94	37.22	27.35
New vehicle price	VEHCLE	$	24,736	28,368	115,482	184,178	250,670	278,106	302,954	350,304	571,031	326,309
Sales tax rate	TAX	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Time depreciation rate	TIMDEP	%/year	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Distance depreciation rate	DISDEP	%/1000 Km	0.224	0.311	0.311	0.205	0.155	0.137	0.137	0.137	0.137	0.137
TIME & CRASH PARAMETERS:												
Commercial Time value	COMMTIM	¢/Hr/Person	5,276	2,817	2,967	3,566	4,467	4,896	5,053	6,109	7,269	7,269
Commercial Vehicle Occupancy	COMMOCC	Persons /Vehicle	1.3	1.3	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Weighted Average Crash Cost	UACCST	$/Crash	452,617 (rural) 137,437 (urban)									
Private Car Occupancy	PRIVOCC	Persons /Vehicle	1.7									
Private time value	PRIVTIM	¢/Hr/Person	1,626									

Source: Estimated by Economic Evaluations. Road user cost parameters were based on the 2015 National Guidelines for Transport System Management Australia (NGTSM). Commercial time values were based on time value of occupants, freight and vehicle occupancy. Weighted average crash cost was based on the Willingness To Pay (WTP) approach.

3. Rail and bus operating cost

3.1 Heavy Rail

Operating and maintenance cost parameters of suburban and intercity trains are presented in Table 42. Rolling stock maintenance, presentation and cleaning costs are higher for suburban trains than intercity trains. However, power, traction and crew costs are lower for suburban trains.

In economic evaluation, marginal cost may be relevant which can be estimated by removing costs which do not vary with kms or are fixed in nature, e.g., rolling stock presentation / cleaning as these are done based on time schedule and may be independently of number of kms.

Table 42 Train operating and maintenance costs, Sydney Trains and NSW Trains

Cost description	Average cost	Marginal cost
	Cost per car km ($)	Cost per car km ($)
Power / Traction	$0.24	$0.24
Rollingstock Routine Maintenance (RM)	$0.33	$0.33
Rollingstock Presentation/Cleaning*	$0.16	
Rollingstock Major Periodic Maintenance (MPM)*	$0.92	
Infrastructure Routine Maintenance (RM)	$0.92	$0.93
Infrastructure Major Periodic Maintenance (MPM)*	$1.46	
Crew	$1.26	$1.28
Total recurrent costs	**$5.30**	**$2.78**
	Surface Station $million/year	**Underground Station $million / year**
Station Maintenance and Operating Costs	**$0.6**	**$1.0**
Range	**$0.6 - $0.8**	**$1.0 - $1.6**

Source: Railcorp Operating and Maintenance cost analysis, June 2015. Values indexed to March 2016 dollars.
* These items are not included in the marginal cost.
Note: Some operating and maintenance costs have decreased due to addition of new Waratah trains which have lower operating costs compared to older fleet.

High level benchmark station maintenance and operating costs are included in the table above. Further refinements and details are still being collected and will be presented in future versions of the guidelines.

3.2 Heavy Rail – Freight Operating Costs

Table 43 below provides cost data for calculating freight rail operating and maintenance costs for below-rail and above-rail freight operations. These values are preliminary and based on a study undertaken by the Freight and Regional Development Division in 2013.[79] These will be refined in the future updates of economic parameter values. The values exclude GST and other taxes so are suitable for economic analyses.

The below-rail maintenance activities typically include, but are not limited to, re-railing, ballast cleaning, rail-grinding and re-sleepering. Above-rail maintenance typically includes locomotive and wagon maintenance / refurbishment, crewing costs and diesel fuel consumption costs.
Freight rail operating costs can vary widely depending on a range of factors. Some of the factors that may affect **below** rail operating costs include tonnage carried, axle loads, line speed, age and type of infrastructure and rolling stock characteristics. The factors that may affect **above** rail

[79] TFNSW (2013), Strategy Paper on Below and Above Rail Maintenance Costs, October 2013.

costs include type of rolling stock, condition of asset, level of usage, gradient, curvature, speed limits, number of wagons, axle load and payload.

Given the wide variability in freight rail operations the costs are provided in a range (i.e. low, medium and high). The below rail costs are provided as annualised average costs for the coal network and the interstate freight network.

Users should exercise judgment when choosing the most appropriate value. Explanatory notes are provided below for each cost item to guide users as well as examples for calculating below and above rail costs.

Table 43 – Above & Below Rail Freight Maintenance & Operating Costs, March 2016 Prices

Below rail costs (annualised average costs)			
Cost Components	**Low**	**Medium**	**High**
Item 1a - **Rail track fixed maintenance cost by volume** ($/track km)			
Coal Network			
1 – 10 million ton per annum (mtpa)	$10,600	$15,900	$26,600
10 – 30 mtpa	$15,900	$26,600	$42,500
30 mtpa and above	$21,300	$26,600	$53,100
Item 1b - **Rail track fixed maintenance cost by volume** ($/track km)			
Inter-state Network	$20,200	$24,400	$34,000
Item 2 - **Network control & corporate overheads** ($/track km)	$6	$10	$13
Item 3 - **Rail track variable maintenance costs** ($ /'000 GTK)	$1	$2	$3
Item 4 - **Major Periodic Maintenance** – assume every 5 or 10 years based on usage ($ / track km)	$10,600	$26,600	$53,100
Above Rail Costs			
Rolling Stock –Upfront CAPEX			
Item 5a - Locomotive ($m per DC 3000 hp locomotive)	$4.0m	$4.1m	$4.3m
Item 5b - Locomotive ($m per AC 4500 hp locomotive)	$5.1m	$5.2m	$5.3m
Item 5c - Wagon ($ per wagon)	$85,000	$127,500	$170,000
Item 6a-Locomotive (re-fit cost) *($m per DC 3000 hp locomotive)* *($m per AC locomotive)*	$1.3 m $1.6 m	$1.4 m $1.7 m	$1.5 m $1.8 m
Item 6b - Wagon *(re-fit cost)*	$8,500	$31,900	$85,000
Rolling Stock – Maintenance Costs (annualised average costs)			
Item 7 A - Locomotive maintenance ($ per loco per year), assuming 250,000 kms per year operations, and including scheduled, unscheduled, wheels, component change out (CCO) and maintenance facility charge	$371,900	$425,000	$478,200
Item 7 B - Locomotive Maintenance ($/locomotive km travelled)		$1.86	
Item 8 A - Wagon maintenance ($ per wagon per year), assuming 250,000 kms pa operations including scheduled, unscheduled, wheels, component change out (CCO)& maintenance facility charge	$13,300	$15,900	$19,900
Item 8 B - Wagon maintenance ($ per km per wagon)	$0.05	$0.06	$0.08
Fuel and Crew Costs			
Item 9 - Fuel consumption (Litre per locomotive km)	3 (Flat or empty train)	5 (Loaded train or Mixed terrain)	8 (Hilly or bulk coal or steel)
Item 10 - Crewing cost *(standard two person crew per hour)*	$270	$320	$360

Values have been indexed to March 2016 by CPI Sydney All Groups. Values for Crewing cost have been indexed by AWE to Nov 2015.

Explanatory Notes on Table 43:

1. **Items 1a and 1b - Rail track fixed maintenance costs** are fixed costs of track maintenance for two types of network mentioned and do not vary with the number of services provided. Typically it covers the costs of track maintenance over 3 distinct phases:
    - Immediately after construction – inspection and routine maintenance
    - After 5 years – inspection and routine maintenance, regular rail regrinding and resurfacing
    - After 10 years - Major Periodic Maintenance.

2. **Item 2 – Network Control and Corporate Overheads** are overhead costs based on the Freight and Regional Development Study report.
3. **Item 3 – Rail track Variable Maintenance Costs** are for grinding, ballast cleaning, etc. and vary with loads carried. The estimates are in $/'000 GTK (Gross Tonne Kilometres).
4. **Item 4 – Major Periodic Maintenance** (MPM) costs cover re-sleepering and laying ballast. They are typically incurred every 10 year. However, heavy usage may result in more frequent MPM.
5. **Item 5- Rolling stock Cost –** This is the cost of new rolling stock including locomotives and wagons purchased. The economic life of rolling stock is assumed to be 30 years.
6. **Item 6- Refit costs** cover the cost of refitting locomotives and wagons depending on usage. Assume these occur every 10 years for locos and 15 years for wagons. It should be noted that locomotive and wagon refit costs can vary significantly between 15% and 50% of the cost of a new wagon.
7. **Items 7 and 8 – Rolling stock Maintenance Cost**- If no refurbishment or half-life fit out costs is available, use costs in Items 7 and 8. Alternatively, Items 7b and 8b are per km values which may be used if detailed maintenance costs are not available. To avoid double counting, if items 7 and 8 are used, item 6 should be excluded.
8. **Item 9 - Fuel cost**- To estimate fuel costs multiply the fuel consumption rate in item 9 to the economic price of fuel (market wholesale price for diesel fuel less price reduced for 10% GST and 38.14 cents per litre for excise taxes)[80]. This will provide the fuel cost per locomotive km. Fuel cost will vary significantly with load, terrain and distance travelled.
9. **Item 10 – Crew Cost** – These provide the hourly cost of a two person crew which can be used to estimate crew costs for each trip or over one year making assumptions about working hours and working conditions.

Worked Example – Estimating Below Rail Costs

Fixed Track Maintenance Costs

To derive the fixed track maintenance costs assume that we are evaluating costs for a coal network carrying between 10 and 30 million tonnes per annum (mtpa) over 100 kms. A median value of $26,600 per track km is chosen from above table Item 1. Then add in Item 2 network control costs median value of $10 / track km ($26,600 per track km + $10 per track km *100 kms). This is equal to $2,661,000 pa.

[80] On 1 February 2015 CPI indexation on fuel excise rate applies. Assume that the indexation factor for 1 February 2015 is 1.022. Accordingly the CPI indexed duty rate for diesel on 1 February 2015 is 40.3 cents per litre (or $0.403 per litre). This is calculated by multiplying the indexation factor by the 1 August 2014 rate before rounding (39.478 cents per litre x 1.022 = 40.347 cents per litre). The result of this calculation is then rounded down to one decimal place of a cent being 40.3 cents per litre.

Variable Track Maintenance Costs
To derive variable track maintenance costs, let us assume there is track of 100 kms and 20 mtpa which gives 2,000,000,000 GTK. Use the median figure from Item 3 ($2/'000GTK) gives a value of $4,000,000 pa.

Major Periodic Maintenance Costs
To derive major periodic maintenance costs choose the most relevant value from Item 4, say $26,600 per track km. For 100kms of track this will be $2,660,000. To annualise this value over 10 years divide this cost by 10 (i.e. $2,660,000/10= $266,000).

Total below rail costs pa will be the sum of fixed track maintenance costs, variable track maintenance costs and the major periodic maintenance costs.

Worked Example – Estimating Above Rail Costs

Capital Costs
To estimate above rail capital costs, assume a project requires 5 train sets with 4 DC 3000 horse power (hp) locos each and 60 wagons per train set. The locos use diesel and coal wagons are required. The upfront CAPEX cost will be number of locos x locos per train x cost per loco (5 train sets x 4 locos per train x $4.1 m per loco) and for wagons the cost will be the number of wagons x wagons per train x cost per wagon (5 train sets x 60 wagons x $127,500 per wagon) (Items 5a and above). Then either add in half-life cost of refurbishment (Item 6a and 6b) and spread evenly over 10 years. This will provide total capital cost per annum.

Maintenance Costs of Rolling stock
To derive maintenance costs, use data from Items 7A or 7B for locos and 8A or 8B for wagons, depending on data availability. Items 7b and 8b are cost estimates per km. Assuming the median value this will be $425,000 per loco per annum x 4 locos using above example plus 60 wagons X $15,900 per wagon.

It should be noted that maintenance costs for new locos with lesser usage are significantly less than say an older locomotives with 20+ years of service. Users should endeavour to collect data and form their own estimates if usage is less / more than 250,000 kms.

Operating Costs
To derive operating costs, multiply kilometre travelled pa for each locomotive by fuel consumption rate (Item 9) by price of fuel. The operating cost will vary depending on the type of terrain and commodity carried. For example, for mixed terrain, use 5 litres per loco per km and multiply by kms of travel and the price of diesel. Then add in crew cost estimates per hour and multiply by estimated hours worked per year.

Total above rail costs will be the sum of the above annual capital and maintenance costs of rolling stock and the operating costs pa.

3.3 Light Rail –Operating and Maintenance Costs

Table 44 presents the operating and maintenance parameters for light rail, with cost breakdown of track, station and train.

Table 44 Operating and maintenance cost: light rail

Cost items	Unit Cost	Unit
Light rail vehicle	$3.4m to $4.9m	Per unit
Track maintenance cost		
Fixed: track and right of way	11,610	$ / track km
Fixed: electric overhead	10,844	$ / track km
Variable: track and right of way	0.58	$ / train km
Variable: signals & communications	11.67	$ / train km
Variable: electric overhead	0.14	$ / train km
Station		
Station staff	23.22	$ / train hour
Station maintenance	14,513	$ / station per year
Train		
Driver	43.54	$ / train hour
Maintenance	1.30	$ / train hour
Customer services and ticketing	22.35	$ / train hour
Cleaning	13,062	$ / train-year
Materials and overheads	56,732	$ / train-year
Fuel	0.72	$ / train km

Source: North West Transport Link Economic Appraisal by Douglas Economics (Jan 2006). Values have been indexed to March 2016 using CPI, Sydney, All Groups. Values in this table are indicative only.

3.4 Transitway and metro bus

Table 45 presents the operating and maintenance parameters for metropolitan buses and transitway buses, with the breakdown of fixed and variable costs.

Table 45 Operating and maintenance cost: buses

Cost Items	(including dead running)
Cost per bus km (excluding labour)[1]	$1.40 x 1.259
Cost per bus hour (labour cost)[2]	$57.42

1. Cost per revenue and dedicated school bus kilometre taken from average of Sydney Transit Authority (STA) for a standard bus covering all running cost of a service variation excluding labour for a weekday between hours of 0559 and 2359. Dead running cost has been loaded to revenue and school bus kilometres by factor of 1.259.
Values have been indexed to March 2016 using CPI, Sydney, All Groups. Values in this table are indicative only.

3.5 Bus depot

Table 46 presents a list of potential costs in a bus depot proposal. Each applicable cost item should be quantified for a typical evaluation period of 30-40 years.

Table 46 Parameters for evaluating bus depot

Cost Items	Unit	Value (March 2016)
Depot operating costs		
Employee related	$/Bus Lot	32,554
Other operating cost	$/Bus Lot	1,703
Maintenance costs	$/Bus Lot	1,584
Administration	$/Bus Lot	2,295
Bus depot lease costs		
Imputed rent [1]	$/Bus Lot	5,032 – 20,130
Other economic costs [2]		
Road repair and maintenance cost [3]	$/Bus KM	0.04

Crash cost	$/Bus KM	0.02
Road congestion cost	$/Bus KM	0.72
Air pollution	$/Bus KM	0.36
Greenhouse gas emission	$/Bus KM	0.15
Noise	$/Bus KM	0.02
Water pollution	$/Bus KM	0.05
Nature & landscape	$/Bus KM	0
Urban separation	$/Bus KM	0.02
Upstream and downstream	$/Bus KM	0.22
Bus Cost by Type[4]		
Category 1	$/Bus	61,528
Category 2	$/Bus	112,802
Category 3	$/Bus	348,660
Category 4	$/Bus	379,425
Articulated bus	$/Bus	707,575 to 769,104
Double deck bus	$/Bus	707,575

1. Depends on land value and location.
2. Refer to relevant tables for details of these economic values, i.e., Table 64 for Crash cost, Table 21 for road congestion cost and Table 58 for environmental effects.
3. Road repair and maintenance cost accounts for 46% of total repair, maintenance and provision (construction) cost (refer to Table 65).
4. Category 1: 13 to 18 passengers, Category 2: 19 to 24 passengers, Category 3: 25 to 41 passengers and Category 4: 42 + passengers

3.6 Ferry Service

Table 47 present the unit costs of ferry services, vessels and wharf. From the 28th July 2012, Harbour City Ferries have taken over the operation of Sydney Ferries. The fleet includes different vessel types: First Fleet, Harbour Cat, Super Cat, Freshwater, Lady Class, River Cat and Fantasea. These vessels have different capacities thus would have different operating costs per hour.

Table 47 Ferry operating costs

Items	Unit	Unit costs $
River Cat Ferry[1]	per vessel	5,313,000
Manly Class[1]	per vessel	26,564,000
Ferry wharf (commuter) upgrade[2]	Per wharf	6,375,000
Ferry wharf (recreational) upgrade[2]	Per wharf	1,594,000
New ferry wharf[3]	Per wharf	7,438,000
Boat ramp upgrade[4]	Per ramp	425,000
Harbour rate (Parramatta & Inner Harbour) [5]	Per service hour	891
Freshwater rate[5]	Per service hour	1,170

1. Ferry financial performance data 2012/13, indexed by Sydney CPI March 2016. Based on Sydney Harbour Wharf Upgrade projects
2. Based on completed new wharf project in Rhodes
3. Based on ramp upgrade projects under better boating program
4. Cost per contract including margin applied to base rates

3.7 Benchmark Costs for Local Infrastructure Projects

Table 48 provides benchmark costs calculated by IPART for infrastructure items which can be reasonably established based on efficient cost estimates. There are three components of the benchmark cost estimates

Benchmark cost=Base cost x Adjustment factors x Contingency allowance

Where a single benchmark cost could not be established, IPART established 2 reference costs using 2 different examples of the infrastructure item e.g., either a simple and complex example, a small and large example, or for delivery in 2 different locations. The project cost estimate could be selected from one of the reference costs.

The base costs were as recommended by Evans & Peck for separate benchmark items, and sub-items, where both IPART and Evans & Peck carefully considered feedback from stakeholders in relation to the benchmark costs in the Draft Report. The benchmark costs were tested through a public submission process, during which stakeholders provided useful feedback on all 3 components of the benchmark costs.

The benchmarks represent the median cost of delivering the infrastructure item and should be used as a guide. The benchmark costs already included the recommended contingency allowance of between 10% and 30% of the total adjusted base cost of the project. Reference cost is provided where the scope of the item is reasonably consistent with 1 of the 2 reference cost items, or there is not sufficient design information available to use the cost estimation approach. There is no need to apply contingency allowance to the reference cost as these costs are based on infrastructure project examples which already include the appropriate contingency allowance.

The use of these benchmark and reference costs is recommended as a guide in establishing development costs for various transport infrastructure projects.

Table 48 Infrastructure Benchmark and Reference Costs - Various Transport Projects

Infrastructure Type	Detail Description	Unit	Base Cost ($/unit) In March 2016 $
New sub-arterial road	New 3 lane flexible pavement road	m	9,293
	New 4 lane flexible pavement road	m	10,791
Sub-arterial road widening	Flexible pavement	m	6,584
	Rigid pavement	m	6,771
New rural road	New 2 lane, flexible pavement road	m	2,448
Rural road widening	Widening flexible pavement by 1 lane	m	3,725
Guide posts/safety barriers/pedestrian fencing	Metal guide posts	Each	58-108
	Guardrail safety barriers	m	216-355
	Steel pedestrian fencing	m	770-1,346
Traffic calming on 2 lane road	Flat top road hump	Each	32,563
	Concrete road hump	Each	8,692
New concrete footpath adjacent to traffic lane	1.2m wide footpath	m	238
	2.2m wide footpath	m	575
	2.5m wide footpath	m	705
Removal of old footpath and replace with new.	1.2m wide footpath	m	269
	2.2m wide footpath	m	600

	2.5m wide footpath	m	727
Un-signalised intersection	"T" intersection	Each	18,670
	4 way intersection	Each	31,330
Signalised intersection	"T" intersection	Each	230,769
	4 way intersection	Each	274,839
Roundabout	4 leg roundabout with 2 approach lanes-greenfield	Each	36,180
	4 leg roundabout with 2 approach lanes-brownfield with existing traffic	Each	105,504
	4 leg roundabout and pavement with 2 approach lanes-greenfield	each	348,359
Pedestrian Crossing	Spanning 2 lanes including pedestrian refuge	Each	5,788
Bus stop	Including enclosure, seating and signage	Each	18,466
Street Lighting	Including post with 4.5m outreach-10.5m high	Each	10,609
	Including post with 4.5m outreach- 12m high	Each	16,202
On road cycleway	2.2m wide lane without kerb separation	m	247
	2.2m wide lane with kerb separation	m	313
Pedestrian underpass	Under rail line	m	161,184
Road pavement resurfacing	Milling and filling of road pavement	m^2	102
Cycleway facilities	Stainless steel bicycle racks	Each	1,182
Pedestrian/cycle overpass with anti-throw screens and covered walkway	Pedestrian Bridge	m	31,965
	Cycle Overbridge	m	33,710
Single lane, on road cycleway, including surface treatment and signage	Without kerb separation		247
	With kerb separation		313
Car park	At grade carpark	Space	6,642
	Multi-storey	Space	35,889
Road bridge over railway, waterway or grade separation (Reference Cost)	Single span bridge 9.4m wide X 19m (lower bound)	Each	1,016,936
	Single span bridge 25m wide X 34m (upper bound) with ramps	Each	6,822,533
Intersection state / local road (Reference Cost)	Intersection with perpendicular junction, widening for turning, profiling & removal of 1.2m w asphalt carriageway for local road tie-in, traffic mitigation measures, 100mm asphalt paving, rework at pavement interface, signage,	Each	63,275
	Above plus acceleration-deceleration lane of and on, stormwater pipe	Each	332,756
Additional Cost for road maintenance attributed to mining activity (reference Cost)	Lower bound (10% acceleration)	km	11,704
	Upper Bound (30% acceleration)	km	45,144

Source: IPART Report on Local Infrastructure Benchmark Costs, Final Report, April 2014. IPART will regularly review the benchmark items and their costs in light of structural shifts in the economy or the construction industry on a rolling basis within 3 years.
Values indexed to March 2016 by Sydney CPI All Groups.

3.8 Average fare

The average public transport fare is required for evaluation of bus and rail projects. The Tables 49 and 50 provide the average bus and rail fares in 2015 values. Average fare was estimated from patronage and revenue data provided by Bureau of Statistical Analysis (BSA).

Table 49 Average bus fare

Patronage Type	Average Fare ($/trip)
Adult	2.88
Concession	1.44
Pensioners Excursion Ticket (PET)	1.14
Weighted Average	**2.09**

Source: Concession & Revenue Foregone Model. Based on BSA patronage and revenue by ticket type 2014/15 Includes Opal & non-Opal trips however Opal trips are currently unable to be separated from other ticket types. GST on ticket price is excluded.

Table 50 Average fares: Sydney Trains and NSW Trains combined

	2014/15 Average Fare ($/trip)		
	Sydney Trains	**NSW Trains**	**Weighted Average**
Adult	3.37	4.26	3.46
Concession	1.69	2.13	1.73
Pensioners Excursion Ticket	1.14	1.14	1.14
Weighted average	**2.91**	**3.64**	**2.98**

Source: Concession & Revenue Foregone Model. Data based on BSA patronage and revenue by ticket type 2014/15. Includes Opal & non-Opal trips however Opal trips are currently unable to be separated from other ticket types. GST on ticket price is excluded.

4. Crash values

4.1 Introduction

Crash[81] values can be estimated based on two main approaches: Willingness to Pay (WTP) and Human Capital Cost:

- Willingness to Pay Approach uses an ex-ante measure of the amount that individuals are willing to pay for crash prevention. Values are derived from Stated Preference surveys where respondents are asked to choose hypothetical scenarios systematically varied in safety, travel time and cost. Econometric models are specified and developed to statistically estimate the monetised valuation of safety.
- The Human Capital Approach captures the ex-post sum of various identifiable costs, such as loss of work income, medical expenses, long term care, insurance cost, vehicle repair, property damage, travel delays and policing. The value of a statistical life or a fatality is the discounted present value of income or output over a period up to 40 years.

There are several limitations of the Human Capital Approach. Firstly, public policy is designed to reduce the risk of crashes or injuries. For most policy purposes, we want to measure what individuals are willing to pay to reduce the possibility of crashes. The ex-post value of crashes is based on what has been lost. Secondly, as the Human Capital Approach is mainly based on future year productivity and income, it can hardly apply to fatalities of non-working individuals. Thirdly, most Human Capital Approaches do not make allowance for pain and suffering. Due to these limitations, the contemporary trend of economic evaluation is to use the crash values derived from the Willingness to Pay approach.

[81] In the road safety community the term “crash” is used rather than “accident” because “accident” implies an event beyond our control. The risks are in fact well known and include speeding, alcohol, non-use of helmets, seat belts and other restraints, poor road design, poor enforcement of road safety regulations, unsafe vehicle design, and poor emergency health services.

- The Inclusive Willingness to Pay approach is recommended by the Australian Government Department of Infrastructure and Regional Development and will be promoted in the updated version of the National Guidelines for Transport System Management. The values are a combination of Willingness to Pay values with some additional vehicle, emergency and other crash related costs, as compiled by the Bureau of Infrastructure, Transport and Regional Economics and ARRB. The rationale for incorporating these costs is that individuals would not factor in costs that are not incurred by the individual, when trading off time, safety and cost in the stated preference survey.

TfNSW recommends using the **Inclusive Willingness to Pay approach** to valuing road trauma in economic appraisals of transport projects, programs and initiatives, policies and regulation reforms that may prevent transport injuries in future years, to be consistent with the approach adopted by National Guidelines for Transport System Management and Australian Transport Assessment and Planning. The values of Human Capital Approach may be used for post completion evaluations or benefits registers where the Human Capital Approach values had been used in original appraisals.

4.2 Value of statistical life in existing literature

The value of statistical life (VSL) is an important parameter in economic appraisals. A literature review indicates that VSL ranges from $2m to $11m (excluding two lowest and two highest outlier values in Table 51).

Table 51 Values of statistical life from existing international literature

Studies	Value of Statistical Life ($m)	Approximate Value in March 2016 (A$m)
Andersson (2005), Sweden	US$1.3	$1.68
Krupnick et al (2000), Canada	US$1.3	$1.97
RTA (2009) Human Capital Cost	AU$1.69	$2.11
Transport Canada *	AU$2.21 in 2007	$2.73
Mrozek and Taylor (2001)	US$2.0	$2.85
Guria et al (1999), NZ *	US$2.1	$3.29
Jones-Lee (1994)	US$2.1	$3.68
Tsuge et al (2005), Japan	US$2.9	$3.75
Kneisner and Leith (1991), Australia	US$2.2	$4.02
UK Dept for Transport *	AU$3.39 in 2007	$4.19
Jones-Lee et at (1995), UK	US$2.7	$4.51
Jenkins et al (2001)	US$3.2	$4.56
NZ Ministry of Transport *	AU$3.95 in 2007	$4.88
US Federal Highway Administration *	AU$4.45 in 2007	$5.50
US Environmental Protection Authority **	US$5.8 in 1997	$12.48
Desaigues and Rabl (1995), France	US$3.4	$5.67
Desvouges et al (1998)	US$3.6	$5.72
Johannesson et al (1997), Sweden	US$3.8	$6.09
Van den Burgh et al (1997), US and UK	US$3.9	$6.25
Gayer et al (2000), US	US$4.7	$7.13
Meng and Smith (1999), Canada	US$5.2	$8.15
Day (1999), US, Canada, UK	US$5.6	$8.78
Viscusi (1993)	Median US$5.5	$9.78
Baranzini and Luzzi (2001), Switzerland	US$7.5	$10.71
Schwab-Christe (1995), Switzerland	US$7.5	$12.53
Miller et al (1997), Australia	Median US$15.2	$24.36
Median international literature value		**$5.19**

* Sourced from PWC (2008).

** Mean value of 26 VSL studies cited by US Environmental Protection Authority.

4.3 Casualty and crash costs - Inclusive Willingness to Pay Approach

The Inclusive Willingness to Pay costs are provided in Table 52 and are indexed to March 2016 dollars. They represent the sum of WTP values and additional vehicle, emergency and other crash related costs compiled by BITRE and ARRB. This approach has been adopted by NGTSM and Australian Transport Assessment and Planning (ATAP).

Willingness to Pay values represent the amount people are willing to pay to avoid death or injury. The WTP values are derived from a NSW Roads and Traffic Authority study in 2008 undertaken by PricewaterhouseCoopers (PWC) in conjunction with the Hensher Group. Stated preference surveys of road users were used to estimate the WTP values for reducing the risk of death and of various levels of injury severity. The WTP values and additional costs are provided for information in Tables 53 and 54, respectively. The calculations for average crash costs also draw on the average number of persons killed and injured per crash, as presented in Table 55.

It should be noted that for the 2016 update to the Appraisal Guidelines, the injury categories and associated values have been updated to reflect nationally accepted definitions of injury[82]. It is expected that the categories and values reported in the NGTSM/ATAP will also be harmonised.

Table 52 Costs per casualty and per crash
Inclusive Willingness to Pay Approach, March 2016$

	Urban	Rural	Average
Inclusive WTP costs per casualty			
Fatality	$6,965,123	$7,626,169	$7,272,032
Serious injury (injury requiring hospitalisation)	$418,789	$554,152	$466,010
Moderate injury (attendance at emergency department)	$64,437	$82,590	$72,804
Minor injury (not requiring attendance at emergency department or hospital)	$64,437	$82,590	$72,804
Unknown injury type prevention	$185,081	$236,030	$203,823
Inclusive WTP costs per crash			
Fatal crash (at least one person killed)	$7,563,434	$8,985,668	$8,143,060
Serious injury crash (at least one person hospitalised, but no fatalities)	$476,777	$683,392	$540,132
Moderate injury crash (at least one person attended emergency, but no serious injuries or fatalities)	$80,546	$111,497	$91,733
Minor injury crash (at least one person received a minor injury, but no moderate injuries, serious injuries or fatalities)	$75,391	$107,367	$86,637
Unknown injury type crash	$201,026	$345,865	$234,015
Property damage only	$9,743	$9,743	$9,743

Source: Values from the Economic Valuation of Safety Benefits, Serious Injuries, Final Report, PWC for Roads and Traffic Authority (now Roads & Maritime Services) and indexed from Dec 2007 to March 2016 using Sydney CPI, all groups. Unknown injury type crash is non-fatal casualty crash where injury severity is unknown.

[82] In previous years, the category labelled "serious injury" in fact represented "severe permanent injuries requiring hospitalisation" (and hence was a higher value) which is not the nationally accepted definition of serious injury.

TfNSW recommends that the values in Table 52 be used in economic appraisals of transport policy, projects and programs.

Definitions

- **Fatality** = a person who dies within 30 days of a crash from injuries due to the crash.
- **Fatal crash** = a road traffic crash on public roads in which at least one person in the crash dies within 30 days from injuries received in that crash.
- **Serious injury** = a person admitted to hospital as a result of a road traffic crash on public roads who does not die within 30 days as a result of those injuries
- **Serious injury crash** = a road traffic crash on public roads in which at least one person was admitted to hospital as a result of the crash, and in which there were no fatalities as a result of that crash.
- **Moderate injury** = a person who attends an emergency department following a road traffic crash on public roads but is not subsequently admitted to hospital
- **Moderate injury crash** = a road traffic crash on public roads in which at least one person attends an emergency department following that crash but is not subsequently admitted to hospital. There were no serious injuries or fatalities from that crash.
- **Minor injury** = a person injured from a road traffic crash on public roads that does not attend an emergency department and is not admitted to hospital.
- **Minor injury crash** = a road traffic crash on public roads in which at least one person injured from that crash does not attend an emergency department and is not admitted to hospital. There were no moderate injuries, serious injuries or fatalities from that crash.
- **Urban** = Sydney, Newcastle and Wollongong metropolitan areas, and town centres where the speed limit is up to and including 80km/h.
- **Rural** = crashes outside the Sydney, Newcastle and Wollongong metropolitan areas, where the speed limit is more than 80km/h.

Components of Inclusive Willingness to Pay Costs

Further information is provided in Tables 53 and 54 below for interested parties to understand the components of the Inclusive WTP values. They are not intended to be directly used in economic appraisals for road projects. The WTP values may be used in economic appraisal for maritime, railway and other initiatives where the inclusive costs are not applicable. The calculations for average crash costs also draw on the average number of persons killed and injured per crash, as presented in Table 55.

Table 53 Value per person or per crash, Willingness to Pay Approach March 2016$

	Urban	Rural	Average
WTP value per casualty			
Value of fatality risk prevention	$6,810,073	$7,471,119	$7,116,982
Value of serious injury risk prevention (requiring hospitalisation)	$245,674	$381,037	$292,895
Value of moderate injury prevention (attendance at emergency department)	$51,725	$69,878	$60,092
Value of minor injury prevention	$51,725	$69,878	$60,092
Value of unknown injury type prevention	$120,483	$171,432	$139,225
WTP per crash			
Fatal crash (at least one person killed)	$7,329,103	$8,722,717	$7,898,630
Serious injury crash (at least one person hospitalised, but no fatalities)	$283,173	$473,699	$343,065
Moderate injury crash (at least one person attended emergency, but no serious injuries or fatalities)	$64,656	$94,335	$75,716
Minor injury crash (at least one person received a minor injury, but no moderate injuries, serious injuries/ fatalities)	$60,518	$90,841	$71,509

Table 54 Vehicle and general costs in Inclusive WTP values, March 2016$

Inclusive costs (vehicle + general costs)	Per fatality	Per seriously injured person (requiring hospitalisation)	Per injured person not requiring hospitalisation[83]	Per injured person[84]
Vehicle costs				
Repairs	$13,869	$11,589	$11,436	$11,486
Unavailability of vehicles	$1,760	$1,561	$825	$1,063
Towing	$413	$368	$194	$250
Total vehicle costs	$16,042	$13,518	$12,455	$12,799
General costs				
Travel delays	$77,343	$93,607	$122	$30,362
Insurance administration	$49,563	$59,987	$78	$19,457
Police	$9,972	$3,426	$52	$1,143
Property	$1,606	$1,943	$3	$631
Fire	$524	$635	$2	$207
Total general costs	$139,008	$159,597	$257	$51,799
Total inclusive costs (vehicle + general costs)	**$155,050**	**$173,115**	**$12,712**	**$64,598**

Source: National Guidelines for Transport System Management in Australia update, 2015.

[83] Note that this category comprises both moderate and minor injuries (which are reported separately in Tables 52, 53 and 55)
[84] Unknown whether hospitalised

Table 55 Average number of persons killed and injured in a crash

	Urban	Rural	Average
Fatal crash			
Average no. persons killed per crash	1.06	1.14	1.09
Average no. persons hospitalised per crash	0.38	0.47	0.41
Average no. persons with moderate injury per crash	0.16	0.14	0.15
Average no. persons with minor/other[85] injury per crash	0.17	0.24	0.20
Serious injury crash			
Average no. persons hospitalised per crash	1.10	1.19	1.12
Average no. persons with moderate injury per crash	0.15	0.14	0.14
Average no. persons with minor/other injury per crash	0.10	0.15	0.11
Moderate injury crash			
Average no. persons with moderate injury per crash	1.13	1.20	1.14
Average no. persons with minor/other injury per crash	0.12	0.15	0.12
Minor injury crash			
Average no. persons with minor/other injury per crash	1.17	1.30	1.19

Source: Number of persons is estimated by Economic Evaluations based on casualty and crash data provided by Centre for Road Safety for urban and rural 2008/09 to 2012/13.

4.4 Human Capital Approach

The Human Capital accident costs were originally estimated by Bureau of Transport Economics (BTE 2000). The values are further updated by National Guidelines for Transport System Management in Australia, 2015 as shown in Table 56.

Table 56 Crash cost per person: Human Capital Approach

Cost components	Fatality ($)	Serious injury ($)	Other injuries ($)
Human costs			
Ambulance	568	568	309
Hospital in-patient	3,070	12,281	62
Other medical	2,276	18,436	89
Long-term care	-	139,504	-
Labour in the workplace	773,205	36,559	0
Labour in the household	643,206	30,484	0
Quality of life	710,455	76,224	4,051
Insurance claims	19,467	34,304	2,050
Criminal prosecution	2,511	726	89
Correctional services	13,806	0	0
Workplace disruptions	13,103	13,466	873
Funeral	2,758	0	0
Coroner	905	0	0

[85] Note that the NSW crash and injury database includes a minor/injury category (rather than a minor injury category) which comprises individuals that have been identified as a casualty in the Police crash report data who are not matched to a hospital admission record or an emergency department attendance record. It may include some individuals that have in fact been admitted to hospital or emergency, but records could not be matched for some other reason.

Vehicle costs			
Repairs	13,869	11,589	11,436
Unavailability of vehicles	1,760	1,561	825
Towing	413	368	194
General costs			
Travel delays	77,343	93,607	122
Insurance administration	49,563	59,987	78
Police	9,972	3,426	52
Property	1,606	1,943	3
Fire	524	635	2
Total costs	**2,340,379**	**535,668**	**20,235**

Source: National Guidelines for Transport System Management in Australia, update 2015. Values are indexed to March 2016 using Australia AWE for labour costs, CPI maintenance & repair of motor vehicle for vehicle costs, CPI health for hospital and medical cost and CPI all groups for other general costs.

Table 57 presents the cost per crash using a Human Capital Approach. These parameters are used when the number of crash preventions has been estimated in project evaluation.

Table 57 Cost per crash: Human Capital Approach

Crash type	Urban ($/Crash)	Urban freeway ($/Crash)	Rural ($/crash)	Total
Fatal crash	$2,680,552	$2,753,861	$3,036,484	$2,928,191
Serious/ Other injury crash	$576,831	$606,606	$621,517	$567,996

Source: National Guidelines of Transport System Management, Road Parameter Values, update 2015, indexed by AWE Australia to Nov 2015.

4.6 Road safety analysis

The crash costs in the tables above are suitable in general economic appraisals. In road projects where the precise definition of crash type is known, more detailed road safety analysis can be undertaken by using the Road User Movement (RUM) codes, WTP crash and casualty costs. The Safer Roads team in the Centre for Road Safety maintains and updates a model that calculates road safety benefits and costs for road infrastructure projects. The Safer Roads team also maintains the Crash Reduction Factor matrix that records the literature based crash reduction or increase factors of individual road safety countermeasures by RUM code. For details, please contact saferroads@transport.nsw.gov.au or Manager, Safer Roads for details.

5. Environmental impacts

Tables 58, 59 and 60 present the environmental parameters for passenger cars, buses, light rail, ferry, freight vehicles and trains. The notes below provide the explanations on how these parameters can be used in transport project evaluation.

Table 58 Externality unit costs for passenger vehicles and buses

Externality type	Urban					Rural		
	Passenger cars[1]	Buses[1]	Rail[2]	Light rail[3]	Ferry[4]	Passenger cars[1]	Buses[1]	Rail[2]
	(Cent /car km)	(Cent / bus km)	(Cent / car km)	(Cent / veh km)	(Cent / vessel km)	(Cent / car km)	(Cent / car km)	(Cent / car km)
Air pollution	3.16 (3.08–3.23)	35.54 (25.15–39.53)	4.84	39.04	900.69	0.03 (0.02–0.03)	0.00 (0.00–0.40)	0.00
Greenhouse Gas Emission	2.49 (2.19–2.79)	14.64 n/a	0.77	30.82	88.44	2.49 (2.19–2.79)	14.64 n/a	0.77
Noise	1.03 (0.73–1.32)	2.49 (1.47–3.51)	2.48	N/A	N/A	0.00	0.00	0.00
Water Pollution	0.48 (0.45–0.49)	5.33 (3.77–5.92)	N/A	N/A	N/A	0.05 (0.05–0.05)	0.06 (0.03–0.06)	N/A
Nature and Landscape	0.06 (0.06–0.22)	0.16 (0.16–0.75)	N/A	N/A	N/A	0.58 (0.58–2.05)	1.61 (1.61–7.47)	N/A
Urban Separation	0.73 (0.43–1.02)	2.35 (1.47–3.23)	N/A	N/A	N/A	0.00	0.00	N/A
Upstream and Downstream Costs	4.25 (3.66–4.83)	21.97 (17.57–26.36)	N/A	N/A	N/A	4.25 (3.66–4.83)	21.97 (17.57–26.36)	N/A

Sources:
1. Guide to Project Evaluation, Part 4, Project Evaluation Data, Austroads, 2012. Values in brackets represent lower and higher ranges. These values were based on Austroads (2003) and Austroads (2012) derived from European Infras/IWW studies on 5 countries considered comparable to Australia. The National Guidelines is in the process of being refreshed.
2. North West Rail Economic Evaluation.
3. National Guidelines for Transport System Management in Australia, Part 3, Appraisal of initiatives, Australian Transport Council 2006. N/A – Not Available.
4. TfNSW estimate based on IPART (2014) Cost of Emissions for NSW Light Rail

Table 59 presents light rail and ferry external costs in terms of VKM and passenger km (PKM). The cost is also estimated at capacity (100% load) which represents the low end of external costs when light rail and ferries are fully loaded.

Table 59 Compare the air pollution and GHG external costs of car, bus, rail, light rail and ferry, in 2016 constant dollars

	Passenger cars	Buses	Rail	Light Rail			Ferry		
	Passenger KM (Cents/ PKM)	Passenger KM (Cents/ PKM)	Passenger KM (Cents/ PKM)	Vehicle KM (Cents/ VKM)	Passenger KM, Ave. patronage (Cents/ PKM)	Passenger KM, at capacity (Cents/ PKM)	Vessel KM (Cents /VKM)	Passenger KM, average patronage (Cents/ PKM	Passenger KM, at capacity (Cents/ PKM)
Transport operation									
Air pollution	2.11	1.78	0.04				900.69	9.48	2.03
Greenhouse Gas emissions	1.66	0.73	0.01				88.44	0.93	0.20
Electricity generation (upstream costs)									
Air pollution				39.04	0.60	0.51			
Greenhouse Gas Emissions				30.82	0.47	0.40			

Source: TfNSW estimate based on IPART (2014) Cost of Emissions for NSW Ferry Networks and Light Rail and ferry operational data. Indexed by Australian CPI

Table 60 Externality unit costs for freight vehicles
$ per 1000 tonne-kilometre travelled

Note	Externality type	Urban			Rural		
		Light Vehicle[1]	Heavy Vehicle[1]	Rail[2]	Light Vehicle[1]	Heavy Vehicle[1]	Rail[2]
1.	Air pollution	197.46 (146.42 – 325.02)	26.32 (12.77 – 32.21)	4.25	0.00	0.26 (0.14 – 0.32)	0.00
2.	Greenhouse Gas Emission	61.50 (57.10 – 64.42)	5.86 (2.93 – 10.24)	0.44	61.50 (57.10 – 64.42)	5.86 (2.93 – 10.24)	0.44
3.	Noise	33.67 (23.43 – 46.86)	4.39 (2.92 – 5.86)	1.85	0.00	0.44 (0.30 – 0.61)	0.00
4.	Water Pollution	29.62 (21.96 – 48.70)	3.95 (1.32 – 4.83)	0.11	0.30 (0.23 - 0.52)	1.58 (0.80 – 1.93)	0.11
5.	Nature and Landscape	21.96 (21.96 – 42.47)	0.43 (0.43 – 0.89)	1.09	0.23 (0.23 - 0.42)	4.40 (4.40 – 8.79)	1.09
6.	Urban Separation	32.21 (19.03 – 45.39)	2.93 (1.47 – 4.40)	1.09	0.00	0.00	0.00
7.	Upstream and Downstream Costs	204.98 (146.42 – 263.55)	23.43 (20.50 – 26.36)	N/A	204.98 (146.42 – 263.55)	23.43 (20.50 – 26.36)	N/A

Sources: 1. Guide to Project Evaluation, Part 4, Project Evaluation Data, Austroads, 2012. Values in brackets represent lower and higher ranges. 2. National Guidelines for Transport System Management in Australia, Part 3, Appraisal of initiatives, Australian Transport Council 2006. N/A – Not Available.

- **Air pollution** is predominantly an urban issue. The externality value is a function of vehicle kilometre travelled (vkt) and population distribution and density which are associated with health impacts. As most bus vehicle kilometres are in urban areas, the rural bus value is set at zero. As a rule of thumb, passenger car rural values are set at 1% of the urban values. Air pollution is lower at free flowing conditions than in congested roads. An urban road improvement project may reduce road congestion and increase the average travel speed, which will lead to benefits of air pollution reduction. Evidence from Commonwealth Department of Environment, Water, Heritage and Arts[86] suggests that vehicle pollutions of CO, HC, NO and Particles increase by 22%, 33%, 14% and 13% respectively when driving conditions change from free flowing (urban vehicle speed 25 km/h or above) to congested conditions (urban vehicle speed less than 25 km/h). It is recommended that lower values in Tables 58 and 60 are applied for free flowing conditions and higher values are applied for congested routes.

- Since **greenhouse gas emissions** have a global impact, the same value is applied to urban and rural areas. Vehicles generate more greenhouse gases in congested roads. It is recommended that lower values are applied for free flow conditions and higher values are applied for congested routes.

- **Noise pollution** is mostly an urban issue. The externality value is a function of population distribution and where vkt take place. As a result the rural noise unit cost is set to zero for passenger cars and buses. This should not imply that rural noise impacts are always negligible as the particular situation or conditions will need to be considered. For rural towns, the urban value is assumed. For urban freeways where there are noise barriers or no noise exposure to residential areas, the rural value is assumed.

- **Water pollution** includes organic waste or persistent toxicants run-off from roads generated from vehicle use: engine oil leakage and disposal, road surface, particulate matter and other air pollutants from exhaust and tyre degradation. Using WTP methodology, water pollution represents approximately 15% of the air pollution. Concentrations of pollutants in urban

[86] Department of the Environment, Water, Heritage and Arts, Assessing vehicle air pollution emissions, July 2008.

waterways are significantly higher compared to rural areas. For rail, rural water pollution cost is assumed the same as urban rail water pollution cost.

• **Nature & landscape** impact is driven by the infrastructure 'footprint', e.g., habitat loss, loss of natural vegetation or reduction in visual amenity as infrastructure is constructed. Key impacts in rural areas are natural impacts, whilst key impacts in urban areas are mostly amenity/visual as the urban environment is already dominated by infrastructure. The sensitivity of the loss is assumed to be higher for rural areas therefore set the urban passenger car and bus values at 10% of the rural value.

• **Urban separation** is an urban externality only. The unit cost is based on three elements: time loss due to separation for pedestrians, lack of non-motorised transport provision and visual intrusion.

• **Upstream and downstream** costs refer to the indirect costs of transport including energy generation, vehicle production and maintenance and infrastructure construction and maintenance.

Table 61 presents the unit values for different types of emissions.

Table 61 Unit values of emissions

Emission	$/tonne
Carbon dioxide equivalent (CO2-e)	59.2
Carbon monoxide (CO)	3.7
Oxides of nitrogen (N_{ox})	2,359.6
Particulate matter (PM10)	375,544.2
Total hydrocarbons (THC)	1,182.3

Source: Guide to Project Evaluation, Part 4, Project Evaluation Data, Austroads 2012, Values are indexed to March 2016 using CPI All Groups Australia.

6. Active transport

The most popular form of active transport is cycling and walking which produce positive financial, environmental and social benefits that can be used in economic evaluations. Table 62 outlines a range of parameters from various literature studies with a recommended value to be used in economic evaluations. The figures below are incremental values compared to car.

Table 62 Active transport parameters

Costs / Benefits	Cycling ($/bicycle-km)	Walking ($/km)
Health benefits	1.14 (0.068 – 1.227)	1.71
Congestion cost savings	0.35	0.35
Vehicle operating cost savings	0.33	0.37
Public transport fare cost savings	0.10	0.10
Tolling cost savings	0.39	0.39
Accident cost	0.27	0.18
Air pollution	0.0316	0.0316
Greenhouse Gas Emission	0.025	0.025
Noise	0.010	0.010
Water Pollution	0.0048	0.0048
Nature and Landscape	0.00057	0.0006
Urban Separation	0.0073	0.0073
Roadway provision cost savings	0.05	0.05
Parking cost saving	0.014	0.014
Travel time cost	0	0

Source: Economic Evaluations, TfNSW. See notes below for details.

- **Health Benefit** – An increase in active transport leads to improved health as well as reduced morbidity and mortality. The existing literature suggests that the value of health benefits range from $0.068 to $1.23 (refer to Table 63). Walking is estimated to have greater health benefits and therefore the value is approximately 1.5 times that of cycling health benefits, consistent with literature reviews. Health benefits largely exhibits diminishing returns in that the health benefit from active transport decreases, the more active transport is undertaken.

  The World Health Organisation (WHO) has developed a recent model to measure the health benefits of walking and cycling known as the Health Economic Assessment Tool (HEAT). The model calculates health benefits based on a reduction in mortality risk as a result of changes in walking and cycling activity.

Table 63 Health Benefit Literature Review

References	Cycling	Walking
AECOM (2010)	$0.068	
Marsden Jacob Associates (2009)	$0.410	$0.410
WHO (HEAT tool) (2012)	$0.871	$2.104
NZTA (2010)	$1.141	$2.282
PWC (2011a)	$1.23	$1.84
Range	**$0.068 - $1.23**	**$0.410 – $2.28**

- **Congestion cost savings** – This benefit is applicable only when cycling and walking replace car trips. It is assumed that both cycling and walking impose no congestion cost compared to motor vehicles.
- **Vehicle operating cost savings** – This benefit is applicable only when cycling and walking replace car trips. It is net savings calculated from VOC minus any operating cost for cycling. The operating cost of a bicycle is approximately $0.04/km.[87] No operating cost is incurred.
- **Public transport fare cost savings** – This benefit is applicable only when cycling and walking replace public transport trips. Based on RailCorp survey, the average fare is close to $3 (Table 50) and assuming average trip distance is 30km.
- **Tolling cost savings** – This benefit is applicable only when cycling and walking replace tolling road trips. The Westlink M7 toll rate is used to estimate the benefit.
- **Accident cost** – Average annual number of crashes was obtained from RTA Road Safety (period 2007-2011) broken down by mode (car, bus, bicycle, pedestrian) and type of crash - injury, fatality and non casualty (property damage).

  The accident unit cost (i.e. WTP/HC approach) per injury, fatality and property damage was halved (assumed that only 2 vehicles are involved in a crash). This unit cost was then used to determine the total accident cost for each type of crash and then summed to get the grand total accident cost of all types of crashes. This total crash cost was then allocated to each mode using a weighting, represented in a matrix. e.g. 95.50% of pedestrian accidents are with cars. This weighting is multiplied by the allocated crash cost: 50% of the grand total accident cost for pedestrians is allocated to cars and 50% to pedestrians. This cost allocation is done for each mode for each accident combination (i.e. pedestrian with car, pedestrian with bus, pedestrian with bicycle; car with car, car with bus, car with bicycle, car with pedestrian etc). The allocated cost for each mode is then summed. This represents the total allocated crash cost to each mode (car, bus, bicycle, pedestrian) as a result of crashes with other modes. This is then divided by the annual million kilometres travelled (MKT) for each mode provided by BTS, to arrive at the accident cost ($/km).

[87] New Zealand Transport Agency (NZTA) 2010 Economic Manual pg 3-15. Indexed and converted to 2015 Australian Dollars.

Cycling incurs greater accident costs compared to cars, as there are more cycling accidents than vehicle accidents per kilometre travelled. The accident costs per kilometre travelled for car, bus, cycling and walking are estimated in Table 64.

Table 64 Crash costs

	Car	Bus	Cycling	Walking
Average annual no. of crashes[1]	29,966	598	891	1,841
Fatal[1]	94	7	4.8	37.5
Injury[1]	12,256.0	265.8	883.5	1,797.0
Property Damage[1]	17,616	326	2.25	7
Allocated crash cost ($M)[1]	$1,693.27	$41.66	$71.01	$186.34
MVKT[2]	42,876	1,932	229	849
Cost / vkt	**$0.04**	**$0.02**	**$0.31**	**$0.22**

1. Based on RMS Road Safety crash statistics 2007-2011.
2. 2013/14 figures provided by Bureau of Transport Statistics (BTS), Household Travel Survey.
3. Note: Values have increased slightly due to the use of the higher inclusive WTP values in the calculation.

- **Environmental cost savings** – The same values as Table 58 are to be used.

7. Road Damage Cost

The unit cost of road damage was calculated using the process described below. This is mainly based on NTC methodology.

Step 1: Collect and source road expenditure data in NSW. The expenditure is grouped into:
- Road servicing and operating
- Road pavement and shoulder construction
- Bridge maintenance and rehabilitation
- Road rehabilitation
- Road safety and traffic management
- Asset extension and improvements
- Other items including corporate services, enforcement of heavy vehicle regulations, vehicle registration, driver licensing and debt servicing.

Step 2: Estimate traffic related costs by excluding costs for:
- Vehicle registration: not directly related to road traffic and its cost has been recovered from registration fees.
- Driver licensing: not directly related to road traffic and its cost has been recovered from licensing fees.
- Debt servicing: a funding mechanism. Not directly related to road traffic.
- Local road access and community amenity: Only partly related to road traffic. A proportion of costs has been collected from developers' contributions.

Step 3: Separate the cost into the following groups:
- Vehicle kilometre travelled (vkt): This part of the cost is equally distributed to vkt regardless of vehicle size, mass or axle weight.
- Passenger Car Equivalent (PCU) kilometres: This cost is distributed based on PCU thus large sized vehicles bear more costs than cars.

- Equivalent Standard Axle (ESA) kilometres: This cost is distributed based on damages caused by vehicle axle weight. Heavier vehicles reduce the serviceability in a much shorter time than light vehicles. It is assumed that damages caused by vehicles are related to the 4th power of their axle weight. The 4th power law describes the relationship between vehicle's axle weight and road damage.

- Average Gross Mass (AGM) kilometres: This cost is allocated based on gross mass of vehicles.

- Heavy vehicle kilometres travelled: This cost is related to enforcement of heavy vehicle regulations. The cost is distributed based on heavy vehicle vkt.

- Costs that cannot be allocated into any of above groups are referred to as non-separable items, which are distributed based on vkt for all vehicles.

- Percentages of cost allocation are sourced from latest NTC report.[88]

Step 4: Allocate the cost into different vehicle types.

- The following vehicle types are used in the analysis:
    - Cars and motor cycles
    - Light Commercial vehicles (LCV)
    - Rigid Trucks (2, 3 and 4 axles of different gross mass, with or without a trailer)
    - Articulated trucks (3, 4, 5 and 6 axles)
    - B doubles
    - Road trains
    - Buses (2 and 3 axle rigid buses, 3 axle articulated buses)
    - Special purpose vehicles (light and heavy)

- Vehicle kilometres by vehicle types are sourced from ABS Survey of Motor Vehicle Use (SMVU) 2010.

- PCU and ESA by vehicle types are sourced from NTC and Average Gross Mass (AGM) is sourced from ARRB report.[89]

Step 5: Estimate the unit costs by vehicle types as shown in Table 65 below.

Table 65 Unit costs of road maintenance by vehicle types

Vehicle types	Unit Costs (cent/vkt)
Cars and motorcycles	4.11
Rigid Truck	
Light (LCV)	4.11
Medium (2 Axle)	9.45
Heavy (3-4 axle)	14.20
Sub-group: Rigid Truck	**5.14**
Articulated trucks	
4 or less axles	13.98
5 axles	15.54
6 or more axles	18.12
Sub-group: Articulated Truck	**17.54**
Combination Vehicles	
Rigid 3 axle plus trailer	15.43

[88] Heavy vehicle charges, report to the Standing Council of Transport and Infrastructure, February 2012, national Transport Commission.
[89] Vuong, B. and Mathias, C. (2004) Estimates of unit road wear cost, ARRB Research Report ARR 361.

Rigid 4 axle plus trailer	24.02
B-double	23.66
Double Road Train	26.63
B-Triple	33.42
Sub-group: Combination trucks	**23.31**
Buses	
2 axle light bus	4.11
Rigid bus	9.58
Articulated bus 3 axle	10.94
Sub-group: Buses	7.74
Special purpose vehicles	**12.90**
Sub-total light vehicles	4.11
Sub-total heavy vehicles	14.15
Total all vehicles	**4.78**

Source: Estimated by Economic Evaluations, TfNSW. Values are indexed to March 2016 using Sydney CPI, all groups.
Note: 46% of total cost is for road repair & maintenance and 54% for road provision (construction).

- **Roadway provision cost savings** – Cycling and walking produce less wear and tear on roads and require less space than cars and heavy vehicles. Footpaths and cycle paths relatively cost less than roads. Roadway provision cost consists of capital costs, operating costs and depreciation. It is estimated by TfNSW by using annualised road expenditure on capital, depreciation and maintenance[90] and total vehicle kilometres travelled. The roadway provision cost for cars is estimated by annualised road expenditure on capital, depreciation and maintenance divided by total vehicle kilometres travelled to arrive at $0.08/km. The roadway provision cost for cycling (cycle lanes/paths) is approximately $0.03/km (RTA 2003), which gives a cost saving of $0.05/km for cycling.

- **Parking cost savings** – This benefit is applicable only when cycling and walking replace car trips involving a parking cost. Travelling by car may incur parking costs which include costs associated with the provision of a parking facility infrastructure (land) and maintenance. Parking costs vary depending on the location. In the Sydney CBD, metered parking costs can range from $3.30 to $7.00 per hour on weekdays to $3.30 on weekends.[91] Car parks can also charge a flat fee of up to $30 per day. While cycling requires provision of bicycle racks for parking, the cost is small compared to the car and bicycles are mobile enough to park in unused spaces. The recommended value that can be applied when cycling / walking replaces car trips is a saving of $0.014/km (RTA 2003).

- **Travel time costs** – Cycling and walking is usually slower than car driving or public transport which means that cycling and walking involve a net cost in travel time. However, the travel time is not a key decision factor when people walking and cycling. People's decision for walking and cycling as a transport mode is for enjoyment or to improve health and fitness. Thus, no travel time cost or saving is allocated for cycling and walking.

8. Transport elasticity

Elasticity is a measure of the responsiveness of the quantity demand to a change in a variable, typically price, time or a service. Direct elasticity measures the responsiveness of demand to a change in its own price, whereas cross elasticity measures the responsiveness of demand to a change in the price of a substitute (or complement).

[90] NSW Budget Paper 2011/12, capital cost of RTA.
[91] City of Sydney Parking Meter Tariff area, accessed on July 2014, available at http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0006/117645/ParkingMeterTariffArea.pdf

Table 66 summarises direct and cross elasticities of public transport and car use. The ranges of the elasticity are based on an international literature review of transport elasticity particularly focusing in Sydney and Australia. The values are based on a review undertaken by the Independent Pricing and Regulatory Tribunal (IPART) which uses the rail weekly and bus travel ten as the fare type.

Table 66 Direct and cross elasticities of demand with respect to price

Mode	Rail fare cost[5]		Bus fare cost[5]		Car operating cost (Petrol price)[5]		Public transport fare cost[4]		Car in-vehicle time[4]
	Range	Value	Range	Value	Range	Value	Range	Value	Value
Rail	-0.043 to -1.103[2]	-0.250	0.004 to 0.500[5,1]	0.004	0.009 to 0.190[4,5]	0.009	N/A		N/A
Bus	0.009 to 0.400[5,1]	0.009	-0.040 to -0.822[4,5]	-0.383	0.005 to 1.010[4,5]	0.005	N/A		N/A
Car	0.015 to 0.090[5,1]	0.015	0.020 to 0.007[5,1]	0.007	-0.014 to -0.800[5,1]	-0.014	N/A		-0.17
Public Transport	N/A		N/A		0.07 to 0.8[3]	N/A	-0.100 to -0.600[4]	-0.35	N/A

Sources: Transport for NSW's estimates based on:
1. Transport Elasticities Database, BITRE, 2009.
2. CityRail Fare Elasticities, Booz & Co, 2008.
3. Exploring the impacts of fuel price increases on public transport use in Melbourne, Currie & Phung, 2006.
4. Survey of Public Transport Elasticities, Industry Commission, 1993.
5. Estimation of Public Transport Fare Elasticities in the Sydney Region, IPART, 1996, Table 16, p. 25.

N/A Not Applicable

RailCorp estimated the demand elasticity as shown in Table 67. Compared with other studies, the elasticity for in-vehicle time and generalised journey time is high.

Table 67 Demand elasticity estimated by RailCorp

	Peak	Off peak	Overall
Fare (price)	-0.35	-0.42	-0.38
Rail in-vehicle time	-0.63	-0.74	-0.67
Service interval	-0.28	-0.32	-0.30
Generalised journey time	-1.00	-1.16	-1.07

Source: A compendium of CityRail travel statistics, June 2010.

Australian Transport Council estimated the short run elasticity as shown in Table 68. For long run elasticity, the best evidence is that elasticity is about twice of short run elasticity.

Table 68 Short-run elasticity

Attributes	Best estimate			Typical range
	Peak	Off peak	Overall	
Fares	-0.25	-0.50	-0.35	-0.2 to -0.6
Service level #	+0.25	+0.50	+0.35	+0.2 to +0.5
In vehicle time	-0.30	-0.50	-0.40	-0.1 to -0.7

Reflect medium frequency 20-30 minutes typical of suburban bus services.
Source: National Guidelines for Transport System Management in Australia, Australian Transport Council, 2006.

TfNSW recommends that the elasticity as estimated by ATC be used in NSW transport project evaluation.

9. Expansion factors

Transport demand modelling is usually undertaken in 1 hour, 2 hour or 3.5 hour peak periods. The estimated demands are then expanded into annual numbers by "expansion factors". Table

69 provides expansion factors for urban roads, rural roads, CityRail train services and Sydney buses.

Table 69 Volume expansion factors

	Roads	
	Sydney (A)	**Rural (B)**
From peak 1 hour to weekday	14.31 (AM Peak: 07:00 AM – 08:00 AM)	12.10 (15:00 PM – 16:00 PM)
From peak 2 hours to weekday	7.21 (AM Peak: 07:00 AM – 09:00 AM)	6.13 (15:00 PM – 17:00 PM)
From peak 3.5 hours to weekday	4.46 (AM Peak: 06:30 AM – 10:00 AM)	3.61 (14:30 PM – 18:00 PM)
From weekday to year	345	347
	Public transport	
	Train (Sydney) (C)	**Bus (Sydney) (D)**
From peak 1 hour to weekday	6.08 (AM Peak: 8:00 AM – 9:00 AM)	7.10 (AM Peak: 7:30 AM – 8:30 AM)
From peak 2 hours to weekday	3.58 (AM Peak: 7:30 AM – 9:30 AM)	4.34 (AM Peak: 7:00 AM – 9:00 AM)
From peak 3.5 hours to weekday	3.04 (AM Peak: 6:00 AM – 9:30 AM)	3.19 (AM Peak: 7:00 AM – 10:30 AM)
From weekday to year	300	300

Sources: Estimated by Economic Evaluations, TfNSW, based on the following datasets:

A. Traffic volume data in 2011 provided by Roads and Maritime Services. Expansion factors are based on traffic data at 7 tolled freeway stations, 22 arterial stations and 31 local road stations. Stations are selected for fairly representing traffic conditions in Sydney Inner, Middle and Outer rings.

B. Traffic volume data in 2011 provided by Roads and Maritime Services. Expansion factors are based on traffic data at 65 arterial stations and 26 local road stations in Hunter, Northern, South West, Southern and Western regions.

C. A compendium of CityRail travel statistics, 7th edition, June 2010

D. Sydney Buses boarding data by time of day and weekday of the year in 2010/11. Data were sourced from State Transit Authority (STA).

The volume expansion factors in Table 70 have been estimated from those in Table 69 to provide the volume expansion factors if the practitioner has Average Annual Daily Traffic (AADT) i.e. traffic volume on an average day which considers the full 365 days in a year, as opposed to the values in Table 69 which is calculated based on the more common Average Daily Traffic (ADT) which is calculated over a sample of days.

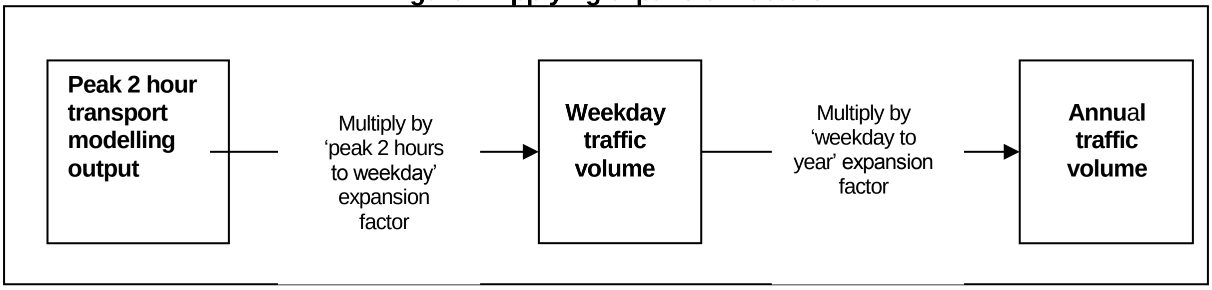
Table 70 Volume expansion factor by AADT

	Roads	
	Sydney (A)	**Rural (B)**
From peak 1 hour to average day	13.53 (AM Peak: 07:00 AM – 08:00 AM)	11.50 (15:00 PM – 16:00 PM)
From peak 2 hours to average day	6.81 (AM Peak: 07:00 AM – 09:00 AM)	5.83 (15:00 PM – 17:00 PM)
From peak 3.5 hours to average day	4.22 (AM Peak: 06:30 AM – 10:00 AM)	3.43 (14:30 PM – 18:00 PM)
From average day to year	365	365

Sources: Estimated by Economic Evaluations, TfNSW

Expansion factors can be applied to transport modelling outputs. Figure 2 illustrates how to use the expansion factors to estimate annual traffic demand from transport modelling outputs. The appropriate expansion factors in the Tables above should be used depending on whether the results of transport modelling are in 1 hour, 2 hour or 3.5 hour peak.

Figure 2 Applying expansion factors



For example, in a particular Sydney region, 2 hour AM peak car trips of 10,000 expanded to annual trips would be 24.9 million (10,000*7.21*345).

The expansion factors in Table 69 and 70 are for volume expansions, which are not necessarily same as cost expansions. The distribution of hourly costs is not the same as the distribution of hourly volumes. For example, if we were to model an intersection at AM peak hour, we would get a traffic volume and an estimated cost for that hour. The use of cost expansion factors takes into account the impacts of increased congestion, vehicle operating costs and environmental costs as a small reduction in demand during the peak period can have a large impact on travel cost savings. If transport modelling output is in terms of traffic volume for a given period and the practitioner wishes to expand to annual value then volume expansion factors should be used and then traffic costs can be calculated using these values. However, if transport modelling output is already in terms of traffic cost for a given period and the practitioner wish to expand to determine the annual cost, then the cost expansion factors discussed below should be used. Using volume expansion factors tend to overestimate travel costs.

Cost expansion factors in Table 71 have been estimated from calculating the traffic cost using 2011/12 hourly traffic volume data from RMS for a sample of freeway, arterial and local roads on the Sydney urban and rural road network. The traffic cost is composed of travel time cost, vehicle operating cost, accident cost and environmental cost and also takes into account the impact of business trips, vehicle occupancy and traffic composition i.e. the value of travel time during business hours is greater compared to the peak period due to a higher proportion of business vehicles. Results show that the cost expansion factors are lower than volume expansion factors as the proportion of daily traffic cost is higher than the proportion of traffic volume in the peak periods, for urban areas. In the rural regions, there is a lesser impact in the difference between cost and volume expansion due to a more even distribution of traffic throughout the day. Traffic volume data provided could not differentiate between vehicle types limiting the calculation for cost expansion factor for bus. It is recommended where appropriate that cost expansion factors be used to expand the modelled traffic costs.

Table 71 Cost expansion factors: road traffic

	Roads (ADT)			**Roads (AADT)**	
	Sydney (A)	**Rural (B)**		**Sydney (A)**	**Rural (B)**
From peak 1 hour to weekday	12.45	10.81	From peak 1 hour to average day	12.56	10.92
	AM Peak: 08:00–09:00 AM	16:00–17:00 PM		AM Peak: 08:00–09:00 AM	16:00 -17:00 PM
From peak 2 hours to weekday	6.29	5.51	From peak 2 hours to average day	6.34	5.56
	AM Peak: 07:00–09:00 AM	15:00–17:00 PM		AM Peak: 07:00–09:00 AM	15:00–17:00 PM
From peak 3.5 hours to weekday	4.04	3.32	From peak 3.5 hours to average day	4.07	3.34
	AM Peak: 06:30–0:00 AM	14:30 –18:00 PM		(AM Peak: 06:30–10:00 AM	14:30–18:00 PM
From week day to year	336	349	From average day to year	336	350

Sources: Detailed methodology is provided in Orthongthed et al (2013). Estimated by Economic Evaluations, TfNSW, based on the following datasets:

A. Traffic volume data in 2011 provided by Roads and Maritime Services for each hour and direction. Breakdown of traffic volume by vehicle type was not available. Expansion factors are based on traffic data at 5 tolled freeway stations, 4 arterial stations and 5 local road stations. Stations are selected for fairly representing traffic conditions in Sydney Inner, Middle and Outer rings.

B. Traffic volume data in 2011 provided by Roads and Maritime Services for each hour and direction. Expansion factors are based on traffic data at 26 arterial stations and 10 local road stations in Hunter, Northern, South West, Southern and Western regions.

Similarly to Table 70, the cost expansion factors have been calculated to obtain the AADT cost expansion factor values.

Cost expansion factors by vehicle types (car, rigid truck and articulated truck) have not been estimated at this stage because appropriate vehicle breakdown is not available in the input source data. The costing expansion factors are only estimated for road traffic at this stage. The cost expansion and volume expansion factors are considered the same for public transport modes (rail, bus and ferry). However additional crowding cost can be included for peak hours in the project appraisals.

10. Public transport attributes

10.1 Train crowding

Crowded trains have negative effects on passengers and service operations, i.e., cause discomfort to passengers, cause delay and affect reliability of the services due to time taken for passengers to alight and board the train. Thus, overcrowding poses an additional cost to on-board train time.

Data from Stated Preference surveys was used to estimate the multipliers of three levels of on-board crowding, as shown in Table 72. Standing in a crowded train is valued at 1.6 times on-board train time (or an additional 0.6 of the travel time cost).

TfNSW Multipliers are also presented which represent NSW train crowding conditions. These parameters can be used to evaluate transport projects that change on-board crowding (e.g., increasing service frequency, introducing new services or building new links).

Table 72 Train crowding multipliers

Category	TfNSW Multiplier[1]	National Guidelines Multiplier[2]
Crowded seat	1.17	1.20
Standing	1.34 - 1.81	1.65
Crush standing	2.04 - 2.52	2.10

Sources: 1.Multipliers sourced from RailCorp. 2. NGSTM Refresh 2015 draft Public Transport Parameters
Note: International (Global) Benchmark for train overcrowding is no more than 4 passengers per square metre. (Compared to benchmark, CityRail's overcrowding is an average of 1 passenger per square metre (in 2010 & 2011).

10.2 Station crowding

Four levels of station crowding were defined and referenced to Fruin's station classification:[92]

- Low crowding (Crowding level A: max density of 0.31 persons per square metre (psm)).
- Medium crowding (Crowding level B:max density of 0.43 psm, level C: max density 0.71 psm)
- High crowding (Crowding level D: max density of 1.08 psm, level E: max density of 2.13 psm).
- Very high crowding (Crowding level F: max density of 3.6 psm)

The multipliers in Table 73 convert waiting and walking in crowded station into on-board train time. For example, one minute waiting time in a very high crowded station is equivalent to 3.66 minutes on-board train time. These multipliers can be used to evaluate projects that impact station crowding (e.g., station upgrade, increasing service frequency or introducing new services).

Table 73 Station Crowding Multipliers

National Guidelines[1]	Station crowding level					
	Low	Medium		High		Very high
	A	B	C	D	E	F
Waiting	1.0	1.0	1.0	1.02	1.55	3.66
Walking	1.0	1.0	1.0	1.0	1.10	2.77

Source: 1. NGSTM Refresh 2015 draft Public Transport Parameter Review

10.3 Value of stop and station quality attributes

Public transport projects often involve construction or improvement of bus stop and rail station attributes such as seating, information, cleanliness & graffiti. Valuation of these attributes is often conducted using In Vehicle Time (IVT) minutes which convert peoples' willingness to pay for the improvement in the attribute to equivalent time spent travelling on-board bus, train or light rail.

Table 74 presents the IVT minute values from the 2013 Stated Preference and quality rating surveys on bus, light rail and rail services, as well as the converted dollar value. The values represent a service quality improvement from customer rating of 40% to 80% in the 0% (very poor) to 100% (very good) scale. At the 2013 survey, the average stop/station rating was 65%, 79%, 62% for bus, light rail and rail respectively with an overall rating of 67% for all modes.

In practical economic appraisal, an analyst needs to estimate the rating in the base case (denoted as A in the equation below) and the project case (denoted as B) for a particular mode, the yearly economic benefit can be estimated as:

Stop / Station quality improvement benefits = Number of yearly pax entries and exits x $Values in Columns (5) to (7) x (B – A) / 40%

The analysis can be done at individual attribute level or overall rating level dependent on information availability.

[92] Fruin, JJ (1971) Pedestrian Planning & Design.

Table 74 Value of stop/station quality attributes

Attribute	IVT minutes			Dollar value of stop/station quality ($)		
	Sydney 2013 survey			Sydney 2013 survey		
	Bus	Light Rail	Rail	Bus	Light Rail	Rail
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Weather Protection	0.95	0.53	0.35	$0.26	$0.14	$0.09
Seating	0.69	0.60	0.46	$0.19	$0.16	$0.12
Information	0.86	0.72	0.37	$0.23	$0.20	$0.10
Lighting	0.40	0.53	0.37	$0.11	$0.14	$0.10
Cleanliness & Graffiti	0.55	1.30	0.61	$0.15	$0.35	$0.17
Ticket Purchase	0.23	0.57	0.60	$0.06	$0.15	$0.16
Platform Surface	n/a	n/a	0.57	n/a	n/a	$0.15
Platform On/Off	n/a	n/a	0.40	n/a	n/a	$0.11
Toilet Availability & Cleanliness	n/a	n/a	0.09	n/a	n/a	$0.02
Staff	n/a	n/a	0.24	n/a	n/a	$0.07
Retail Facilities	n/a	n/a	0.11	n/a	n/a	$0.03
Car Access Facilities	n/a	n/a	0.08	n/a	n/a	$0.02
Bus Access Facilities	n/a	n/a	0.07	n/a	n/a	$0.02
Other[1]	n/a	n/a	n/a	n/a	n/a	n/a
Attribute Sum	3.7	4.3	4.3	**$1.00**	**$1.15**	**$1.17**
Overall Rating	3.0	3.2	3.4	**$0.81**	**$0.87**	**$0.92**

1. Other includes Building 0.4, Safety 0.24, Taxi 0.04, Bike 0.08, Telephone 0.04.

Source: Douglas Economics (2014) Passenger service quality values for bus, LRT and rail in inner Sydney, report to Bureau of Transport Statistics, TfNSW, August 2014.

Note: The values in the table represent the quality improvement from a rating score of 40% to 80%. The value of each attribute can be used if the individual attributes are known. Otherwise, the 'overall rating' value can be used for a 'package' of improvements or if the individual attribute is unknown.

10.4 Value of vehicle quality attributes

Table 75 shows the value of vehicle quality attributes such as improvements to outside appearance, seat availability and heating & air-conditioning in terms of IVT minutes and dollar value. The average vehicle rating was 57%, 71%, 62% for bus, light rail and rail respectively with an overall rating of 63% for all modes in the 2013 survey. The method of economic benefit estimation is the same as stop/station quality improvement.

Table 75 Value of vehicle quality attributes

Attribute	IVT minutes				Dollar value of vehicle quality ($)			
	Sydney 2013 survey				Sydney 2013 survey			
	Bus	Light Rail	Rail	All	Bus	Light Rail	Rail	All
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Outside appearance	0.18	0.50	0.70	0.47	$0.05	$0.14	$0.19	$0.13
Ease of on/off	0.20	0.41	0.17	0.27	$0.05	$0.11	$0.05	$0.07
Seat availability & comfort	0.33	0.31	0.52	0.37	$0.09	$0.08	$0.14	$0.10
Space for personal belongings	0.01	0.14	0.07	0.04	$0.00	$0.04	$0.02	$0.01
Smoothness & quietness or ride	0.35	0.43	0.24	0.38	$0.09	$0.12	$0.07	$0.10
Heating & air-conditioning	0.29	0.31	0.53	0.38	$0.08	$0.08	$0.14	$0.10
Lighting	0.14	0.27	0.24	0.21	$0.04	$0.07	$0.07	$0.06

Inside cleanliness & graffiti	0.44	0.19	0.34	0.37	$0.12	$0.05	$0.09	$0.10
On-board information & announcements	0.14	0.11	0.36	0.22	$0.04	$0.03	$0.10	$0.06
Ability to use computer & internet	0.03	0.00	0.10	0.01	$0.01	$0.00	$0.03	$0.003
Bus driver/on-board train staff	0.42	0.49	0.00	0.50	$0.11	$0.13	$0.00	$0.14
Environment: noise & emissions	0.28	0.42	0.29	0.37	$0.08	$0.11	$0.08	$0.10
Toilet availability & cleanliness	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Layout & design	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Attribute sum	**2.8**	**3.6**	**3.6**	**3.6**	**$0.76**	**$0.97**	**$0.96**	**$0.97**
Overall rating	**2.2**	**2.2**	**2.8**	**2.5**	**$0.60**	**$0.60**	**$0.76**	**$0.68**

Source: Douglas Economics (2014) Passenger service quality values for bus, LRT and rail in inner Sydney, report to Bureau of Transport Statistics, TfNSW, August 2014.

Note: The values in the table represent the quality improvement from a rating score of 40% to 80%. The value of each attribute can be used if the individual attributes are known. Otherwise, the 'overall rating' value can be used for a 'package' of improvements or if the individual attribute is unknown.

10.5 Reliability

Travel time reliability is defined as reaching the destination in acceptable time, consistency and dependability in travel times of a given trip or travel time variability in journey times. Statistical range measures provide information on the range of travel time variability that transport users experience. One of these is the use of 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. For example, a travel route has an average travel time of 60 minutes and standard deviation of 10 minutes. If the trip-maker needs to be 99.7% confident to arrive on time, the trip should start 30 minutes earlier. If a trip-maker needs 95% confidence to arrive at the destination on time, departure time needs to be 20 minutes earlier. However, the actual travel time is mostly likely to be 60 minutes in that the trip-maker will arrive 20 minutes earlier, which attract additional waiting time cost.

The valuation of travel time reliability attempts to value 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 cost 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.

Table 76 summarises various studies of the value of travel time variability. Empirical evidences indicate that the valuation of travel time reliability varies. The relativity of the value of travel time variability to the value of in-vehicle travel time ranges from 0.10 to 3.23.

TfNSW recommends that the value of travel time variability be set at the same value of in-vehicle travel time.

Table 76 Value of travel time reliability

Study and year	Mode	Country	Relativity of value of travel time reliability to value of normal travel time
Hollander (2006)	Bus	UK	0.10
Bhat and Sardesai (2006)	Multi-modes	US	0.27
Brownstone and Small (2005)	Car	US	0.40
Hensher (2001)	Car	NZ	0.57
Lam and Small (2011)	Car	US	0.66
Small et all (2005)	Car	US	0.91
Batley and Ibnez (2009)	Rail	UK	2.06
Small et al. (1999)	Car	US	3.23
Reliability Ratio recommended by TfNSW	**Multi-modes**		**1.00**

11. Asset life

The residual value should be added as a benefit at the end year of economic evaluation. Residual value is the lower of the replacement cost and the present value of future net benefits from the asset. The estimate of the residual value requires the economic life of asset as input. The economic lives of various asset types are summarised in Table 77.

Table 77 Economic Life of Asset

Asset class	Economic life (years)
Network infrastructure	
Earthworks	100-150
Bridges	120 (concrete)
Tunnels	100
Culverts	100-120
Rail sleepers	20 (timber), 50 (concrete)
Road pavement: asphalt / bitumen	20 (resurfacing every 10 years)
Road pavement: concrete	40 (resurfacing every 20 years)
Nodal infrastructures	
Interchanges	50
Commuter parking facilities	50
Bus stops	20
Wharves	40
Rail stations	50
System infrastructure	
Rail signals and communications	10-20
Traffic lights	20-30
Control systems (IT system)	5
Fleet and rollingstock	
Bus	15
Rollingstock	35

12. Contingency

Contingency allows for possible cost increases and the uncertainty of cost estimates. In TfNSW, there is a Project Cost Estimating Standard released in 2012 which provides some guidance for rail projects. Table 78 shows the level of contingency required at the strategic phase of rail projects to be applied to the base estimate.

Table 78 TfNSW contingency allowance

Category	Types of projects	Stage	P50	P90
Rail	Light Rail and Heavy Rail	Strategic Phase	40%	60%
Road	Major projects	Strategic Phase		30-70%
	Other projects	Strategic Phase		15-25%

Source: TfNSW (2012) Project Cost estimating standard.

The RMS uses its Project Estimating Guide to produce cost estimates. It has a policy of producing only P90 estimates. These are estimated at the strategic, concept and detailed design phase. For major road projects a contingency of 30-70% is applied to base estimates whereas for other road projects the contingency ranges from 15-25% at the Strategic phase.

The Australian Government on the other hand has the following levels of contingency for rail and road projects. It requires cost estimates for project proposals at both the P50 and P90 levels.

Table 79 Commonwealth contingency allowance

Category	Types of projects	Stage	P50	P90
Rail	Light Rail and Heavy Rail	Strategic Phase	20-40%	30-70%
Road	Highways	Strategic Phase	10-15%	25-40%

Source: Department of Infrastructure and Transport (2012) Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction, Canberra.

13. Disability

Rail station lifts are important station facilities for wheelchair access. Research suggests that economic benefits for people with disability are higher than benefits to regular passengers especially for accessible travel projects and programs. Research has been undertaken to estimate the benefit of lift to wheelchair users, people with disability and regular users, as shown in Table 80 below.

Table 80 Benefits of rail station lift to passengers (\$/train trip, in March 2016 dollars)

User group	Regular passengers	Mobility challenged (mild disabilities)	Wheelchair
Sydney Station Survey 1997 (WTP) (A)	\$0.66	\$2.59	
UK survey 2009 (B)	\$0.07	\$0.83	\$1.50
UK survey 2007 (C)	\$0.56	\$3.41	
Sydney Observation Survey (WTP) (A)		\$3.58	\$4.03
Recommended value (based on SP surveys from Sydney Trains)	**\$0.66**	**\$3.09**	**\$4.03**

Sources: (A) Douglas (2011) Estimating the user benefit of rail station lift, ATRF 2011, (B) Duckenfield et al (2010) Measuring the benefits of the access for all programme, European Transport Conference 2010, (C) Maynard, A, (2007) Monetising the benefits of disabled access in transport appraisal, Transed 2007 Conference Transport Canada.

Based on Sydney Rail Stations Survey undertaken by RailCorp in 2009, wheelchair users account for 0.05% and mobility challenged passengers account for 8.1% of total passengers. In the evaluation of station or interchange upgrades, an economic benefit of \$0.66 for regular passengers and \$4.03 for wheelchair passengers can be included. Mobility challenged passengers include elderly people and those with heavy luggage, bicycle and strollers. The benefit of this group is estimated at \$3.09 per train trip.

14. Option Value

Option Value represents the individual's willingness to pay to have an option or potential to use another mode of transport even if they may not use it. For example, a car driver benefiting from having the option of a bus service available in case the car unexpectedly breaks down.

The following factors need to be considered when estimating Option Value:

- The catchment area. This should consider the number of households that are likely to be affected by the project. A catchment area of 2km is appropriate for minor stations while a catchment of 5km is suggested for main stations.

- Alternative transport solutions in the area. If a train service is added to an area where public transport does not exist in the Base Case, the full option value is used. If there is already an existing bus service, the option value is lower and is the difference between the train and bus option values.

There is limited evidence of monetary values for Option Values in NSW. As a result, it is recommended to be included as a benefit as part of the sensitivity test. Table 81 provides indicative monetary values for Option Value.

Table 81 Option Value ($/household per annum)

New service type	Option value only	Option value and Non-use value[1]	Mixed mode package value
Introduce train service where no public transport exists	$265	$443	
Introduce bus service where no public transport exists	$145	$242	
Introduce both bus and train service where no public transport exists	$265	$443	$685
Introduce train service where bus exists	$120	$201	

Source: UK DfT 2013, Transport Analysis Guidelines. Values in March 2016 dollars and converted to Australian Dollars.

1 Non-use value refers to the value placed on the existence of a service regardless of any possibility of future use of the individual.

15. Key Indices

Table 82 presents the key indices used to escalate the parameter values and forecast.

Table 82 Key indices for backcasting and forecasting

	Indices	Uses	Historical				Forecast	
			2012/13	**2013/14**	**2014/15**	**2015/16 (To March 2016)**	**2016/17**	**2017/18**
1	CPI Sydney (Index)[1]	Congestion cost; Operating & maintenance cost; Infrastructure cost; Crash costs; Environmental externality costs; Active transport costs; Road maintenance cost; Disability costs; Option value	102.58	105.23	107.25	108.73	110.91	113.40
2	CPI Private Motoring (Index)[2]	Light VOC	100.60	102.33	98.65	97.67	99.62	101.86
3	CPI Maintenance & Repair (Index)[3]	Vehicle costs	104.28	103.00	101.43	104.50	106.59	108.99
4	CPI Motor vehicles (Index)[4]	Vehicle price	98.53	95.55	95.68	97.77	99.72	101.97
5	AWE NSW ($)[5]	Value of Travel Time; Labour	1403.35	1440.05	1502.20	1527.30	1565.48	1608.53
6	PPI road freight (Index)[6]	Value of freight travel time; Heavy VOC	104.23	106.28	107.20	105.30	107.41	109.82
7	Fuel cost excluding GST (Cent/L) - petrol[7]	Unleaded petrol fuel cost	87.9	91.8	76.8	63.80	65.08	66.54
8	Fuel cost excluding GST (Cent/L) – diesel[7]	Diesel fuel cost	91.8	95.3	76.6	58.70	59.87	61.22

Source: Estimated by Economic Evaluations, TfNSW 1. ABS 6401.0 All Groups CPI Sydney. CPI forecast from NSW Treasury Budget Paper 1;
2. ABS 6401.0 CPI private motoring Australia. Assume growth by Sydney CPI.
3. ABS 6401.0 CPI maintenance & repair of motor vehicles Australia. Assume growth by Sydney CPI.
4. ABS 6401.0 CPI motor vehicles Australia. Assume growth by Sydney CPI.
5. ABS 6302.0 Average Weekly Earnings, Full Time Adult Ordinary Time Earnings NSW Seasonally Adjusted. Assume growth by wage price index from NSW Treasury Budget Paper 1.
6. ABS 6427.0 Producer Price Index Australia road freight transport. Assume growth by Sydney CPI.
7. Average of actual Sydney monthly fuel prices from Exxon Mobil TGP. Assume growth by Sydney CPI.

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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, the Long Term Transport Master Plan 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*" V1.7, , Appendix 4 - Economic Parameter Values and Valuation Methodologies updated to June 2016.
- Transport and Infrastructure Council, "Australian Transport Assessment and Planning", (previously called National Guidelines for Transport System Management (NGTSM)) with the latest release on 31 August 2016.
- NSW Treasury, "NSW Government Guidelines for Economic Appraisal", OFM tpp07-5, July 2007.

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 / Sydney Trains 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	**@4% 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%	**@4%**	**@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 4%, 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.

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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	SCORED QUALITATIVE ASSESSMENT — BASE CASE AND OPTIONS: BASE CASE	1	2	3	4
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**	**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.**

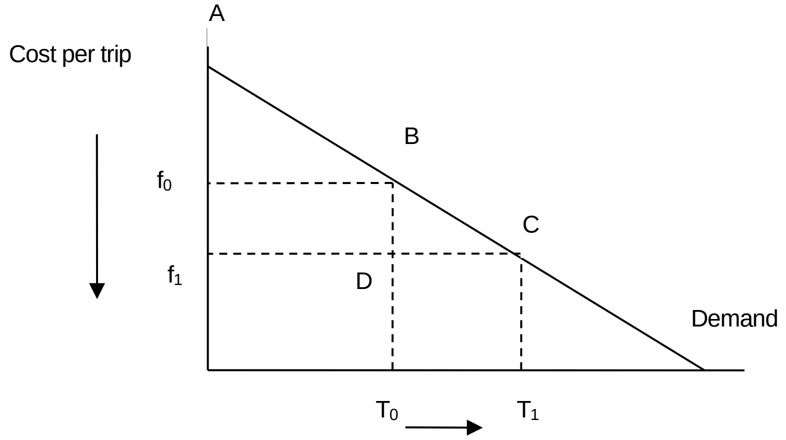
APPENDIX 9

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:

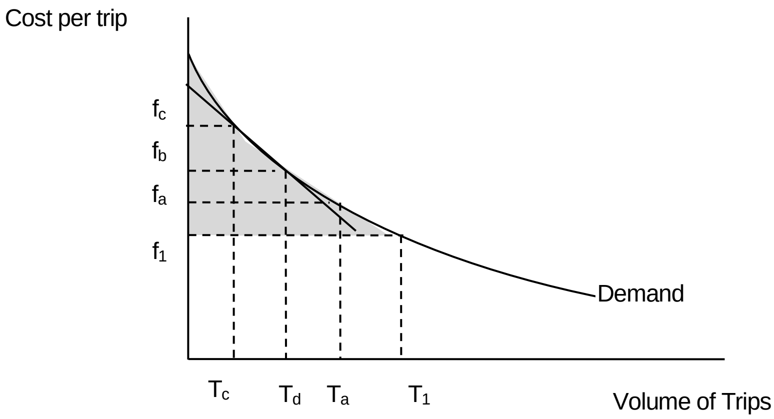
$$CS = \frac{f_1 \, x \, Q}{\varepsilon} = \frac{f_1(T_1 - T_0)}{\varepsilon}$$

where:
CS = consumer surplus
f = average fare
Q = number of induced trips (T_1-T_0)
ε = fare (price) elasticity

<u>Numerical Integration</u>

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[93]. 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



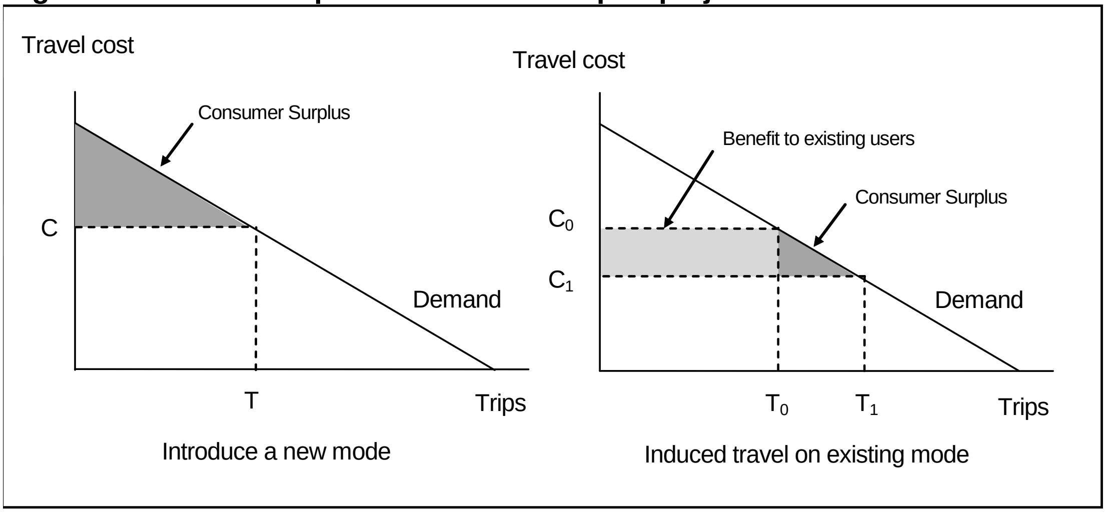
2. Use of Logsum measure of consumer surplus benefits

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.

93 Nellthorpe, John & Hyman, Jeff (2001). Alternatives to the Rule of Half in Matrix-Based Appraisal. Institute of Transport Studies, UK

Figure 3 Consumer surplus benefits of transport projects



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:

$$E(CS_n) = \frac{1}{\propto n}[ln\left(\sum_{j=1}^{JA} eVA_{nj}\right) - [ln\left(\sum_{j=1}^{JB} eVB_{nj}\right)$$

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, ……, JB*, representing that there are *JB* transport alternatives. After transport improvement, *j = 1,2, ……, 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

$ln(\sum_{j=1}^{JA} eVB_{nj})$ represents total utilities derived by all individuals *n* from all transport mode alternatives *JB* before transport improvement.

$ln(\sum_{j=1}^{JA} eVA_{nj})$ 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*.

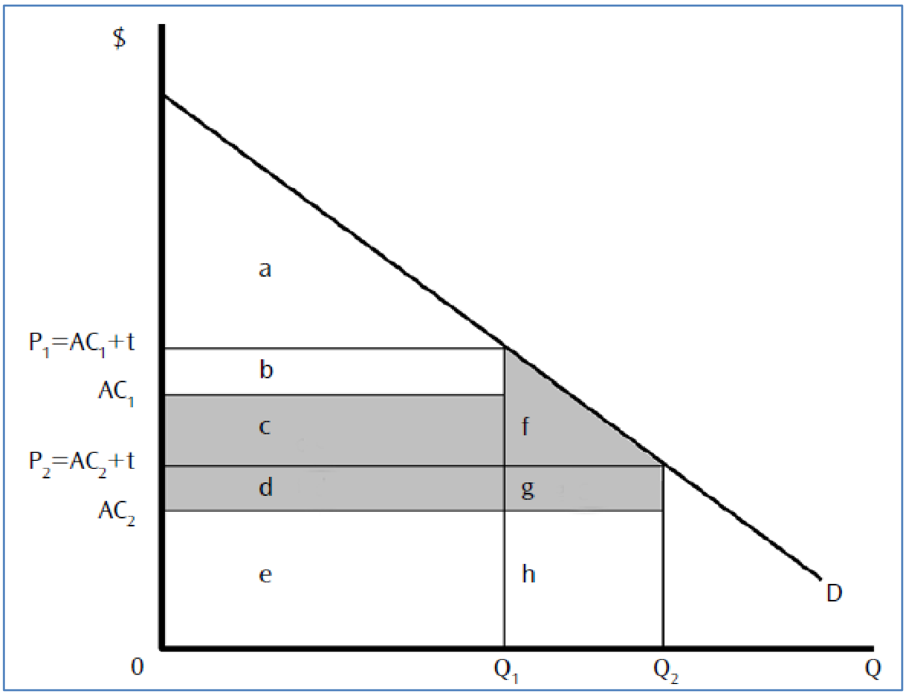
Theoretically, the logsum approach is more accurate because it is based on actual demand curves, while the ROH approach assumes the linearity of the demand curve as shown in Figure 1. However, the logsum approach has not been used often in actual economic appraisals. This is because the logsum is essentially 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≥1 or NPV≥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

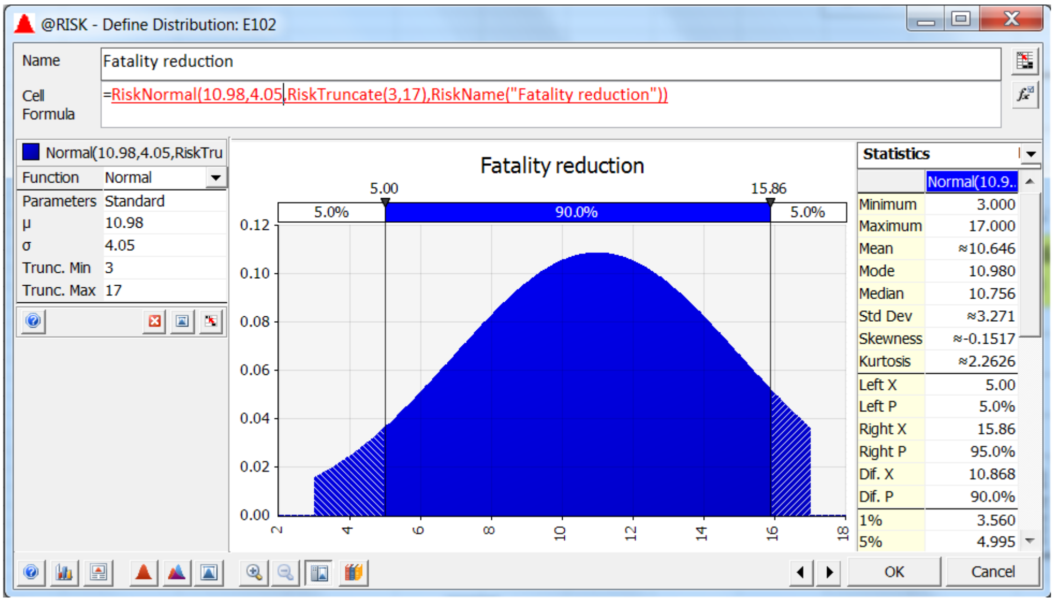
Statistical modelling shows that the preventable fatalities are 11.79 per annum without the campaign reduced to 10.98 with the campaign (see table below). The estimated preventable fatality reduction is subject to certain level of statistical confidence, which is set as the first input variable.

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**

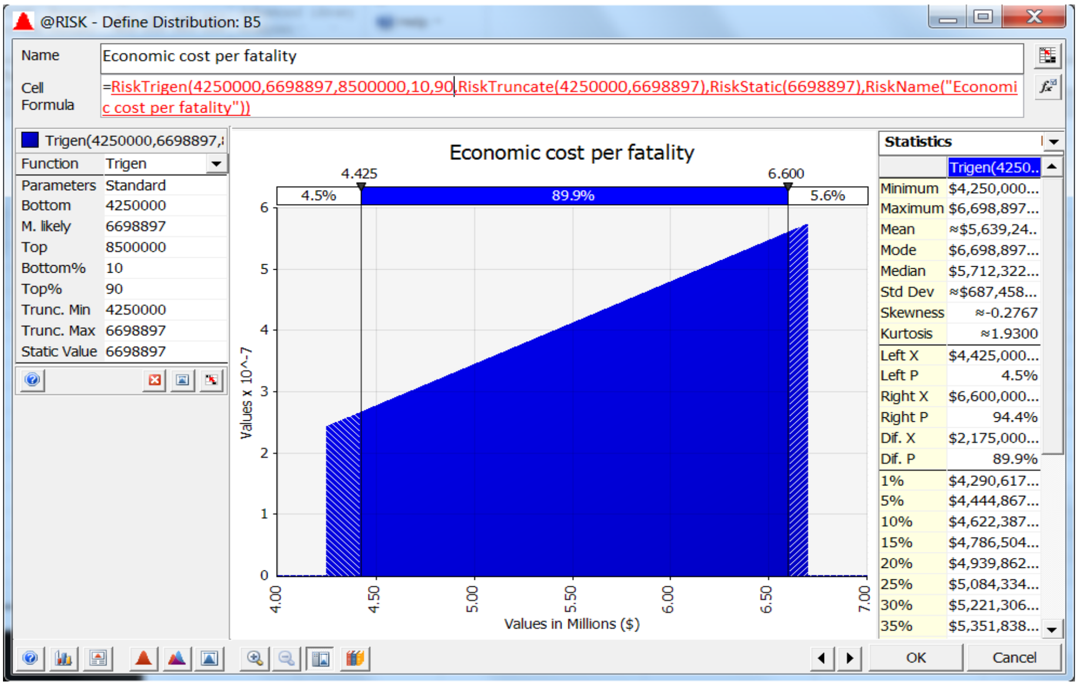
The historical preventable fatality data from 2003/04 to 2014/15 roughly follow a normal distribution, with the standard deviation of 4.05, minimum value of 3 and maximum value of 17. As such, the

@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.



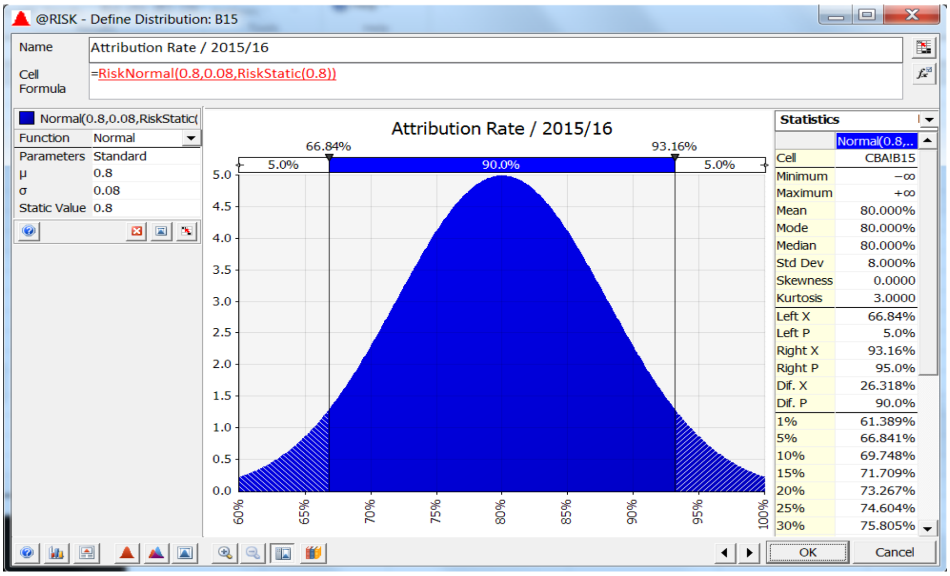
@Risk Input Variable 2: Economic cost per fatality

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:



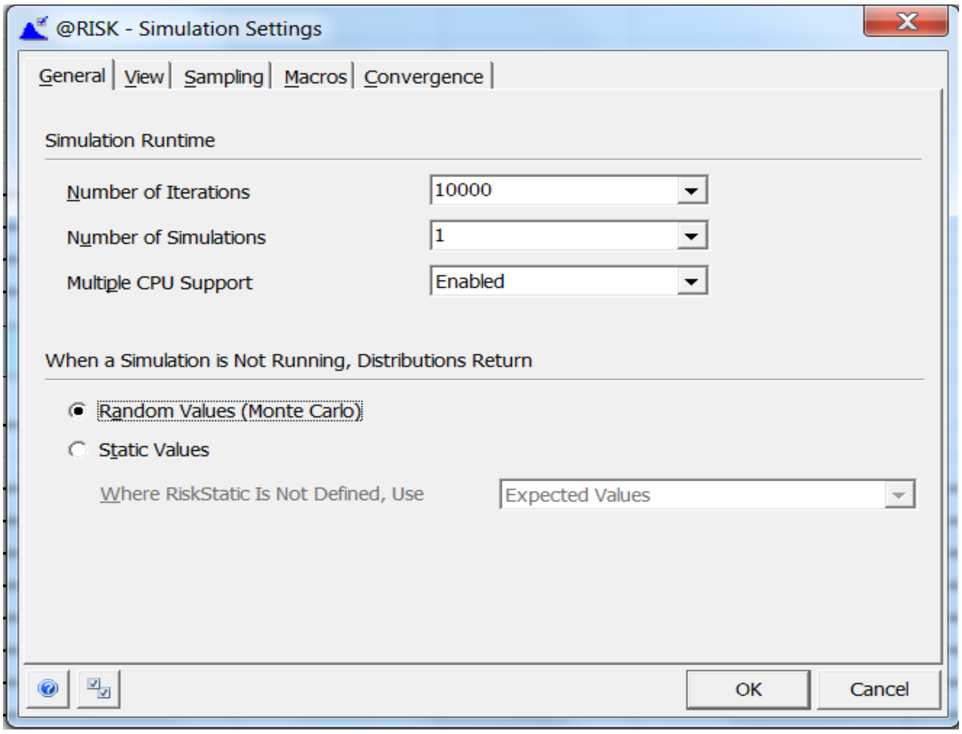
Run @Risk Simulation for identified risk elements

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

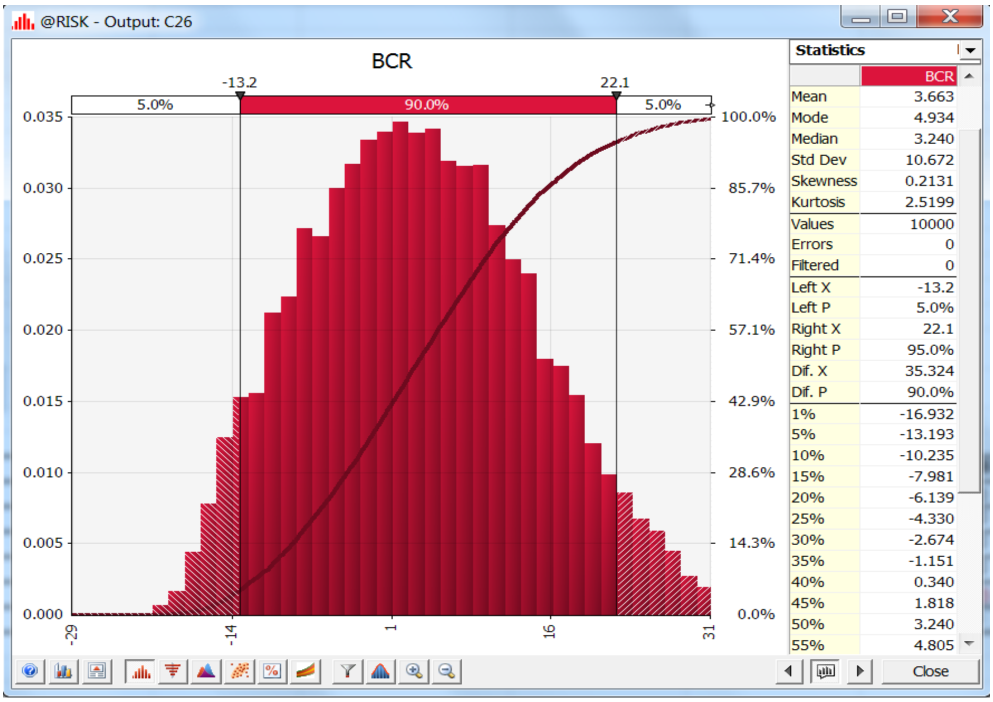
	Discount rate 7%
PV Cost ($m)	$1.40
PV Benefit ($m)	$6.13
NPV ($m)	**@Risk Output 1**
BCR	**@Risk Output 2**

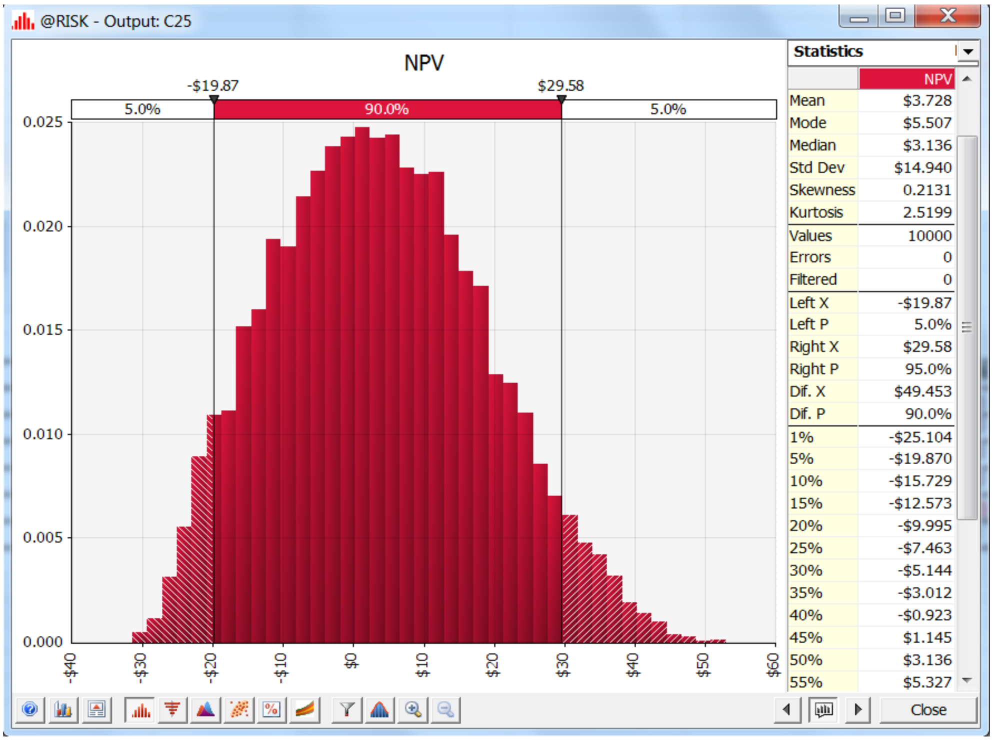
In the Simulation Settings, specify the number of iterations and number of simulations (Figure below). When a simulation is running, @Risk randomly draw values from the specified input variables. A typical simulation will run 1-2 minutes depending on model complexity, number of input variables and simulation 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[94]. 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[95]. In the USA, the social exclusion issues are incorporated in "environmental justice" and "just transportations"[96]. In Canada, social exclusion has been regarded as a transport planning and transport equity issue[97]. In Australia, research has been undertaken on social exclusion for specific groups (e.g., children)[98] or specific region[99]. Social exclusion has not been accommodated

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

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. A potential Transport Social Exclusion Index is described in the table below[100]. It uses six factors that

[100] Adapted from "Social inclusion as a transport planning issue in Canada", Victoria Transport Policy Institute, 2003

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	
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)[101] 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 $6.88 per trip (half of value of travel time of $13.76/h, see Appendix 4, Table 1). The average public transport fare is estimated as $3.30 per trip (see Appendix 4, Table 38). The total generalised travel cost would be $10.18 for the trip. As the person is willing to pay $19.30 for the trip, the consumer surplus is $9.12 for the trip. The willingness to pay and its consumer surplus are particularly relevant to the assessment of new public transport services.

[101] 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

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.

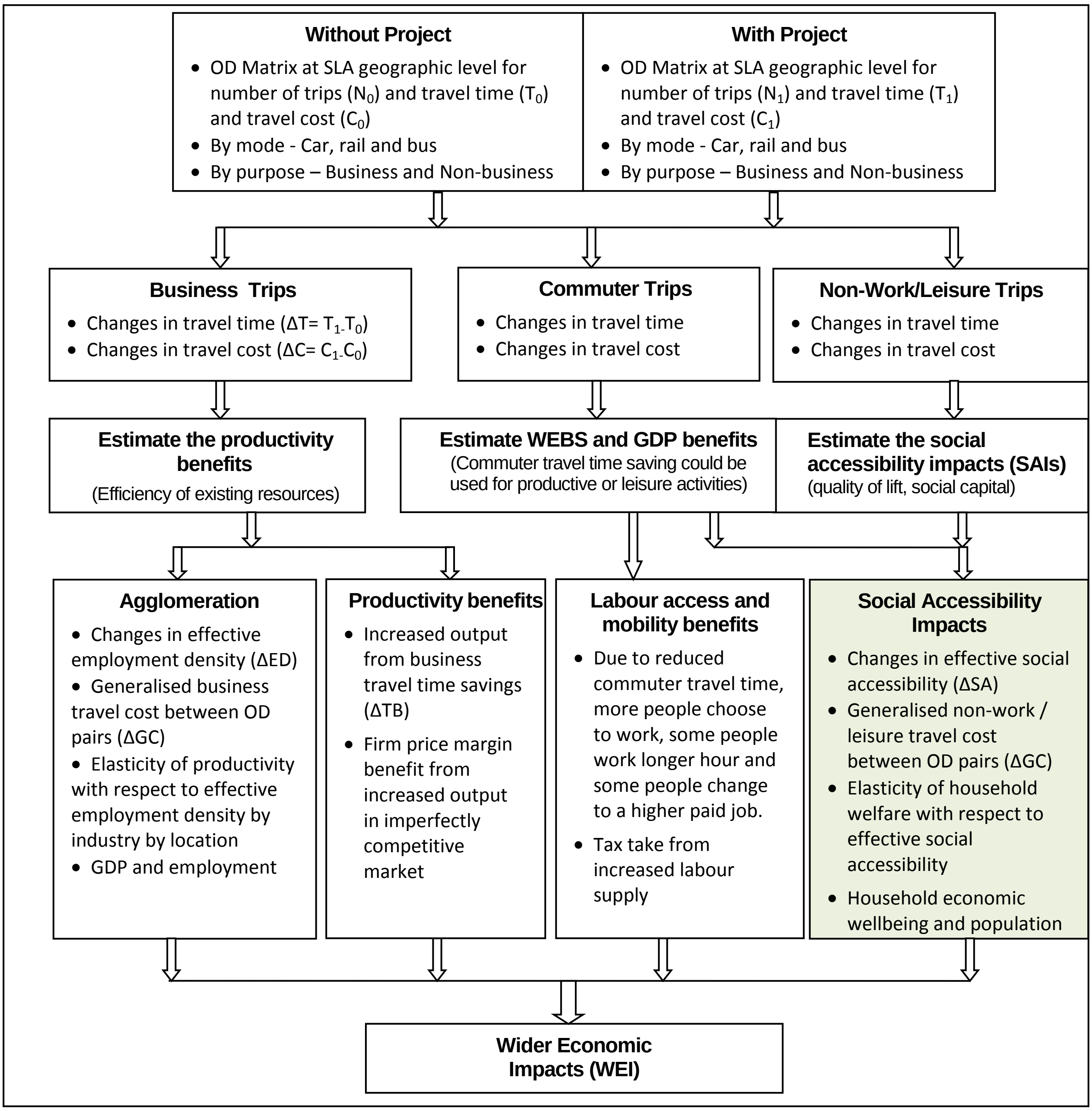
These outputs are loaded to a macroeconomic model to estimate the impacts of transport investments on welfare and gross domestic products. The welfare impacts refer to agglomeration economies, benefits of the increased competition caused by the increased market catchment due to better transport infrastructure, 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.

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[102]

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

[102] 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

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