Queensland Government



Transport and Main Roads

# Cost-benefit Analysis Manual

## Road projects

Connecting Queensland
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# Introduction

# 1 Introduction

The *Cost-benefit Analysis manual* (the manual) is a practical reference tool for Transport and Main Roads (TMR) staff and consultants evaluating the economic merits of transport and road projects. The manual replaces the *Cost-Benefit Analysis Manual for Road Projects*, which was produced in 1999.

The manual presents a number of case studies to help give system users an understanding of the principles involved in evaluating transport and road projects. It details TMR's cost-benefit analysis (CBA) tool, known as CBA6, which is used to evaluate rural and urban projects.

The manual is aimed at a broad range of stakeholders including policy makers, managers, regional staff, project managers, engineers and system users. It is divided into three different parts to help meet the needs of all stakeholders:

- *Theoretical Guide*
- *User Guide*
- *Technical Guide*

## 1.1 Purpose

Project evaluation is an essential element in the development and delivery of successful transport systems. CBA remains a complex and highly technical process and usually should be undertaken only by qualified and experienced specialists in economics. The purpose of the manual is to provide system users and decision makers within TMR with an appreciation of how welfare economics in general, and CBA in particular, may be applied to support the project evaluation process. Regions using CBA6 will find the *User Guide* helpful.

CBA provides a framework for organising information, listing the advantages and disadvantages of each alternative course of action in terms of economic values and ranking alternatives on the criteria of net economic value. CBA can be used to compare alternatives for transport and road projects by the net benefits that they create over time, when the broad social view is important and when projects may be characterised by a flow of benefits and costs over time.

CBA helps the decision-making process by:

- determining what constitutes a tangible benefit or a cost to the wider community over and above a 'no project' alternative
- preventing 'double counting' of either benefits or costs
- incorporating a time dimension via discounting of benefit and cost streams
- identifying net benefits of project alternatives
- presenting how variance, particularly assumptions, influences the net benefits of alternatives
- presenting the preferred course of action which offers the highest net benefit to the community.

More broadly, CBA can help by:

- bringing economic theory into decision making
- improving the logic of thinking and problem solving
- reducing the complexity of decisions.

The objective of the manual is to provide techniques and methodologies for undertaking CBA and promoting the use of project evaluation in the decision-making process.

CBA can be a complex process, and CBA6 cannot be applied in all situations. The manual provides the scope of evaluation that can be undertaken by system users without the need for specialised assistance.

## 1.2 Scope

The manual provides a comprehensive guide to CBA in the context of roads and transport. Concepts, theories, methodologies and processes relevant to CBA are explained in sufficient detail for any system user with a basic background in economics to comprehend. The manual focuses on the application of the TMR CBA tool (CBA6) but provides sufficient instruction and reference to alternative approaches to project evaluation. The manual is divided into three sections: the *Theoretical Guide*, the *User Guide* and the *Technical Guide*.

The *Theoretical Guide* introduces the reader to the theoretical basis of CBA. This section also discusses complementary issues associated with CBA such as the treatment of externalities and tolling. The section also contains a discussion of other important issues including development benefits and issues of Wide Economic Benefits. The manual does not provide general coverage of CBA or welfare economics outside of transport and roads.

The *User Guide* is an instructional aid for system users when operating CBA6. All characteristics of the tool are described in detail. Using 18 different case studies, the *User Guide* enables the navigation and exemplification of the functionality of all CBA6 modules.

The *Technical Guide* contains relevant information on, and a practical explanation of, the formulae and equations found in CBA6. It also explains the background and context of the tool within TMR. The technical guide also provides information relating to Austroads endorsed harmonisation publications, therefore establishing the technical basis for project evaluation in Australia.

## 1.3 Alignment with national strategies and guidelines

National frameworks, guidelines, processes and methodologies have been established which underlie Australian Government funding for transport and road projects. CBA is used to support funding submissions by outlining the viability of a project. The Queensland Government has also established a framework and process incorporating the economic evaluation of projects for state funding.

### 1.3.1 National Guidelines for Transport System Management in Australia

The Australia Transport Council (ATC) *National Guidelines for Transport System Management in Australia* is endorsed by the Council of Australian Governments as the high-level framework for transport system management. Volume 3 provides principles and methodologies for appraising transport and road projects. CBA is endorsed in the guidelines as an important decision-making tool. However, additional tools including strategic merit test, rapid CBA, non-monetised evaluation, detailed CBA, adjusted CBA and evaluation summary tables are also recommended.

### 1.3.2 Guide to Project Evaluation

The Austroads *Guide to Project Evaluation* provides guidelines and techniques for appraising transport and road projects, and is a complementary source of information to the manual. It also provides economic data sets for calculating travel time, vehicle operating costs, accident avoidance and externality benefits. These data sets are used by all transport and road agencies and jurisdictions in Australia and are regularly updated.

## 1.4 Alignment with state strategies and guidelines

The Queensland Government has established a framework outlining the overall direction and governance procedures for the planning and evaluation of projects. This framework is supported by a number of strategic processes and outcomes.

### 1.4.1 Project Assurance Framework

The *Project Assurance Framework* (PAF) is the Queensland Government's project evaluation process for project initiation, evaluation, procurement and assurance across government. The PAF is broken into the various stages of a project's lifecycle.

CBA is required at the preliminary evaluation and business case development stages of the PAF. At the preliminary evaluation stage, CBA is used to assess project options using incremental analysis. This includes determining all potential project impacts including any unpriced outcomes such as social and environmental. Each project option is evaluated under the same assumptions to ensure a suitable comparison can be made. The measurement of these impacts is refined at the business case stage along with more detailed sensitivity testing. The manual provides a more transport-specific focus on CBA.



### 1.4.2 Outcomes

The Queensland Government *Value for Money Framework* is used to progress potential projects under a Public Private Partnership (PPP) delivery model. If a project is considered to have PPP potential, the *Value for Money Framework* is used for business case development. The framework is also designed to help optimise the delivery of a project. Under the *Value for Money Framework*, economic CBA is required at the business case stage. A separate financial evaluation is used to determine the success of a project at the 'expression of interest' stage.

## 1.5 Alignment with TMR strategies and guidelines

TMR's strategic processes govern the way TMR identifies and develops transport and road projects from concept through to business case development and implementation. CBA aligns with each strategic process to deliver outcomes that are consistent with whole-of-government strategic objectives, and ensures TMR achieves value-for-money outcomes. The manual links to, and is aligned with, TMR's overall strategic priorities.

### 1.5.1 Roads Connecting Queenslanders

*Roads Connecting Queenslanders* (RCQ) outlines the strategic long-term direction for the road system in Queensland. The four road-based outcomes identified in RCQ are:

- safer communities
- industry competitiveness and growth
- liveable communities
- environmental conservation.

### 1.5.2 Queensland Transport and Roads Investment Program

The *Queensland Transport and Roads Investment Program* (QTRIP) details TMR's program of transport and road projects for the upcoming five years. Each project that is included in the QTRIP must include a CBA. 95% of projects that are justified on economic grounds alone, have a cost-benefit ratio greater than 1.

### 1.5.3 Program Management Framework

The *Program Management Framework* is applied when delivering a series of projects that make up a program. The framework identifies interdependencies between projects and ensures planning, scheduling and operations result in optimal delivery. It also measures the net economic impact of the program.

CBA helps identify projects that will be included in a program, and can be used to prioritise projects within a program.

### 1.5.4 OnQ Project Management Framework

The *OnQ Project Management Framework* is used to ensure the outputs and outcomes of a project are delivered in line with strategic objectives and policy.

Within the OnQ framework, CBA helps in project management throughout a project's lifecycle. CBA is undertaken at various stages including the project proposal, options analysis and business case stages for specific transport and road projects.

## 1.6 Project evaluation process

TMR's project evaluation process uses a three-stage CBA approach that incorporates:

- strategic merits test
- rapid evaluation
- detailed evaluation.

### 1.6.1 Strategic merits test

A strategic merits test evaluates a project's alignment with strategic policy and planning objectives. A strategic merits test should be undertaken for all projects to ensure they align with TMR's strategic and state-wide directions. A strategic merits test is normally undertaken at the project proposal stage.

### 1.6.2 Rapid evaluation

A rapid evaluation measures the 'headline' costs and benefits of a project and determines whether it should progress to the detailed evaluation stage. The rapid CBA is generally conducted in the options analysis stage.

### 1.6.3 Detailed evaluation

A detailed evaluation is a comprehensive analysis of a project, and extends on and refines the findings of the rapid evaluation. A detailed evaluation, incorporating CBA, should quantify all foreseeable project impacts. A detailed CBA provides sufficient evaluation rigor to support a funding submission and is usually undertaken at the business case stage.

## 1.7 Evaluation tools and methodology

CBA is the primary decision-making tool used by TMR to determine the net economic benefits of transport and road projects. Other tools may also be required to address non-monetary or non-quantifiable project impacts. These tools often incorporate a qualitative evaluation of project impacts, and include multi-criteria analysis, adjusted CBA, cost-effectiveness analysis and strategic merits tests. These tools can be used to complement the CBA or, in some instances, as an alternative to a quantitative evaluation.

The level of analysis needed will depend on a project's complexity, risk profile and degree of uncertainty. The purpose of the three-stage approach is to screen out projects at each stage that are unlikely to have merit in developing further.

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# Theoretical guide

# 2

## 1 Introduction to cost-benefit analysis

The application of economic analysis allows decision makers to make better choices regarding the alternative uses of scarce funds. In the case of infrastructure alternatives, those choices are made under conditions of limitation. The most common limiting factor is the availability of financial capital.

Due to the scarcity of resources, decision makers must direct their expenditure to those projects that offer the most efficient outcome. CBA can be used to help make these decisions.

The *Theoretical Guide* will explain the economic principles of CBA and how it is used to assist decision makers.

## 1.1 What is cost-benefit analysis?

CBA is a process used to determine the value of a project in relative terms. Project justification is measured as economic worth to the community. To evaluate a project's benefit to the community, a CBA will compare the benefit with the overall cost, to deliver and sustain the project. If overall benefits are demonstrated to exceed the expected costs, a project is considered economically viable.

As there is no real market for road expenditure (with a few exceptions such as toll roads), consumers are not able to register their preferences as they would in a competitive market. In this sense there is no effective market force which can be used to indicate the amount or frequency of road investment. In the absence of these market forces, CBA provides a framework to consider whether proposed allocations of resources are optimal.

CBA has a consistent approach and methodology that can be applied to all road projects thus enabling projects or project elements to be compared. The method applies monetary values to a project to ensure a robust measure of the economic costs and benefits. This creates a degree of transparency and comparability for the decision maker when considering competing alternatives for funding.

## 1.2 Welfare economics

The theoretical basis for CBA as an analytical tool is developed from a branch of economics called welfare economics. Welfare economics is concerned with the overall economic wellbeing of the community (as compared to individual wellbeing within the community). Welfare economics addresses the most fundamental economic problem – how to efficiently allocate and manage scarce resources to satisfy the demands of the community.

In broad terms, the measure of benefit is determined by the degree to which any proposed pattern of resource use will satisfy the demands of individuals in the community. Costs are represented by the value the community places on the resources required to satisfy those demands.

Welfare economics concentrates on changes in resource use. As a tool for evaluating the economic consequences of changes in patterns of resource use (or 'resource allocation'), CBA is generally concerned with capital projects in the public sector, although CBA can be broadly applied to any choice which is constrained by limited resources or opportunity. It finds particular application in areas of public sector capital works where the market does not provide adequate or complete signals to guide resource allocation (examples being roads and public transport), or where market outcomes might sometimes be socially unacceptable (such as health and social welfare).



Note: Although a familiarity with these concepts is not fundamental to the effective use of the manual, an understanding will assist in the conduct of more complex economic evaluations, and in assessing the implications of the results of CBA work.

### 1.2.1 Economic efficiency

Economic efficiency refers to the optimal allocation of resources in the community where the 'best possible' allocation is made to satisfy individuals to the greatest extent achievable. That is, if resource allocation changes, no individual can theoretically be made better off without another being at least equally worse off. This definition of economic efficiency comprises two technical prerequisites:

1. technical efficiency
2. allocative efficiency.

Technical efficiency is maximised when there is no possibility to shift resources to an alternative allocation and achieve an increase in total output. Allocative efficiency is achieved when no individual can be made better off without making another individual equally worse off. While technical efficiency is a prerequisite of economic efficiency, the failure to achieve allocative efficiency in any sector of the economy may reduce welfare outcomes for the community as a whole. When choosing between alternatives, it is important to achieve both technical and allocative efficiency in order to maximise community outcomes.

The argument for economic efficiency leads to discussions on subset theories that are defined elsewhere in this chapter. Such theories include the theory of consumer surplus and subsequent willingness to pay principal, Pareto efficiency and the Kaldor-Hicks criterion (K-H).

### 1.2.2 Theory of consumer surplus/willingness to pay

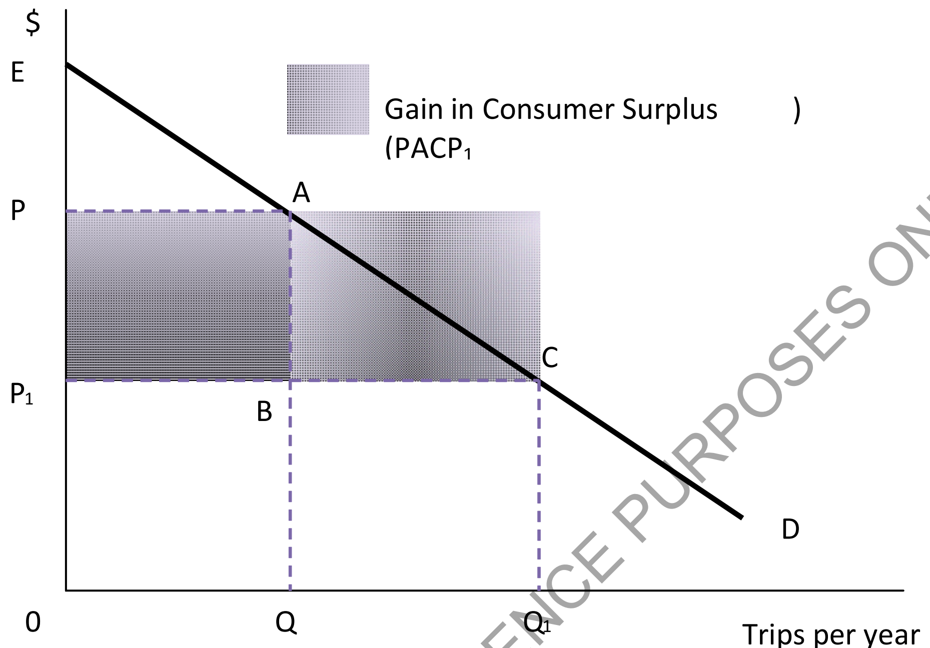
The theory of consumer surplus is based on an individual's willingness to pay for particular goods or services. It provides a link between individual preferences through consumer behaviour theory.

Willingness to pay identifies the amount consumers are willing to pay for particular goods or services in order to satisfy their demand. Thus, willingness to pay is a mechanism by which the market rations scarce resources among competing demands. Resources are allocated to consumers who value those resources the most, and hence are prepared to pay the most for them.

Market prices are the reflection of consumers' combined willingness to pay to achieve the satisfaction (or utility) arising from the consumption of goods and services.

The benefit that an individual consumer receives from undertaking their consumption activity is measured through their willingness to pay for goods or services. When a consumer is able to buy goods or services at a price lower than they would have willingly paid for those goods or services, the difference is said to be their surplus satisfaction, or the consumer surplus. Consumer surplus is presented graphically in Figure 1.

*Figure 1: Consumer surplus*






Referring to Figure 1, consumer Q is prepared to pay price P for the goods or services, but the market price is only $P_1$. Consumer Q has therefore achieved a satisfaction surplus of $\{P-P_1\}$. This consumer has valued the goods or services at P, but only had to pay $P_1$ to obtain the goods or services.

This analysis can be repeated for all consumers in this market. The accumulated consumer surplus is represented therefore as the summation of all individual surpluses and is shown in the diagram as area E-$P_1$-C when the price is $P_1$.

In the event that the price level was originally P, and is subsequently reduced to $P_1$, the increase in consumer surplus can be measured as the area P-A-C-$P_1$ (shown on the diagram as the shaded area).

At an aggregate level, CBA measures total surplus with and without the capital investment. If total surplus is greater post initiative, then the project should proceed, as it has a positive net impact. If the total surplus is less after the initiative, then the project should not proceed, as it has a negative net impact.

Total surplus, however, does not measure the equity effects of a welfare increase. Even in a situation where a project yields an increase in total community welfare, some people may be disadvantaged. A total surplus gain from a project does not mean everyone is better off, as the gains may be captured by some individuals while others lose, without offsetting compensation. (This is discussed further in Section 1.2.2.2).

For example, TMR is conducting an economic analysis of a potential widening and reconstruction of a rural road with demand given by D in Figure 1. Current road use is identified by Q, which shows the current quantity of road use (trips per year). These users incur (through operating costs and travel time costs) annual costs for their trips made, which are valued at P. The widening and reconstruction of the road provides increased capacity and a smoother ride which results in the reduction in journey time and vehicle operating costs. As a result, the upgraded road is expected to reduce the aggregate trip cost to $P_1$. Road users at Q now experience a cost reduction of $P_1$-P. The aggregate benefit to these users can be measured by $(P_1\text{-}P)Q$ or the area under PABP1.

As travel costs have significantly declined (P1-P) with the upgrade, users who were not prepared to pay the original price will be attracted to the newly upgraded road which now has a lower cost. Assuming that the demand curve is linear, the net value of the generated trips is given by (P1-P)/2 and the total value is given by (P1-P)(Q1-Q)/2. For more detailed information on the calculation of generated traffic, see Section 8.5 of the *Technical Guide*.

The willingness to pay for the road is illustrated by the area under the demand curve up to the point representing the current level of consumption. In Figure 1, total willingness to pay for Q trips is measured by the area E-A-Q-0. The logic states that someone is willing to pay 0-E for the first trip, and that person and others are willing to pay amounts measured by the height of the demand curve for subsequent additional trips.

#### 1.2.2.1 Pareto efficiency

Pareto efficiency is related to allocative efficiency. A Pareto improvement can be achieved if a shift in resource allocation results in one individual being better off without any other individual being worse off. If a change in resource allocation cannot make an individual better off without making someone worse off, then the allocation is termed Pareto optimal and no improvement in resource allocation can be achieved. If Pareto efficiency does not exist, there is potential for a Pareto improvement by shifting resources to a better use. In CBA, a project does not have to constitute a Pareto improvement to add economic welfare. The potential for a Pareto improvement is sufficient. i.e. the 'losers' could theoretically, but need not actually, be compensated by the project. This leads into further optimisation discussions using the Kaldor-Hicks criterion. (Sinden & Thampapillai 1995, Campbell & Brown 2003).



#### 1.2.2.2 Kaldor-Hicks criterion

In project evaluation, ensuring that no one is disadvantaged usually requires compensation to one or more parties. This is the essence of the Kaldor-Hicks (K-H) criterion which states that even if some members of the community are made worse off as a result of undertaking a project, the project confers a net benefit if the gainers from the project could (theoretically) fully compensate the losers and remain more satisfied themselves after making this compensation.

For instance, if a road project disadvantages homeowners but road users gain a time saving, the homeowners could be compensated for their loss from the gains of the road users. If so, the project satisfies the K-H criterion (Campbell & Brown 2003).

## 1.3 Resource costs and shadow pricing

Under perfect market assumptions the resource cost of goods or services is accurately reflected in the market price. Put simply, this means the economic value of the goods or services is reflected in the price paid for those goods or services.

When the perfect market assumption is relaxed, for example where a buyer or seller has undue influence over the price or where there are other limitations to efficient pricing, the market price may not accurately reflect the economic value of the goods or services. In these cases, it is common to apply a shadow price. A shadow price is a non-market determined price that has been calculated to approximate the economic value of the resources involved in the provision of the goods or services.

There are two common reasons for a market price to be economically distorted. First, market prices generally include taxes and subsidies. These distortions must be excluded as they are classified as a transfer within the community and not a use of resources. Second, many impacts (such as noise and other forms of pollution) have no market price as no market currently exists. Thus, in CBA, shadow prices are used to ensure that these distortionary impacts do not skew the results of the analysis.

Nationally endorsed shadow prices used within CBA are provided as an appendix to the manual as they are released through Austroads publications.

## 1.4 Discounting

It is important that the CBA takes into account both the time value of money and the alternative use to which the financial capital could have been applied. CBA typically involves comparing benefit and cost streams that occur over long time frames.

The time value of money refers to an individual's intertemporal preference function. With respect to the value of money, this determines an individual's willingness to value a fixed nominal amount of money at different points in time. For example, a rational individual would prefer to receive a dollar today than in five years' time. This preference can be interpreted as the individual placing a higher value on money in the present time period than on the same money in a future time period.

The difference in value is due in part to a perceived risk of uncertainty in the future, and an underlying assumption by all individuals that they will be better off in the future (Perkins, 1994, p53).

The alternative use to which the financial capital could have been applied is referred to as the opportunity cost of capital. The opportunity cost of capital is defined as the highest rate of return that the financial capital could have received if it was allocated to the next best investment alternative. In other words, one of the costs of using the financial capital on a proposed project is the income that could have been earned if that financial capital had been invested elsewhere.

These factors are taken into consideration in CBA by applying a discount rate. The discount rate is defined as the rate at which future cash flows must be adjusted to reflect the current values of those cash flows. The discount rate incorporates the time value of money and the opportunity cost of money.

## 1.5 Selection of discount rate

The selection of the appropriate discount rate to use in a CBA depends largely on the requirements of the state and national treasury departments. Projects funded by the state require the use of discount rates determined by the representative state treasury, while projects which are funded at a federal level require a discount rate determined by the federal authority. In either case, a sensitivity analysis around the determined rate will be required. The calculation and selection of the discount rate is quite complex and is the subject of ongoing debate in academic circles. Accordingly, it is outside the scope of the manual.

### 1.5.1 Real vs nominal

As noted above, a CBA will estimate the costs and benefits of a project over time. Economic theory suggests that if inflation is included in an analysis through the use of nominal prices (prices including inflation), it may create a bias within the evaluation. Inflation tends to overstate benefits and costs. The inclusion of inflation is therefore a distortion to the real economic value.

In order to include nominal prices in CBA, there is a requirement to predict future inflation rates. Since such predictions introduce further uncertainty in the estimation process, inflation should generally be avoided in CBA and real prices (prices net of inflation) should be applied in preference.

If it was theoretically possible to accurately predict the rate of inflation throughout the life of the evaluation, then nominal pricing should be used. However, for the evaluation to be consistent, the system user would also need to use a nominal discount rate (i.e. a discount rate inclusive of projected inflation). Under normal conditions, real prices are used in CBA so a real discount rate (net of inflation) should also be used.

### 1.5.2 Social vs private

Essentially, the concept of the social discount rate has arisen due to the inability/failure of the market to adequately value benefits that accrue in the later years of the evaluation period. This is particularly the case for traditional public sector projects such as schools and hospitals where the benefits are typically derived some time in the future. As a consequence, the social discount rate is below the market discount rate (Brown/Campbell, 2003).

### 1.5.3 Project requirements

Through the Project Assurance Framework (2008) CBA guidelines, the Queensland Treasury provides basic advice on the selection of appropriate discount rates for Queensland projects. The Queensland Treasury states that the following reference points may be used in determining the discount rates for projects:

- The interest rate for government borrowings for a term relevant to the expected duration of a project (e.g. for Queensland, this would be the interest rate for 10-year QTC bonds for a project expected to generate most costs and benefits within 10 years). An allowance for inflation can be deducted from this rate if costs and benefits are expressed in real terms.
- The long-term average real economic growth rate, with an additional allowance for major risks and time preference for current consumption. As this is a real discount rate, an allowance for inflation would need to be added to discount flows of costs and benefits expressed in nominal terms.
- The rate of return on debt and equity for comparable private sector projects (as a public sector project would be competing with other activities for debt and equity capital).

Whenever these methods are used to determine a discount rate, sensitivity testing with higher or lower variations on the chosen rate should be used to allow for a margin for error, and the possibility of a project having unique characteristics which would limit the relevance of rates of return for other projects as a benchmark.

A ready reference on discount rates is included in the UK Government, HM Treasury, The Green Book, and Appraisal and Evaluation in Central Government, 2003 (Austroads PEGv2).

Traditionally, infrastructure projects in Queensland have used 6% as the standard discount rate including sensitivity analysis at the 4%, 7% and 10% discount rates. Before any discount rate is applied in a CBA, it is advisable to seek confirmation of the appropriate discount rate from the relevant authority.

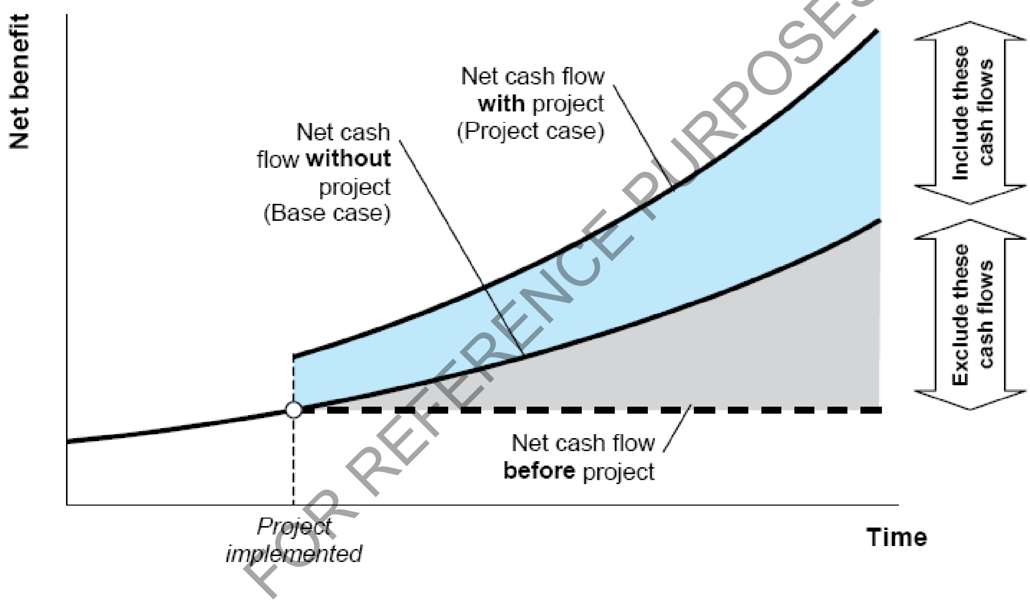
## 1.6 Definition of cases

Two hypothetical futures exist in any CBA process: the future with a project (project case) and the future without a project (base case). A successful CBA is dependent on the accurate and complete definition of both hypothetical cases within the model.

The base and project cases provide a comparison for calculating costs of capital investments and as such, the difference between them measures the change in total surplus attributable to an investment.

The first hypothetical case is the base case, which has previously been described as the world without a project. The base case should represent all future programmed and required investment based on the current level of service (business as usual). For example, when defining the base case of a highway upgrade project, it would not be accurate to exclude programmed maintenance. It is more likely that in the absence of a project the road would deteriorate to such a point where maintenance would be required. If maintenance were to be omitted, it is likely that the CBA would distort the results of a project.

*Figure 2: Base Case Definition*






Source: Austroads (2005 ) Figure

The project case is often more easily specified than the base case due to the amount of planning involved, and represents the future with a project. Accurate definition of the project case is required for an accurate CBA.

In practice, inaccurate CBA is often the result of incomplete, incorrect or inaccurate specifications of the evaluation cases. Therefore, it is necessary to ensure that the base case and project case specifications are a true reflection of the hypothetical worlds. Any incorrect specification of these cases can lead to misleading results either understating or overstating the net worth of a project. As the purpose of the CBA is to provide decision makers with enhanced information sets with which to make allocation choices, misleading results must be avoided.

## 1.7 Selection of decision criteria

Decision criteria are employed within CBA to provide governance on interpretation of the measurable outcomes of a project. The key decision criteria are:

- Benefit-Cost Ratio
- Net Present Value
- First Year Rate of Return

### 1.7.1 Benefit-Cost Ratio

The Benefit-Cost Ratio (BCR) is defined as the present value of benefits divided by the present value of operating costs. A BCR greater than 1 indicates a project is economically viable while a BCR less than 1 indicates that a project is not viable. The BCR is the most widely used criterion with regard to transport, is applicable to both small and large projects and is unique to CBA (P21, Part 2, Austroads Guide).

### 1.7.2 Net Present Value

The Net Present Value (NPV) is defined as the present value of the benefits minus the present value of operating costs. The NPV can be used in all decision contexts and should be reported for all evaluations. One disadvantage of the NPV is that it tends to place a higher priority on larger projects (P21, Part 2, Austroads Guide).

### 1.7.3 First Year Rate of Return

The First Year Rate of Return (FYRR) advises on the optimal timing for construction. The FYRR is found by dividing the benefits in the first full year of operation with total costs. The optimal implementation time is the first year in which the FYRR is greater than the discount rate, otherwise deferral of a project is warranted. Consequently, the criterion indicates if the optimal construction period is now or in the future.

### 1.7.4 Decision rules

The following economic rules apply when interpreting and using the decision criteria:

If the BCR is greater than 1, a project is viable

If the BCR is less than 1, a project is not viable

If the NPV is greater than 0, a project is viable

If the NPV is less than 0, a project is not viable

IF the FYRR is greater than the discount rate, immediate construction is warranted

IF the FYRR is less than the discount rate, construction should be delayed

Note: The incremental BCR should be used when options involving different sizes of initiatives or standards of infrastructure are compared. It is defined as the present value of the additional costs when going from one size or standard to the next. It is used to select between mutually exclusive options (Page 89, Volume 5, ATC Guidelines).

## 1.8 Dealing with risk and uncertainty

All benefits and costs that are included in a CBA are based on forecasts. By definition, all forecasts contain an element of uncertainty and therefore risk.

Dealing with uncertainty requires a distinction between downside risk and pure risk. Downside risk arises since not all negative outcomes can be foreseen, causing evaluations to be biased in favour of a project[1]. If downside risk has been eliminated from projections, the remaining variation about the expected value is called pure risk. In most cases, pure risk can be ignored in CBA[2].

There are three accepted methods in CBA to manage associated project risks. These are the incorporation of risk in the discount rate, quantitative risk analysis and sensitivity analysis.

### 1.8.1 Risk analysis

Risk is defined as, 'A state in which the number of possible future events exceeds the number of events that will actually occur, and some measure of probability can be attached to them' (Bannock et al.2003, p. 338) (Austroads 2002, p. 3).

#### 1.8.1.1 Quantitative analysis

In order to model future risks, probability distributions are applied to event outcomes. A probability distribution takes the description of uncertainty a level beyond sensitivity analysis (which is noted as a variables uncertainty in discrete possible values). A probability distribution describes the likelihood of occurrence of values within a given range.

Discrete probability distributions incorporate known probabilities for the likelihood of a variable's uncertainty. The system user is able to calculate the expected value of the variable and use this as an estimate within the CBA, rather than a point estimate that would have been used if uncertainty was ignored.

### 1.8.2 Monte Carlo simulation

The characteristics of a variable's probability distribution are important inputs into formal risk modelling using spreadsheet add-ins such as the @RISK tool. The system user must decide on what type of probability distribution best describes the variable in question. When there are multiple uncertain variables in a project, this type of continuous probability modelling may be undertaken. In this case, distributions of simulated probabilities are assigned to the values of all key variables, and through repeated computer calculations based on random sampling of the values of the variables, a probable distribution is formulated to calculate the NPV of a project[3].



1 An example of bias in infrastructure assessment is noted as optimism bias.
2 See ATC Material, Volume 5, Section 2.1.1 or BTRE (2005) for a detailed explanation.
3 This type of technique is known as Monte Carlo simulation.

### 1.8.3 Sensitivity analysis

Sensitivity analysis is a simple, albeit limited, method of analysing the uncertainty surrounding CBA results. In its most basic form, it involves changing one variable at a time by a standard percentage, for example, +10% followed by -10%, or by an absolute amount to gauge how much NPV changes. If the NPV changes by only a small amount, (e.g. ±10% change causes a ±3% change in NPV), it implies that the uncertainty surrounding the variable is not significant and is not critical to decision making. Conversely, if the affect on NPV is large in percentage terms, the robustness of the CBA conclusions or its underlying assumptions can be called into question. It may be worthwhile to expend more resources to obtain a better estimate of the variable, though this will not reduce risk arising from its inherent volatility.

When choosing the percentage variations to use for sensitivity tests, a system user should consider the range of plausible values that a variable can take. The range of variance that a variable takes may not be symmetrical, owing to technical or other factors as informed by historic data or other sources.

Table 1 shows the sensitivity ranges for road initiatives recommended by Austroads.

*Table 1: Austroads Suggested Sensitivity Ranges*

| | Variable | Suggested minimum value | Suggested maximum value |
|---|---|---|---|
| Capital | Concept estimate | -20% of estimate | +20% to 35% of estimate |
| | Detailed costing | -15% of estimate | +15% to 25% of estimate |
| | Final costing | -10% of estimate | +10 to 20% of estimate |
| | Network operation | -10% of estimate | +10% of estimate |
| Traffic | AADT | -10% to -20% of estimate | +10% to +20% of estimate |
| | Proportion of HV | -5 percentage points | +5 percentage points |
| | Average car occupancy | -0.3 from estimate | +0.3 from estimate |
| | Traffic growth rate | -2% from forecast | +2% from forecast |
| | Traffic speed changes | -25% of estimated change in speed | +25% of estimated change in speed |
| | Changes in crash rates | -50% of estimate | +50% of estimate |

*Source: Austroads 1996. p28: 2005. p27.*

# 2 Measuring costs and benefits

This chapter provides an understanding of how benefits and costs are measured in CBA. This chapter will discuss both the measurement and estimation of capital and maintenance cost incurred by road agencies and road user costs, including travel time, vehicle operating costs, accidents and externalities.

## 2.1 Evaluation period

The evaluation period represents the period of time over which the benefits and costs of a project will be measured. The impact of a transport project will change over time as it moves through development, construction, commissioning and ramp-up, and then mature operations through to decommissioning and possible disposal. The evaluation period should incorporate both the initial time taken to develop and build a project as well as decommissioning or disposal costs associated with its eventual closure at the end of its operating life, however given future impacts are discounted, early establishment costs will generally far outweigh closure costs in NPV terms.

### 2.1.1 Selection of analysis period

The period over which costs and benefits are calculated in a CBA should reflect the physical life of the asset. The evaluation period can incorporate both the physical life and the time taken to complete the project. For example a project that takes 3 years to complete can have an evaluation period of 33 years, incorporating a 3-year construction period and a 30-year operating life. This will ensure a whole-of-life cost comparison for a project as against other projects. The recommended evaluation periods for a number of different transport projects are shown in Table 2.

*Table 2: Estimated economic lives for infrastructure assets*

| Type of infrastructure | Asset Class | Estimated Economic life (years) |
|---|---|---|
| Systems infrastructure | Control centres (IT systems) excluding bridges | 4 |
| | Rail signals and communications | 10-20 |
| | Traffic Lights | 20-30 |
| | Navigation equipment | 5-20 |
| Network infrastructure | Earthworks | 100-150 |
| | Bridges | 40(timber),120(concrete) |
| | Tunnels | 100 |
| | Culverts | 100-120 |
| | Rail | 100 |
| | Turnouts | 12 |
| | Ballast | 60 |
| | Sleepers | 20(timber), 50(concrete) |
| | Road Pavements | 40-60 |
| Nodal Infrastructure | Rail and light rail stations | 50 |
| | Interchanges and commuter parking facilities | 50 |
| | Bus stops | 20 |
| | Wharves | 40 |

*Source: ATC (Volume 4, pp.44)*

Measurement of project impacts longer than 30 years is generally not recommended due to uncertainty in the forecast. Where projects are expected to have benefits beyond the evaluation period, the system user can calculate a residual value[4].

When comparison of alternatives with different evaluation periods is required, care should be taken when interpreting the incremental results. The use of the same evaluation period when comparing alternatives is preferred, however system users can either evaluate the project over a common time period or convert the project cash flow into an annuity.



4 For more information, see Part 1, Chapter 3.3.3.

## 2.1.2 Selection of base years

The base year is the year to which all future costs and benefits are to be discounted. Future benefits and costs will be discounted back to the base year's price level to give an indication of the present value of these factors[5].

The selection of the base year should be consistent with the price year used to value benefits and costs. The base year is generally the 'current year'.



[5] Discounting is automated in CBA6. Discounting formula is provided in Part C, Chapter 9.1.

## 2.2 The concept of road user costs

The economic impacts of projects are measured by identifying project economic and financial benefits and including, in some cases, revenue streams. Applied to a transport and road environment, road user costs include all the opportunity costs of travel rather than simply financial costs. Road user costs represent the real (resource based) impact of a project on the community. Road user costs also take into account safety and environmental considerations associated with transport and road projects.

Consequently, CBA with respect to transport usually takes into account:

- travel time costs (TTC)
- vehicle operating costs (VOC)
- accident costs

Project impacts are calculated by focusing simply on the difference in road user costs between the base case and project case. This resulting difference is referred to as road user savings, where road user costs are lower in the project case, and as dissavings, where road user costs are higher in the project case.

### 2.2.1 Travel time cost savings

Travel time, or journey time, savings are generally considered to be the most important component of transport projects designed to improve transport route and network efficiency. Reduction in congestion and lower travel times therefore represent the majority of road infrastructure benefits.

The measurement of time is divided into two distinct streams based on the purpose of the trip. These are either private (non-work) or business related travel. The valuation of business travel time is equal to the average wage rate. Austroads measures business travel time based on the driver's cost to the employer. Freight is also incorporated in the valuation of business travel time by multiplying vehicle payloads (measured in payload tonnes) and estimates of unit freight travel time estimated at a per pallet level[6]. Private road users' TTC, not on business trips, are generally valued at a 'leisure rate' which is lower than business travel time.

TTC are calculated from the average trip time, average occupancy rate, the value of time per occupant or value of freight per hour, and the Annual Average Daily Traffic (AADT).

### 2.2.2 Vehicle operating cost savings

VOC are the ongoing expenses incurred by road users that result from car ownership. These costs comprise consumable items such as fuel, oil and tyres as well as repairs and maintenance and vehicle depreciation. VOC will vary from vehicle type to vehicle type and according to road roughness, alignment (vertical and horizontal), average speed and congestion. Improving the roughness or alignment of the road will reduce VOC.

VOC are measured in resource prices and not at market rates. Parameters such as fuel and tyre costs have been adjusted to eliminate the effect of taxes and charges on unit values and are subsequently represented in resource prices. With respect to fuel for example, the unit values are expressed net of excises and levies.

The measurement of VOC incorporates a number of complex algorithms developed by Austroads. For detail on the calculation of VOC, see Section 4 of the *Technical Guide*.



[6] See Austroads Guide to Project Evaluation Part 4.

### 2.2.3 Accident (reduction) benefits

Accident cost savings arise when a project reduces either the expected accident rate (frequency) or the accident severity. The accident rate can improve due to changes in alignment, road type, lane width and speed factors.

The average cost of a crash is measured by the number of all crashes and the resultant number of fatalities, serious injuries, minor injuries and property damage incurred from each accident across the state. A detailed safety analysis should be undertaken with the assistance of specialised support.

### 2.2.4 Impacts of changes in vehicle composition

Certain types of heavy vehicles do not have general access to the state-controlled road network. For example, B-double vehicles have general access except in some urban areas, but access for road trains and newer multi-combination vehicles is more limited. In many instances these heavy vehicles are more efficient than a standard semi-trailer. As they can carry larger payloads than the smaller vehicles, the advantages for the transport system are fewer vehicle movements and reduced driving and loading/unloading costs for the same volume of freight moved.

Road widening projects and highway upgrades can improve road conditions sufficiently to provide access to larger freight vehicles. CBA of widening works where heavy vehicles are prevalent measures the freight efficiency benefits of improved width, in addition to the other benefits that would accrue to normal traffic. To measure freight efficiency benefits, it is necessary to alter the vehicle composition between the base case and the project case for each heavy vehicle type. Techniques to undertake this form of analysis are presented in Part 2, Section 5.3.

### 2.2.5 Influence of time of day on benefit estimation

A key characteristic of transport demand is the fluctuations for road use during the day. In both urban and rural areas, the demand for road use is markedly higher in the early morning and late afternoon than for any other time of day. These periods are known as the peak usage periods. The tendency for peaks and troughs throughout the day represents the demand for final goods. In this instance, the peak periods represent travel to and from work for the commuting public.

Benefits are usually measured for all periods of the day. Where traffic data is not available for all periods of the day it is recommended that data covering the two daily peak periods form the minimum requirement to undertake a CBA.

### 2.2.6 Impact of changes in vehicle regulations

Changes in vehicle regulations which are an integral part of a project, can often result in changes in expected road project benefits. Two examples of possible regulatory changes include reductions to the speed limit and additional restrictions being placed on freight-efficient vehicles on access to certain parts of the road network. A reduction in the speed limit associated with a road widening project may have the effect of reducing project benefits due to the possible reduction in TTC savings. Also, if access to the network of particular types of freight vehicles was increased through regulation changes associated with a bridge upgrade project, this could have the effect of increasing the number of freight vehicles, consequently increasing AADT and further increasing project benefits.

### 2.2.7 Impact of road capacity saturation

Road capacity saturation can influence the results of the CBA in a number of ways. Capacity saturation is a function of road type and traffic volume. When traffic reaches a certain point, at a given road capacity, saturation will occur. Traffic will be forced to delay or to not travel at all. This will reduce AADT in the base case, potentially distorting the results of the CBA. Road capacity saturation tends to occur mostly in urban areas or along motorways.

## 2.3 Agency costs

Agency costs in CBA refer to the infrastructure expenditure incurred by road agencies for the procurement of roadworks. Infrastructure agency costs include capital investment for new infrastructure works, and ongoing agency costs such as maintenance and operational costs needed to service the infrastructure over the life of the asset.

Capital and maintenance agency costs should be included in both the base and project cases in the year of analysis in which they are to be incurred. Accurate estimation of the agency maintenance costs in the base case is important in order to gather a full representation on the magnitude of resources required even if a project does not proceed. In some instances, new capital outlay will save expenditure in the long run where agency maintenance costs are high due to poor quality infrastructure. For example, a timber bridge that requires constant maintenance could cost the agency more in the long run than to design and construct a new concrete bridge. On completion of the CBA, net agency costs may be positive (when project case agency costs are higher than base case agency costs) or negative (when the project case accrues a saving in agency costs relative to the base case). In this scenario, the system user should be cautious when interpreting the BCR as it will not always provide a true indication of a project's economic worth. The NPV, on the other hand, will always be a reliable measure of economic worth.

### 2.3.1 Capital costs

Capital costs represent the initial outlay of expenditure required to start up a project (planning, design and construction). There are a number of inputs and activities that make up the total capital costs for a road project. Each input and activity must be estimated as accurately as possible and a project plan is often required to determine the timing and duration of each task. The timing of capital cost expenditure must also be estimated. CBA can be used to inform decision makers between the staging options of projects. The makeup of capital expenditure can include:

- design and construction costs
- earthworks
- pavement and seal
- intersection work
- value of land resumptions or voluntary acquisitions
- value of any land purchased at an earlier date even if the land has been in Crown ownership for several years
- costs of environmental mitigation such as noise barriers, fencing, landscaping or drainage
- project construction and design contingences
- project management and other professional costs.

The value of land that is expected to be resumed by a project should be entered in Year 1 of the evaluation as a capital cost. This value should be the current market value. Market values should be based on the sales data or the advice of suitable experts where large parcels of land are involved. Long, narrow lengths of road reserve are unlikely to be marketable and as such, have an opportunity cost of years.

A sunk cost represents expenditure that cannot be recovered. Sunk costs should therefore be excluded from the CBA, as these costs are not relevant to the decision regarding a project.

### 2.3.2 Maintenance costs

Maintenance costs include all labour, machinery and materials costs for routine, periodic and rehabilitation maintenance. Estimates of annual expenditure required to maintain and preserve road infrastructure can generally be determined based on historical expenditure levels.

Changes in maintenance costs commonly arise when:

1. pavement improvement reduces the need for maintenance costs
2. the maintenance effort is reduced in line with declining traffic volumes. In this situation, the gain to a project from reduced maintenance may be offset by increases in user travel time and VOC, and decreased benefits from the lower amount of traffic using the road
3. maintenance costs may be higher in the project case due to an asset extension, e.g. the addition of an overtaking lane
4. maintenance effort is increased to improve service standards or to postpone the need for capital works.

Consistent with Austroads methodology, maintenance costs are considered part of the 'cost' measurement in the BCR. This recognises an assumption that the road agency's objective is to efficiently utilise all resources, not only its capital budget. As such, any saving in maintenance costs as a result of a project, is considered as a reduction in costs in a whole-of-life context.

### 2.3.3 Residual value

Residual value is the estimated remaining value of the asset at the end of the evaluation period. It represents the capacity of the asset to accrue benefits past the end of the evaluation period. For example, a concrete bridge structure with a life of 100 years has a capital expenditure of $10 million. If the evaluation period is 30 years and the project life is 100 years then this represents a 70% remaining life of the bridge. Using a straight line depreciation method, the residual value would be $7 million.

The depreciated value of the new bridge after 30 years represents the minimum value that could be returned. The maximum value would be the present value of the benefits (road user cost savings) the project could produce between years 31 and 100. Where the range between these two measures is large, the CBA should be tested for sensitivity around the minimum and maximum residual values.

The residual value is treated as a negative value, reducing project capital costs and improving the BCR. Care should be taken when using residual value, as inclusion of a residual value in the project case will improve the BCR. When using a residual value, it is important that the method used to calculate it is appropriate and the value is justifiable. It is generally recommended that specialised economic advice be sought to calculate the residual value.

## 2.4 Measuring additional benefits by project type

Road user cost savings represent the direct benefit of most road projects. This section will discuss methodologies used to measure additional benefits depending on the project type. More detailed benefit calculation is required for a number of projects including:

- flooding
- generated traffic
- bypass
- livestock
- overtaking lanes
- intersections.

### 2.4.1 Benefits of flood proofing and reduced road closure

Flood proofing an area has important social and economic implications. Improved flood immunity ensures road users have access to their homes and the surrounding road network, while reduced road closures are important for freight reliability and delivery times.

In economic terms, the efficient level of access in the road system is determined by users' willingness to pay. All-weather access might not always be economically efficient, unless users' willingness to pay exceeds the costs. As with other types of benefit, data describing actual willingness to pay for all-weather access is not readily available. Rather, valuation is made by reference to a postulated change in access between the base case and project case.

The accepted approach to measure the benefits for improvements in access is to compare the avoided costs of traffic delay and/or diversion as a result of inundation. Diversion and delay costs that would be saved by improved access are estimated. The delay or diversion costs saved represent the benefits of the flood proofing works.

Measurement and estimation of the duration of road closures can be estimated using stream gauges located near a bridge to represent historical flood levels. Where a crossing does not have a stream gauge, a theoretical model of flooding must be used. The most important task in this process is to calculate design flood hydrographs for the crossing site which can be achieved by application of a catchment hydrology model. For more detail on road closure time calculation see the flood immunity case study in Chapter 5 of the *User Guide*.



#### 2.4.1.1 Local inundation

Local inundation occurs where access is impeded during flood incidents at a local site or along a single road link only. Delay and diversion cost savings are suitable measures of benefit for this type of flooding impact.

Factors to consider in the base and project cases include:

- the capital costs of the proposed proofing works
- ongoing maintenance and rehabilitation costs in the base case to repair water damaged roads, or to repair levees or elevated road structures in the project case
- local factors of trip patterns and composition
- local response to flooding
- suitable diversion route and in a broader sense the importance of the road in providing access to employment and community services.

A suitable diversion route provides the same form of access as the closed road. For example if a road train route is flooded, a suitable diversion route will also allow access for this vehicle. However a suitable diversion route for all vehicle types may not always be physically possible, and in Queensland the length of the diversion route can sometimes be significant, requiring an inland diversion. In these instances it is appropriate to assume that some road users will not divert but will wait for the site to reopen.

#### 2.4.1.2 Network inundation

Elsewhere, inundation may be a network problem. Flooding may sever access simultaneously at a number of points in a network or on a link. Depending on the proportions of local and through traffic in the network or on the link, the full benefits of flood proofing may not eventuate until all crossings are treated.

Local knowledge and research are important prerequisites before all or some of the impacts can be identified. Where they are relevant, a network or link level of CBA would be appropriate.

The following factors can make the CBA difficult in this type of case:

- flood mitigation benefits might not be realised until a number of sites in the network are treated
- capital costs to flood proof a network and priority of crossings in a network
- suitable diversion route
- if the flood damage area is widespread, traffic demand during a significant flood incident may decline anyway.

Road user costs might not increase directly with length of inundation. Some users might postpone or cancel their trip or undertake their holiday or business elsewhere. The disbenefits to them will not be the total costs of diversion or the loss of opportunity to undertake the trip, depending on the duration of the incident, amount of warning and availability of alternatives.

Benefits may only be maximised at the cost of improving pavement and shoulder condition along whole lengths of road.

#### 2.4.1.3 Traffic behaviour

The estimation of benefits of a project will depend on the behaviour of road users. During times of flooding, users have three options. Users can choose to:

- wait – remain at the flood site for waters to subside
- divert – use an alternative route around the flood affected area
- do not travel – choose not to travel at all.

If there is a suitable diversion route, some road users may choose to divert along that route if their willingness to pay exceeds their perceived cost of travel. In a real sense, a road user's willingness to pay to get to a destination will largely vary among individuals and may require extensive modelling to estimate the relative proportion of road users who will divert, not travel or wait. In general, those road users who choose to divert will bear a cost equal to the characteristics of the diversion route. These road users will affect and be affected by traffic that exists on the route prior to the diverting users (i.e. diverted traffic will be affected by poor road conditions while those existing users will be affected by the burden of possible increased congestion). Therefore road user costs will increase on the diversion route.

Those road users who choose to wait at a project site during periods of flooding incur waiting costs. In an economic sense, the cost to those road users who choose to wait will be equal to the value of their personal (and business) time multiplied by the time spent waiting. This value represents the opportunity cost (loss of economic productivity) for road users to wait at flooded sites.

The road user costs borne by existing traffic, extra costs incurred by diverted users and waiting costs will be substantially reduced as road users benefit from the improved access under a new project. Under the project case, road users gain from the mitigation of flooding costs, waiting and diversion costs borne in the base case.

It is important to note that flooding effects are only relevant while the project area is flooded and closed. This is typically a small percentage of time over a whole year. Therefore, it is important to reiterate that flooding benefits are relative to the scale of flooding time and the costs borne during that time.

### 2.4.2 Benefits to generated traffic

Generated traffic is the additional number of trips expected to be made by road users in response to perceived reductions in costs from a proposed road project. The extent of generated traffic depends upon the sensitivity of road travel to a change in the perceived costs of road travel.

The benefits derived by the generated road users are equal to the gain in consumer surplus the road users obtain by switching from their previous activity to a new activity, which in part involves travelling along the upgraded road. For example, a man has a choice of fishing in a pond in his own garden or fishing in a lake on the other side of town. The man is willing to pay $5 extra to fish in the lake but he perceives the cost of the journey to the lake to be $6; therefore, he fishes in his garden. If the road to the lake is upgraded, the man perceives the cost of the journey to be $4; therefore, he drives to the lake to fish. The man can be considered as generated traffic on the upgraded road. His benefit from the upgraded road is $1, which is equivalent to his additional consumer surplus which is derived from travelling to the lake to fish rather than fishing in his own pond.

Perceived costs and benefits of using a road vary from road user to road user, thus the generated traffic benefits for each road user will vary. Demand and cost functions can be modelled so that changes in consumer surplus can be calculated. A common practice is to assume that the demand for travel is linear. A linear demand function enables the use of the rule of half to estimate changes in consumer surplus from an upgrade in road infrastructure.

Benefits to the generated traffic should always be positive but the net impact of the inclusion of generated traffic in an evaluation may not be positive. The generated traffic may cause congestion and reduce benefits to other road users. The generated traffic will also increase the externality costs.



### 2.4.3 Benefits accruing from bypasses

A bypass is a road that acts as a permanent diversion to enable road users to travel to a destination at a reduced cost. Bypasses are typically constructed to provide through traffic with the option to avoid the delays in travel associated with passing through a town.

TTC savings normally comprise the highest proportion of benefits accruing to bypasses. VOC savings can be relatively high if the bypass reduces the distance travelled and also if start-stop traffic movements in town are avoided. A bypass may reduce overall accident costs if the road alignment has improved, busy intersections are avoided and the length of the bypass is shorter than the route through town. A bypass could potentially increase accident costs, as the severity of accidents increases in the faster speed environment of the bypass. Externality costs are likely to be reduced as pollution decreases through the reduction in the number of vehicles passing through the town. The overall reduction in costs of travelling on the bypass could result in generated traffic and is likely to be a small component of benefits accruing from a bypass.

Bypasses are also likely to have other impacts, which cannot be easily quantified. Bypasses often have a negative impact on the growth and economic activity of the town bypassed. This growth and activity is likely to be passed on to another town, thus making it difficult to determine if the movement in activity is a negative or positive impact of the bypass.

### 2.4.4 Benefits accruing from sealing roads

Freight vehicles carrying livestock on unsealed roads incur costs associated with damage and/or death of their cargo. Of all roadway impacts affecting livestock carried in open vehicles, dust inhalation is the most harmful. By providing upgrades and sealed roads, commercial road users carrying livestock will benefit from reduced livestock loss.

For further information on the benefits of sealing roads, see Chapter 5 of the *User Guide*.

## 2.4.5 Benefits of overtaking lanes

Overtaking lanes are additional lanes added to a road to enable the safe overtaking of slower vehicles that impede traffic flow. Overtaking lane benefits are calculated over three sections: the project site of the overtaking lane, the downstream area and the upstream area. The downstream area of the overtaking lane is the section of road immediately following the overtaking lane. The upstream area is the section of road immediately preceding the overtaking lane.

The overtaking lane itself has benefits attributed to increased overtaking opportunity and increased safety. The additional lane allows faster vehicles to overtake slower vehicles, thus improving travel time through increased operating speed. Accident costs are reduced, as overtaking does not require the use of the opposing lane. The downstream area is assumed to operate at above capacity as faster vehicles are assumed to have moved to the front of the platoon. The length of road required before slower vehicles again impede faster vehicles is a determinant of the length of the downstream area. The main benefits from the downstream area are improved travel time for overtaking vehicles and reduced accident costs from reduced overtaking. The upstream area is assumed to have a decrease in accident costs, as road users will refrain from overtaking when an overtaking lane is approaching.

### 2.4.5.1 Within the overtaking lane

The predominant benefit within the overtaking lane is a reduction in the collision rate. The overtaking lane section generally has a lower rate of collisions than two-lane road sections due to the following:

- The additional road width provides more space for errant vehicles to recover and for vehicles to avoid each other.
- Overtaking is safer in an overtaking lane than in an opposing traffic lane.

The overtaking lane also provides significant TTC savings. As a result of the additional lane and width, capacity is improved along the length of the overtaking lane. The additional lane and the increased capacity allows more overtaking opportunities and higher operating speeds.

### 2.4.5.2 Outside the overtaking lane

By concentrating overtaking manoeuvres in the relatively safer overtaking lane section, overtaking manoeuvres and crashes associated with the manoeuvre should be reduced on adjoining sections of conventional two-lane road. The frequency of collisions should therefore be reduced immediately before and after the overtaking lane.

- Before the overtaking lane: Road users can be expected to be more conservative in overtaking behaviour if they are aware an overtaking lane is ahead. This behaviour is encouraged by the practice of providing advance information such as signage on the location of the upcoming overtaking lane.
- After the overtaking lane: Having overtaken a vehicle in the overtaking lane, it will typically be some time or distance before the next slow vehicle on the road is encountered. This reduction in overtaking demand following an overtaking lane will reduce the crash rate along the two-lane road section immediately after the overtaking lane section.

### 2.4.6 Benefits of intersection upgrades

There are many intersection upgrade options available to road transport authorities. Different intersection upgrades have different impacts on road users. The type of upgrade is tailored to the need of the intersection. Signals and overpasses improve traffic flow and reduce congestion. Roundabouts and turning lanes reduce a large variety of accident types. Some upgrades are targeted at reducing certain types of accidents that are prevalent at particular intersections.

Traffic signals coordinate traffic flows and reduce delays at the intersection during peak periods. During off-peak periods, signals may cause increased delays if road users are required to wait at an empty intersection. The cost of these delays are normally small in comparison to the reductions in delays if the intersection has a high volume of off-peak traffic. Traffic signals can reduce the number of severe accidents caused from vehicles approaching from adjacent roads but normally increase the number of rear-end accidents (RTA 2004). Overpasses significantly reduce delays throughout the day and reduce intersection related accidents, such as those caused from vehicles approaching from adjacent roads and from opposing vehicles that are turning at the intersection (RTA 2004).

Roundabouts are designed to improve traffic flow and safety. The capacity of a roundabout can be tailored to the traffic flow of the intersection. Roundabouts have the advantage of allowing a constant flow of traffic from all directions, thus reducing delays. Roundabouts normally generate more accident cost savings than traffic signals because of lower speeds, angle of contact and reduced number of contact points (Gibbon and Martinovich 2010). Turning lanes can improve delays and reduce accident costs. Turning lanes can be used in particular to reduce rear-end accidents and accidents with opposing vehicles that are turning at the intersection (RTA 2004). There are other intersection upgrade options designed to address accidents of a specific nature. Definition for classifying accidents (DCA) codes can be used to determine the accident cost benefit of a particular intersection upgrade.




## 3 Measuring externalities

An externality occurs when a transaction takes place and causes an impact on a third party that was not directly involved in the transaction. Put another way, externalities exist when the actions of one group affect the welfare of another group without compensation being made. Externalities are the indirect consequences of transport by road users. In economic terms, externalities exist when the marginal cost to the firm is not equal to the marginal costs for the community. Therefore prices of these goods and services do not reflect the true economic cost, which results in excess or shortage of supply in the market depending on the nature of the externality.

Externalities may be positive (where a third party incurs benefits from the transaction) or negative (where a third party incurs costs from the transaction). For example a positive externality may occur when a third party benefits from improved medical research, while a negative externality may occur when a third party suffers the impact of pollution generated by a factory.

Transport systems have generally been associated with negative externalities, impacting the environment and human health. The most significant of these externalities in terms of scale include air pollution, greenhouse gas emissions, noise, water pollution and ecological impacts. Specific examples on how these externalities are present in different types of road projects are described in Chapter 7 of the *Technical Guide*.

To accurately reflect the impact of a proposed activity it is necessary to include as many externalities as possible into the CBA. Inclusion of these externalities into the evaluation (that is, by internalising the externality) ensures decision makers will be better able to assess the likely economic impacts of a proposed activity.

The incorporation of externalities into the evaluation is achieved by estimating its monetary value. In theory, this monetary value is the financial cost that would be incurred by those that benefit from the externality, to compensate those that incur the impact of the externality. In the case of a transport-related evaluation, the preferred treatment for externalities is to internalise these costs by calculating a monetary value expressed per VKT for inclusion in the CBA. To achieve this, externalities must be quantified and measured. There are different methodologies to value externalities. The complexity of the effects and the large number of diverse stakeholders involved make it very difficult to develop a homogenous method for the evaluation of transport externalities.

To simplify the valuation of externalities with respect to transport, Austroads has produced a standardised set of default values for various categories of externalities associated with road projects. The methodology and valuation technique used by Austroads is based on research conducted in a variety of jurisdictions. The technique is described in *Austroads Guide to Project Evaluation*, *Part 4* and *Australia Transport Council's National Guidelines for Transport System Management in Australia Volume 3: Appraisal of Initiatives* and *Volume 5: Background Material*.

These references are used as sources of externalities default values in cases where externalities costs are not critical to the overall project evaluation. When externalities are significant, a specific quantification and valuation has to be undertaken as the default values may not necessarily reflect the actual externality values involved. This can be done using techniques such as hedonic pricing which estimates the price of a commodity based on its characteristics which yield utility/disutility, for example estimating noise costs (characteristic of disutility) by estimating changes in house (commodity) prices based on volume of noise. Where externalities cannot be quantified, a qualitative evaluation using an evaluation summary table should be included in the analysis. See Chapter 7 of the *Theoretical Guide* for further information on the evaluation summary table.

Externalities that are valued in transport evaluation include:

- air pollution
- greenhouse gas emissions
- noise
- water
- nature and landscape
- urban separation
- downstream effects.

Default externality unit values are presented in Table 3 for cars and buses in an urban and rural environment. Generally urban externalities will impact a larger number of third parties and are therefore valued higher than externalities that occur in a rural setting.

*Table 3: Externality unit costs for passenger vehicles and buses (cents per vehicle kilometres travelled (vkt))**

| | Vehicle/units | Urban | | Rural | |
|---|---|---|---|---|---|
| | | Passengers cars | Buses | Passengers cars | Buses |
| 1 | Air pollution | 2.54 (2.48-2.60) | 28.61 (20.24-31.82) | 0.03 (0.02-0.03) | 0.00 (0.00-0.32) |
| 2 | Greenhouse | 2.00 (1.77-2.24) | 11.79 (n/a) | 2.00 (1.77-2.24) | 11.79 (n/a) |
| 3 | Noise | 0.82 (0.59-1.06) | 2.00 (1.18-2.83) | 0.00 (0.00) | 0.00 (0.00) |
| 4 | Water | 0.38 (0.37-0.39) | 4.29 (3.04-4.77) | 0.04 (0.04-0.04) | 0.04 (0.03-0.05) |
| 5 | Nature and landscape | 0.05 (0.05-0.17) | 0.13 (0.13-0.6) | 0.47 (0.47-1.65) | 1.3 (1.3-6.01) |
| 6 | Urban separation | 0.59 (0.35-0.82) | 1.89 (1.18-2.6) | 0.00 (0.00) | 0.00 (0.00) |
| 7 | Upstream and downstream costs | 3.42 (2.95-3.89) | 17.68 (14.14-21.21) | 3.42 (2.95-3.89) | 17.68 (14.14-21.21) |

*Sources: Austroads (2008)*

Note: *All values are adjusted from 2005 Australian dollars to 2007 Australian dollars using the change in CPI for all groups.

Austroads default externalities values for road freight transport are reported separately by rural and urban locations.

*Table 4: Externality unit costs for freight vehicles ($ per 1000 tonne-km)**

| | Vehicle/units | Urban | | Rural | |
|---|---|---|---|---|---|
| | | Light vehicles | Heavy vehicles | Light vehicles | Heavy vehicles |
| 1 | Air pollution | 158.93 (117.85-261.60) | 21.19 (10.28-25.93) | 0.00 (0.00) | 0.21 (0.11-0.26) |
| 2 | Greenhouse | 49.50 (45.96-51.85) | 4.71 (2.36-8.25) | 49.50 (45.96-51.85) | 4.71 (2.36-8.25) |
| 3 | Noise | 27.10 (18.86-37.71) | 3.54 (2.36-4.71) | 0.0 (0.00) | 0.35 (0.24-0.49) |
| 4 | Water | 23.84 (17.68-39.20) | 3.18 (1.06-3.89) | 0.24 (0.18-0.42) | 1.27 (0.64-1.56) |
| 5 | Nature and landscape | 17.68 (17.68-34.18) | 0.35 (0.35-0.71) | 0.18 (0.18-0.34) | 3.54 (3.54-7.07) |
| 6 | Urban separation | 25.93 (15.32-36.53) | 2.36 (1.18-3.54) | 0.00 (0.00) | 0.00 (0.00) |
| 7 | Upstream and downstream costs | 164.99 (117.85-212.13) | 18.86 (16.5-21.21) | 164.99 (117.85-212.13) | 18.86 (16.5-21.21) |

*Sources: Austroads (2008)*

Note: *All values are adjusted from 2005 Australian dollars to 2007 Australian dollars using the change in CPI for all groups.

These tables and how the values are applied in CBA are described in detail in Section 7 of the *Technical Guide*. The following sections provide detail for each externality with default values from Austroads.

## 3.1 Flora and fauna

Transport projects commonly influence natural vegetation and landscape in some form. The development of land-based transportation has led to deforestation, habitat loss, loss of natural vegetation, reduction in the quality of landscape, land pollution and reduction in visual amenity.

Austroads values for nature and landscape externalities are based on an avoidance cost methodology with respect to repair and compensation/restoration measures. The calculated values are then adjusted for vehicle occupancy rate to achieve an estimated cost-per-vehicle occupant.

## 3.2 Emissions

Emissions are the primary and most commonly included externality used in CBA. Emissions encompass greenhouse gases and air pollution.

### 3.2.1 Air pollution

Air pollution refers to the introduction of chemicals, particulate matter and biological material into the atmosphere that cause or have the potential to cause harm or discomfort to humans and other living organisms or damage the natural environment (Austroads, 2009, P.3). The emission of air pollutants from transportation mainly consists of exhaust emissions, but there are also impacts of fuel vapours and emissions that result from the contact between vehicles' tyres and the road surface. Emissions also vary by type of vehicle (truck, private car, engine size and model) and fuel (diesel/ petrol).

Pollutants identified as being significant to the Australian transportation industry include Carbon Monoxide (CO), Particulate Matter (PM), Oxides of Nitrogen (NOx), Carbon Dioxide (CO2) and Total Hydrocarbons (THC) (Austroads, 2009, P.3). Some of these emissions have purely local impacts; others contribute to effects at a regional or even global scale and can affect human health, infrastructure, forests and crops. The calculated value of air pollutant values for CBA evaluation purposes differentiates the costs of pollutants with a local impact from those with a wider impact.

Air pollutant values are derived from control and avoidance costs estimates, which are adjusted for population density, and vehicle occupancy (Austroads, 2009, P.3). The values are calculated using health costs, emission factors and motor vehicle use data. The effects of transport-attributed pollutants on health are quantified using willingness to pay. Values for cost per tonne have been transferred to Australian values according to a comparison of population densities in Australia (Austroads, 2009, P.7).

### 3.2.2 Greenhouse gases

Gases which have the potential to trap heat within the atmosphere are often referred to as greenhouse gases (Austroads, 2009, P.7). Some greenhouse gases such as carbon dioxide, methane or water vapour are produced naturally, while others (e.g. fluorinated gases) are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are: Carbon Dioxide (CO2), Nitrous Oxide (N2O) and Fluorinated Gases.

Transportation is a significant source of greenhouse gas (GHG) emissions, which are defined in the National Greenhouse Gas Inventory (NGGI) as emissions from the direct combustion of fuels in road transportation, railways, navigation, aviation and off-road recreational vehicle activity. Transport emissions are one of the strongest sources of emissions growth in Australia, and contribute around 13.2% of Australia's net emissions. Since 1990, transport emissions have increased by approximately 58%.

Greenhouse gases are valued using a damage cost approach (Austroads, 2009, P.7). As greenhouse gases have a global impact, the same value applies for rural and urban areas.

## 3.3 Noise pollution

Noise pollution is the presence of a noticeable extent of noise above background levels which presents an irritation or loss of amenity for those exposed to it. In extreme cases, prolonged exposure to noise pollution can produce significant health impacts. As the effects of noise pollution in a transport context are typically not experienced by the producer of the noise, it is considered to be a negative externality (Austroads, 1996, P.23).

The prevailing source of artificial noise pollution in built-up areas is from transportation. In rural areas, train and aviation noise can disturb wildlife habitats. Trucks and exhaust braking is a significant contributor of noise pollution in rural towns.

Hedonic pricing can be used to measure the impact of noise pollution (Austroads, 2009, P.5). Consider two identical houses with the same characteristics, except that one house is located further away from a noisy road. The cost of noise pollution would therefore be the difference in house prices.

Austroads values are based on a methodology that uses a combination of willingness to pay and valuation of health effects from noise exposure (Austroads, 2009, P.5). These values are adjusted for vehicle occupancy rate, population density and Purchasing Power Parety factors. Noise barriers used on highways will significantly reduce the noise pollution effect of road users.

## 3.4 Other externalities

### 3.4.1 Water pollution

Transport-related water pollution is defined as the contamination of water bodies such as lakes, rivers, oceans and groundwater, which can be harmful to local and even regional ecological values (ATC5, 2006, P.81). Such contamination may be caused by fuel or oil run-off from the road surface, and particulate matter including tyre fragments washing into waterways.

Austroads values are based on willingness to pay methodology and mitigation costs methodology (ATC5, 2006, P.81). Mitigation costs methodology measures transport-related impacts by estimating the social costs of installing mitigation devices over entire road networks or on a per-vehicle-kilometre basis (Austroads, 2009, P.8).

### 3.4.2 Urban separation

Austroads values are based on avoidance costs through evaluation of the constraints to the mobility of pedestrians, as a technique to value urban separation effects. It includes time lost due to separation for pedestrians, lack of non-motorised transport provision and visual intrusion. Values are adjusted for vehicle occupancy rates (Austroads, 2009, P.9).

### 3.4.3 Upstream and downstream

Upstream and downstream externalities refer to the indirect impacts associated with energy consumption prior to transport end use including energy (fuel) production, vehicle production and maintenance, and infrastructure construction and maintenance (Austroads, 2009, P.9). This externality has a global impact, hence the same value applies for rural and urban areas.

2

# 4 Project evaluation and network effects

This section identifies and explains the key principles in undertaking a road project evaluation within a network (urban) environment. Urban project evaluation involves careful consideration of improvements to road links that benefit the operation of a road network. The best approach for network-based evaluations is a combination of transport modelling and a project-specific CBA model.

Network evaluations require intimate knowledge of the road network and associated economic impacts. System users and decision makers should attempt network evaluations in close consultation with transport modelling teams.

## 4.1 Principles of urban road project evaluation

Urban road projects have considerable differences from rural evaluations, including variable demand, multiple mode choices, network effects, stop-start traffic conditions, congestion and environmental effects.

Network evaluations are typically aimed at improving service and congestion levels in the peak periods. They can and should include effects for public transport users, such as an evaluation of a busway.

### 4.1.1 Urban road projects

Urban traffic patterns are typically more complex than rural traffic patterns due to the far greater number of alternative roads and the origins and destinations of travel. Modelling of an urban project requires detailed evaluation not only of the route under investigation but of all alternative routes that are impacted by a project. The existence of intersections and queuing adds to the complexity. However, a number of transport models are available to measure the effect of proposed improvements. It is important when using a transport model, that it features the correct specifications and outputs required to conduct the economic evaluation. In an urban-based scenario, the typical outputs needed include:

- vehicle kilometres travelled (VKT)
- vehicle hours travelled (VHT)
- average operating speed.

These outputs should be estimated by the transport models in both the base and project cases. Often these outputs will be presented in 5 or 10-year increments to the defined life of the evaluation. It will then be required to interpolate these outputs for the intermittent years. Once these outputs are sourced, it is required to create a road user cost model to estimate the associated user costs for the road improvement. This CBA model should be created using a spreadsheet tool.

As a general outline, the following steps provide guidance for network evaluations:

1. identify problem and develop options
2. consider time frame for analysis and forecast population growth
3. inventory of existing travel patterns
4. undertake transport modelling of the base case and project case options
5. build CBA model using a spreadsheet tool
6. estimate capital and ongoing costs
7. value urban VOC using Austroads stop-start model
8. value travel time and vehicle operating cost benefits using transport modelling outputs VHT, VKT
9. value accidents using accident rate history and VKT
10. value externalities using Austroads unit costs and VKT
11. discount future benefits and costs.

It is beyond the scope of this manual to provide detailed guidelines for network evaluations. Readers are encouraged to consult Volume 4 of the ATC material or obtain specialised economic support before attempting a network evaluation.

#### 4.1.1.1 Brisbane strategic transport model

There are a number of models that can be used to test the impact of changes in the road network. One of these models is the Brisbane Strategic Transport Model (BSTM), initially developed in 2000. The BSTM has recently been updated to incorporate mode choice, and this particular version of the model is known as the Brisbane Strategic Transport Multi-Modal Model (BSTM-MM). It is a four-step strategic transport model with a Logit mode choice module, enabling users to choose between car driver, car passenger, walk to public transport, park and ride, kiss and ride, cycle and walk mode alternatives. The model also includes a car availability module being used as input to the mode choice module.

Brisbane City Council maintains the road only version of the BSTM, which currently sits at BSTM version 6.

The BSTM-MM covers the Greater Brisbane area (equivalent to the 2001 Brisbane Statistical Division) using 1509 transport model zones. The model is calibrated for a 2004 base year. The demographics for this model are currently based on the latest work done by the state's Planning Information and Forecasting Unit, along with work done by the National Institute of Economics and Industrial Research, as well as updates from recent studies such as Australia TradeCoast and local government projections. Future year demographics are available for 2011, 2016, 2021, 2026 and 2031. These future demographics are based on development patterns outlined in the Queensland Government's South East Queensland Regional Plan, including bringing forward Greenfield development areas in line with the State Government's Housing Affordability strategy.

Future year road networks are regularly updated and have been developed through consultation between Brisbane City Council, other south-east Queensland local governments and internally through the Department of Transport and Main Roads. It includes projects listed in the *South East Queensland Infrastructure Plan and Program 2009-2026,* and the *Queensland Transport and Roads Investment Program*. It also includes network scenarios used to develop the document draft *Connecting SEQ 2031: An Integrated Regional Transport Plan for South East Queensland.*



#### 4.1.1.2 Alternative models

In addition to the BSTMv6 or BSTM-MM, a number of alternative transport models are available to assist network evaluations including the South East Queensland Strategic Transport Multi-Modal Model and various others across Queensland's regions. The techniques used and outputs produced by the models depend on the purpose of the modelling exercise. There are four commonly adopted transport modelling techniques.

1. Strategic
2. Mesoscopic or local area modelling
3. Micro-simulation
4. Intersection

A strategic model is capable of modelling the impact of a road project on a city's entire network. The BSTM is an example of a strategic model. This type of model should be used to predict the impacts on urban networks of major road infrastructure projects. Strategic models are useful for examining broad transport impacts at a city-wide level such as changes in mode share, average trip lengths, sector-to-sector travel patterns, etc. They are also useful for testing transport policy impacts such as tolling or road pricing. Examples of strategic modelling tool packages include Emme (BSTM runs in Emme), Cube, VISUM and Omnitrans.

Mesoscopic models are the next step down from strategic models and are used to model smaller areas such as suburbs. These models are more precise in that they are validated down to the turning movement level, whereas strategic models are only validated at a screenline level (travel across cordons of several roads in a certain direction). They are capable of modelling more precise effects of changes to the road network such as banned turns, extra turning lanes etc. The SATURN tool package has regularly been used in the past for this type of modelling, however there are a number of newer options (largely untested in Australia) becoming available including AIMSUN, VISUM, Cube Avenue, Dynameq (part of the Emme suite) and others.

Micro-simulation traffic models are used to model highways, interchanges and congested (small-area) networks. Micro-simulation programs model the movements of individual vehicles travelling on road networks using simple car following, lane changing and gap acceptance rules. Micro-simulation models provide a representation of actual driver behaviour and network performance. This is particularly useful when assessing complex traffic problems, such as the effects of accidents or breakdowns on a network. Micro-simulation can also be used to model projects that incorporate intelligent transportation systems. There are a number of micro-simulation tool packages available such as PARAMICS, AIMSUN and VISSIM. Micro-simulation models should be used with caution but are a useful tool particularly in visualising the traffic impacts of network changes.

Intersection models are used to evaluate the capacity, level of service and performance of intersections. These models evaluate the performance of alternative treatments involving signalised intersections, roundabouts, unsignalised intersections, interchanges and pedestrian crossings. Intersection models include SIDRA and INSECT. TRANSYT is also a tool used for signal coordination. These models should only be used for intersection projects.

### 4.1.2 Urban public transport projects

For public transport projects, modelling of traffic behaviour becomes an increasingly more important aspect of the evaluation. Public transport projects include bus, rail (both heavy and light rail) and ferry projects.

Public transport projects provide an important community benefit to travellers without access to motor vehicles, however the main objective is to shift transport users from the road to public transport.

#### 4.1.2.1 Resource unit costs

Public transport projects will have significant operating and maintenance costs which vary depending on the number of services and the distance of travel required.

Volume 4 of the ATC material provides a methodology to calculate the resource cost of public transport projects. An example of a cost function that estimates the annual costs of operating a bus service is[7]:

C = Npv * Cpv + Bkm * Cbkm + Bhr * Cbhr + RL * Crl

Where:

- C = total annual cost
- Npv = number of peak vehicles
- Cpv = unit annual cost per peak vehicle
- Bkm = number of bus-kilometres operated per annum
- Cbkm = unit cost per bus-kilometre operated
- Bhr = number of bus-hours operated per annum
- Cbhr = unit cost per bus-hour operated
- RL = road length of bus route
- Crl = unit cost per km of road used by bus services

The ATC material provides further guidance on the estimation of resource costs. For more simplified analysis, Volume 4 of the ATC material provides a summary of unit costs of public transport operations typical of Australian conditions. Relevant cost estimates for bus (standard size buses typically 40–45 seats), light rail or tram and rail (three-car electric units) are shown in Table 5.



7 Bray, D.J. and Wallis, I. 1999, 'Public transport costs in Adelaide - Assessment and implications'. *Paper to 21st Australian Transport Research Forum*, Perth.

*Table 5: Operating cost summary (2005-06 prices)*

| Cost category | Unit | Bus | Tram | Train |
|---|---|---|---|---|
| On-vehicle crew costs | $/train or bus-hour | 33 | 60 | 220 |
| Vehicle (direct operating) costs | $/unit or bus-km | 0.9 | 1.5 | 2.8 |
| Infrastructure operations and maintenance costs | $ 000 pa/track-km | | 65 | 115 |
| Overhead (operating) costs | % on other op costs | 21 | 17.5 | 14 |
| Profit margin | % on total op costs | 6 | 4 | 4 |

*Source: ATC (2006) Volume 4 Table 1.6.9*

#### 4.1.2.2 Generalised costs

Generalised costs are the sum of monetary and non-monetary costs of a trip. Motorists incur monetary costs such as petrol, vehicle repairs, tolls and parking charges. They also incur non-monetary costs such as the value of time taken for the journey.

Benefits of public transport projects are equivalent to the reduced travel costs perceived by travellers plus other impacts on travellers. Potential beneficiaries of a public transport project are listed below.

- Existing public transport (PT) users
- Diverted PT users – from other PT modes
- Diverted car passengers – that switch mode to PT
- Former car drivers – that switch mode to PT
- Former bicycle users – that switch mode to PT
- Former pedestrians – that switch mode to PT
- Other generated PT users
- Remaining road users
- Community at large

The benefits of public transport projects are typically defined (with the exception of remaining road users) in generalised costs terms. Generalised costs are the perceived costs that the user experiences during the use of public transport.

The generalised cost function from Volume 4 of the ATC Guidelines is:

$$GC = F + V * [(TA * WA)+(TW * WW)+(TR * WR)+(TI * WI)+NT * \{TP + (TAT * WAT)+(TWT* WWT)\}]$$

Where:

- GC = total generalised cost (=perceived cost)
- F = fare ($)
- V = standard value of time ($/min of, say, in-bus time or some other benchmark)
- TA = access time i.e. between an origin/final destination and the public transport facility (mins)
- WA = weighting on access time (to reflect its perceived valuation relative to in-bus travel time)
- TW = (expected) waiting time at a bus stop or train station for initial boarding (mins)
- WW = weighting on expected waiting time (to reflect its perceived valuation relative to in-bus travel time)
- TR = unexpected waiting or travel time (associated with service unreliability)
- WR = weighting on unexpected waiting or travel time
- TI = in-vehicle time (mins)

- WI = weighting on in-vehicle time to reflect quality attributes (relative to in-bus travel time)
- NT = number of transfers
- TP = transfer penalty to reflect the inconvenience associated with a transfer (equivalent to bus travel time (minutes)) where an interchange occurs
- TAT = access/walk time on transfer
- WAT = weighting on transfer access/walk time
- TWT = waiting time on transfer
- WWT = weighting on transfer waiting time

Generalised costs are the economic costs of travel plus the additional perceived costs of waiting time and journey time that the public transport user perceives as a result of travel. In a broad example, individuals tend to perceive that bus journeys take longer than reality while train journeys are shorter than reality.

This example has a community cost implication that is traditionally omitted from road-based evaluations. The derivations of these benefits are extremely complex in nature and beyond the scope of the manual.

Volume 4 of the ATC material provides information on the calculation of these benefits.

## 4.2 Fixed and variable trip matrix

There are two forms of trip distribution that need to be taken into consideration when formulating the Network Transport Model. These include fixed trip distribution (and hence fixed mode shares) or variable trip distribution. The fixed distribution matrix assumes that trip patterns remain unchanged after the impact of a project, and is only used in those communities with relatively minimal levels of congestion. This depends on the project in question, for instance a new busway would most likely encourage a shift to public transport. The variable trip distribution approach can be applied to those communities with a congested road network, or where a project could potentially result in a change in mode shares or trip distributions.

If a project has the potential to change travel patterns, then a strategic model will need to be used in the first instance to obtain trip matrices by mode for input into a finer grained model, if a finer grained model is to be used. The strategic model is the only type of model that forecasts demand, while the lower level models often assume a fixed demand matrix, or else the matrices can only be adjusted through very basic factors which could be risky.

In addition, large scale projects may often induce traffic onto the network and could effectively lead to a 'variable demand' matrix. In almost all strategic transport models the total number of trips is fixed, however these trips can be differently distributed across transport modes and time of day. The variable demand approach can be used when it is considered likely that a project will lead to increased trip-making behaviour as a result of, for example, a new cross-town tunnel. In most cases variable demand is tested through a series of sensitivity tests in strategic transport models. Note that this approach will result in a different number of total trips on the network.


# 5 Other issues in cost-benefit analysis

This chapter brings together relevant background data and information on a variety of types of projects including rail, busways and cycleways. It does not prescribe a particular method for the evaluation of such projects but communicates a number of key principles recognising that there is no particular method, tool or technique that has been nationally endorsed. A short discussion on the treatment of tolling in CBA has also been included.

## 5.1 Rail

Rail projects can be separated into public transport-based operations and freight-based operations. Improvements to rail passenger services can be evaluated using the generalised cost function discussed previously in Section 4.1.2.2. This approach will compare the perceived cost of rail travel with and without the improved passenger services.

Rail freight projects may include projects that provide additional rail capacity to service a mine or port. When conducting an analysis of this type, the haulage costs via rail should be compared with an alternative transportation mode such as road. An analysis of this type will enable a complete evaluation of freight efficiency. This will also enable road transport authorities to compare the revenue impacts of third party rail access against registration and licensing impacts of road transportation. Other impacts may include a comparison between the costs of building and maintaining a new road compared with construction and operation of a new rail line. Consideration must also be made for road damage caused by heavy vehicles. This comparison will inform decision makers of the most appropriate form of freight transportation.

Issues that should be addressed in rail CBA include:

- accidents and safety – level crossings
- regulatory impacts
- owner and operator – third party access requirements and pricing
- integration between passenger rail and freight rail
- externalities – noise, emissions
- comparison of road and rail freight haulage –incremental analysis
- capacity and bottlenecks – port access and key distribution points
- evaluation period, asset life and residual values
- rolling stock acquisition and maintenance costs.

## 5.2 Busways/tunnels

A busway is a dedicated priority bus corridor. The main benefit of busways over traditional bus services is the TTC savings for existing public transport users. There may also be additional benefits for road users that remain on the existing transport routes. The generalised cost function discussed in Section 4.1.2.2 can be used to assess the benefits of busway projects. However, as with all urban public transport projects, the strategic transport modelling results will have a significant influence on the CBA results.

It is beyond the scope of this manual to provide detailed guidelines for busway evaluations. For more information on public transport evaluation see Volume 4 of the ATC material.

A tunnel (below ground road link) provides additional road network capacity and relieves congestion. The need for a tunnel is evident due to land constraints and lack of sufficient road corridors. As for a traditional road project CBA, the main road user impacts will be TTC savings, VOC savings and accident cost savings. Accident costs are required to be calculated using a different approach for tunnel projects. A detailed safety investigation should be undertaken as the severity of crashes in tunnels may be higher than usual. Transport modelling will also need to model circumstances in which the tunnel is closed, as such an occurrence would give rise to significant road user costs to the surrounding road network and therefore will need to be incorporated in the CBA.

## 5.3 Heavy vehicles/freight

The majority of benefits for transport projects are savings in travel time for road users to complete trips when compared with a base case. Within the travel time estimate is an incorporation of the value of freight transported by heavy vehicles. Faster and more reliable delivery of freight will have flow-on effects for the economy. To address freight-related transport issues, governments have investigated schemes such as performance-based standards and higher mass limits projects to increase freight efficiency.

The following issues should be considered for freight-based CBA:

- vehicles that can carry higher loads and volumes per trip
- less trips to undertake the freight task
- less congestion and accidents
- pavement damage and maintenance
- road design
- access on existing network
- additional capital expenditure.

As discussed previously in Section 5.1, bulk domestic freight can be transported by road and/or rail. CBA of freight-based projects should compare the incremental costs and benefits of the road or rail options. The main benefits that accrue when undertaking freight-based projects should be the value and tonnage of freight transport, travel time and trips and the flow-on efficiency effects for the economy.

Benefits of projects such as higher mass limits are discussed in Part 1, Chapter 2.2.4. For more information on freight-based CBA see the Multi-Combination Vehicle case study in Section 5.1. of the *User Guide*.

CBA of freight projects may also include evaluation of secondary infrastructure works such as heavy vehicle rest areas. Rest areas provide a safe and convenient place for heavy vehicle operators to recuperate from driving fatigue. There is also a legislative requirement for heavy vehicle operators to use designated rest areas at regular intervals. The main benefits of a rest area will be the reduction in fatigue-related crashes. To calculate the benefits of rest areas, specialised economic assistance should be used to calculate the crash reduction benefits.

## 5.4 Tolling

The decision to toll a road has a number of market-related outcomes. For example, a new road will provide savings in travel time for road users and also provide a revenue stream for the operator. The savings in travel time received by road users is passed on to the operator in the form of the toll payment. Therefore, in theory, the monetary value of the savings in travel time is equal to the toll price. This represents a transfer payment of the benefit. To include the travel time benefit and the toll revenue benefit would therefore be double counting.

The impact of toll roads and subsequently double counting is approached differently in the economic and financial evaluation. Generally a financial evaluation will include the toll revenue as a positive cash flow and include the relevant costs (capital, operation and taxes) as a negative flow to determine the net cash flow. In this way the inclusion of toll road impacts in the financial evaluation is relatively simple.

In an economic evaluation, toll revenue is generally excluded from the analysis to avoid double counting. However the impact of tolling can be measured in the economic evaluation through the infrastructure usage and demand for the road through comparisons of the 'with' and 'without' tolling scenario.

A general assumption is that, in the absence of a user charge (tolling) regime, the demand for a road is higher than under a tolling scenario. To include the impact of tolling in the economic evaluation, the price of the toll is added to the cost of travel for road users. Economists value the cost of travel through a measurement of the perceived cost of the journey. For simplicity, the perceived cost of travel can be assumed as a function of the time taken to travel from A to B and an hourly unit cost (or wage rate). The traffic demand modelling is then adjusted based on the perceived cost of travel that includes the toll price. The CBA is then conducted with traffic forecasts under both the tolled and untolled scenario.

The economic value of the toll is therefore incorporated into the analysis through its impact on consumption decisions. In the case of transport infrastructure, the decision is to travel or not to travel. To also include the financial value of the toll would result in a double counting of this parameter.

## 5.5 Multi-modal effects

Multi-modal transport planning provides a transport solution that incorporates more than one mode of transport. Multi-modal projects usually combine two or more of the following modes of transport: road, public transport (rail, bus, ferry), cycling and walking. For example a multi-modal transport project could incorporate a transport hub (Transit-Oriented Development or TOD) that connects a road to both a bus and rail station or a veloway that links cyclists to a ferry station.

The objective of multi-modal transport projects is to provide adequate connections between each mode of transport and provide incentives for car drivers and passengers to switch to public transport. The aim of multi-modal transport planning is to incorporate road operations and management into the wider public transport network and improve coordination with public transport operators such as the Translink Transit Authority.

A CBA of a multi-modal transport project involves complex modelling of the change in travel behaviour with a project. Ideally a transport model that incorporates all modes of transport should be used to assist the economic analysis.

A CBA of a multi-modal transport project should consider a number of issues, including:

- elasticity of demand among modes of transport
- trips by mode with and without a project – mode shift
- generated and induced trips
- change in public transport revenue
- economic and financial costs of changing modes (time, fare, convenience and comfort)
- governance and operation (maintenance costs and management between operators)
- subsidies.

Multi-modal transport projects can also promote the development of transit-oriented communities. TODs have been defined as mixed-use developments which provide housing, retail, offices, open space and other facilities within reasonable walking distance of public transport, making it convenient for residents and employees to travel by all modes of transport. The transport node, either train, light rail or bus terminus, is designed to be the focus for the development, and ideally becomes the community 'heart' where people shop, work, meet, relax and live.

Importantly, TODs have been identified as 'a popular planning strategy to reduce car dependence because it directly encourages public transit, walking and bicycling in mixed-use activity nodes around rail stations' and as a 'smart growth management tool for suburbs'[8].

The implementation of TODs is a key policy of the *South East Queensland Regional Plan* and supports delivery of a range of key government priorities relating to climate change, housing affordability, congestion. health and physical activity.



[8] Renne, John Luciano, Transit Oriented Development (TOD): Measuring Benefits, Analysing Trends & Evaluating Policy, October 2005 p.ii, in: THG, Submission to the Draft Local Growth Management Strategy, January 2008.


# 6 Special topics in cost-benefit analysis

This section identifies some of the broader, special and emerging topics in transport CBA. The topics include discussion of maintenance projects, community service obligation, economic development, wider economic benefits and macroeconomic modelling.

## 6.1 Maintenance projects

Maintenance projects occur in the absence of any capital funding, where the objective is merely to maintain or improve the condition of an existing road. In CBA, maintenance costs form part of the denominator in BCR formulae. Savings in maintenance costs are therefore considered as a saving in cost and not a benefit. This reflects a trade- off between capital expenditure and maintenance expenditure. Implicitly, the CBA process aims to fund projects which maximise return on total agency costs and not solely capital expenditure.

Tools such as the World Bank's HDM-4 system can be used to model the ultimate treatment solution for an entire road network based on cost effectiveness and competing maintenance priorities. TMR currently uses the SCENARIO tool to estimate whole-of-life costs of road maintenance projects.

CBA can play an important role in the efficient allocation of maintenance expenditure across a road network.

## 6.2 Community service obligations

In 2008, the Council of Australian Governments (CoAG) undertook a study titled *Defining and quantifying road-related community service obligations* to further define and measure community service obligations in relation to road use. The study found that road infrastructure community service obligations arise when a government requires a road agency to provide a service that:

- promotes social objectives, or benefits the community at large
- would not otherwise have been provided by the road agency acting commercially.

The first part of the definition requires that the road-related community service obligation be targeted at social objectives or benefits to the community at large. This requires the social objectives, or benefits to the community at large, to be explicitly identified for the associated expenditure to be considered a cost of satisfying a road-related community service obligation. The second part introduces the concept of the road agency acting in a commercial manner. This somewhat hypothetical approach is useful because it provides the basis for distinguishing between roads provided for economic reasons and roads provided for other wider community reasons. The study concluded that using a commercial benchmark is appropriate, because it defines the boundary between what would have been provided based on the private benefits of roads to road users, and what is actually provided.

The study identified that, in principle, the amount of road expenditure that would have been incurred by a commercial road service provider is determined by comparing the marginal value of roads to road users, with the marginal cost of providing roads. The amount of road expenditure associated with this point of equilibrium is then what a commercial road service provider would have incurred to provide roads. This marginal value of roads is based on the benefits users receive from road use, including the economic benefits from the transportation of people and goods.

The study recommended the use of the ATC material and in particular, CBA, as the most efficient method of identifying a community service obligation. CBA can be used to quantify the economic benefits associated with road use as the benchmark against which total road expenditure can be compared. The difference between actual road expenditure and that attributable to the economic benefits is then the estimate for the cost of satisfying the road-related community service obligation.

For new road projects, the economic benefits would be those associated with improvements in travel time, VOC reductions and improvements in road safety. There may also be other economic benefits associated with the scope to transport particular goods and services to markets, such as benefits to freight transporters, mine haulage or agricultural producers.

For existing road projects, a similar approach could be used to estimate the economic benefits associated with maintaining a road at its existing standard, in perpetuity. As with a new road project, it would be possible to identify TTC savings and VOC savings associated with maintaining a road at a certain standard, compared to allowing the road to deteriorate. These benefits could similarly be compared with expenditure to estimate the road-related community service obligation.

## 6.3 Relationship between economic welfare effects and economic impacts

The creation of employment remains a strong objective of government policy. A distinction should be made between the impact of a development and the economic worth of a development. CBA is a useful tool to estimate the welfare effects of development. Other impacts such as output, employment and household income can be measured using other means such as computer general equilibrium (CGE) or input/output. If either of these tools are used, then these results should be reported separately to the CBA.

### 6.3.1 Developmental benefits

A developmental benefit reflects a net increase in the economy's output, where the total developmental benefit equals the increase in gross domestic product or value added. A broad range of investment projects could have developmental consequences for the road network. They include new irrigation areas, new mineral developments, new processing projects such as smelters or refineries, or major tourism resort areas. The net benefit to the road system equals the change in gross domestic product, less the non-road investment in a project (including the value of any private investment). The consequences for the road network will be an increase in traffic volume.

## 6.4 Wider economic benefits – review and guidance

Wider economic benefits (WEBs) are a relatively new topic in transport economics, first developed by the United Kingdom Department for Transport. The Commonwealth Government advisory body Infrastructure Australia has mandated the incorporation of WEBs with traditional CBA in proposals for federal infrastructure funding.

Transport economists have postulated that traditional CBA does not incorporate the wider benefits to the economy from transport projects, in particular those relating to productivity improvements and agglomeration benefits. In 2006, *Transport's Role in Sustaining the UK's Productivity and Competitiveness* outlined a methodology to quantify wider economic impacts without necessarily completing a general equilibrium model of the entire economy.

The primary economic benefits measured in traditional transport CBA are journey time savings. Individuals and businesses place a monetary value on their time, which economists measure through willingness to pay estimates and/or wage rates. Savings in TTC are often transferred to other non-road users. For example, firms that can lower their marginal cost of production through lower transportation costs will pass on the savings to consumers through lower prices of goods. Likewise, the cost of commuting can impact the attractiveness of competing residential locations. Home owners and developers can benefit from improved access to residential sites. In theory, these benefits are captured in traditional CBA travel time calculations. It is argued, however, that the benefits of transport projects outweigh the direct estimates of travel time due to market imperfections.

The United Kingdom Department for Transport provides guidance on the additional benefits of transport projects that are omitted from traditional CBA. These wider economic benefits include:

- agglomeration
- competition
- output
- labour supply.

International experience suggests that these wider economic benefits for transport projects add between 10% and 40% to the conventionally measured benefits. Quantification of wider economic benefits is outside the scope of this manual.

## 6.5 Using macroeconomic modelling tools

This section discusses alternative methodologies currently available to investigate the broader economic impacts of road infrastructure projects. A criterion for this section has been those models that are readily available and have a history of use in this country. For this analysis, four relevant methodologies are discussed. The section begins by covering the basic input/output approach; latter parts of the section discuss alternative methodologies that extend the basic input/output approach and econometric approaches of input/output econometric and CGE models. Each of these sections concludes with a discussion of some of the advantages and limitations of the particular methodology. Since 'applied' as opposed to 'theoretical' multi-sectoral dynamic models are not commonly available in Australia, the following discussion will not detail that class of model[9].

### 6.5.1 Input/output analysis

Input/output tables provide a disaggregation of a region's domestic production account. As such, the table can be seen as a snapshot of the regional economy at a particular point in time. The tables can be used to analyse the linkage between industry output and industry employment, the significance of imports and exports to particular industries, and linkages to household and government demand[10].

There are policy situations where input/output analysis may be useful, for example when governments wish to use public expenditure to relieve high unemployment at the regional level.

Input/output analysis can provide estimates of the employment impacts of the proposed expenditure. Another may be in response to Environmental Impact Statement guidelines requiring the estimation of project economic impacts. Otherwise, the conduct of input/output analysis does not supplant the requirements of this manual for use of CBA.

### 6.5.2 Computable general equilibrium models

CGE models are a class of applied economic models that are used to estimate how an economy might react to changes in policy, technology or government expenditure. These models are denoted as 'general' as they incorporate the impact to multiple markets within an economy. On the other hand, a CBA is considered a 'partial' model as it measures the impact of a market in isolation. However, where CGE models have been used in the roads context, they have taken their key inputs from CBA of projects under consideration. In this sense, CGE models do not supplant CBA.

In a whole-of-government approach, a significant advantage of CGE models is their ability to measure outcomes other than road transport outcomes. Such modelling approaches are capable of capturing (in a broad sense) the indirect and induced effects of road infrastructure on a range of industries[11]. As a general rule, CGE is not appropriate except for very large projects.



9 For a more detailed discussion of non-recursive multi-period CGE models, with or without intertemporal optimising investment behaviour, refer to (Dixon & Parmenter, 1994).

10 P 12, *Estimating the Impact of Investment in Roads,* A Modelling Approach, (An internal paper) DMR, 1999.

11 P 26-27, *Estimating the Impact of Investment in Roads,* A Modelling Approach, DMR, 1999.



# 7 Complementary and alternative evaluation

CBA identifies the main monetised cost and benefits created by a road project to the community. To ascertain a complete understanding of the impacts of a particular project, a broader analysis should also be undertaken where community objectives and non-monetised impacts are considered. As part of this broader analysis, ex-post evaluations should also be performed. This type of analysis complements the CBA and provides a better knowledge base to make informed and transparent decisions. This chapter largely draws upon analysis and extracts contained in Volume 3 of the ATC material.

Some of these complementary analyses include strategic merits test, evaluation summary table, project evaluation summary table, multi-criteria analysis, incremental analysis, adjusted CBA and ex-post evaluation. These provide qualitative assessments of strategic fit evaluations, assess non-monetised impacts, compare and rank different outcomes under different criteria, study small changes in specific variables and their effect, and evaluate projects after completion. A detailed description of these techniques is included in this chapter.

## 7.1 Strategic merits test

The strategic merits test is a strategic qualitative assessment that is designed to evaluate the alignment of transport projects with broader government strategies and policy objectives.

This process acts as an initial filter where only projects that have a strategic alignment with government plans and direction can pass through to further detailed evaluation stages. The strategic merits test provides a series of questions with the purpose of identifying if a proposed project meets the jurisdictional objectives, policies and strategies, and associated risks. It also attempts to determinate if there are any barriers or dependencies on other projects and if appropriate consideration has been given to alternative solutions.

The ATC material provides a strategic merits test template that can be used to evaluate a project's alignment to the government's objectives. A strategic merits test is usually required at the project proposal stage of the On-Q project management framework and for federal funding submissions.

## 7.2 Evaluation summary table

The evaluation summary table is a document which summarises the economic, social and environmental impacts of transport projects. The evaluation summary table presents both monetised (from the CBA) and non-monetised impacts of a project. The non-monetised impacts are represented by a qualitative evaluation that allows decision makers an indication of the benefits not valued in the CBA.

The evaluation summary table includes the proposed project description, the problem that this project is addressing, and other options that have been considered. It also includes:

- strategic plan objectives from an economic, social and environmental perspective
- impacts associated with each objective
- qualitative and quantitative information associated to a project's impacts
- evaluation of each impact expressed in monetised (when appropriate and possible) and non-monetised terms
- summary of CBA results.

The information shown should be supported by appropriate documentation. The evaluation summary table is designed to provide decision makers with a one page summary of the impacts of a project[12].



[12] For more information, see Volume 3 of the ATC material.

## 7.3 Multi-criteria analysis

Multi-criteria analysis is a method used to evaluate a project against a number of criteria. In a transport context, a multi-criteria method evaluates a project against a number of criteria such as economic (CBA), social, environment, cost (capital and ongoing), financing, jobs, distance to public transport, land resumption and so on. This allows an evaluation of a project against a complete set of objectives and can be used to ensure a project meets key government objectives other than economic.

The actual measurement of indicators need not be in monetary terms, but is often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Different environmental and social indicators may be developed side-by-side with economic costs and benefits. Explicit recognition is given to the fact that a variety of both monetary and non-monetary objectives may influence policy decisions.

Multi-criteria analysis provides techniques for comparing and ranking different outcomes, even though a variety of indicators are used. Multi-criteria analysis is particularly applicable in cases where a quantitative criteria approach (such as CBA) falls short, especially where significant environmental and social impacts cannot be assigned monetary values. Multi-criteria analysis allows decision makers to include a full range of social, environmental, technical, economic and financial criteria.

## 7.4 Adjusted cost-benefit analysis

The adjusted CBA is a combination of the standard CBA and multi-criteria analysis methodologies.

This technique is used to incorporate objectives that are not fully quantified in the evaluation, providing the opportunity to apply more weight to objectives that do not relate to economic efficiency. This reflects the importance of other objectives for the government and allows a subjective judgment in the analysis in a quantitative way enriching the decision-making process.

The main argument against this technique is that it can distort the CBA results by favouring less economically efficient projects over more efficient projects. This can be addressed by reporting both the standard CBA and adjusted CBA results for a project. This will enable a robust evaluation of a project alignment with broader government objectives.

## 7.5 Ex-post evaluation

The main objective of an ex-post evaluation is to assess the effectiveness and efficiency of the original investment decision. The ex-post evaluation provides an opportunity to learn from the experiences of a project. The lessons learned from this process could be enormously beneficial to improve future evaluation methods, current decisions procedures, the accuracy of cost benefits and traffic demand forecasts, and to identify any corrective actions. In order to do this, a comparison between the planned and the actual outcomes has to be undertaken.

The ex-post evaluation can be applied to a single project or program, and can apply to both the CBA process and results. Process reviews evaluate how the results were obtained, and reviews results to evaluate the accuracy of the outcomes related to actual outcomes.

An ex-post CBA compares the original CBA with a hypothetical base case where a proposed project does not exist. The objective is to analyse the strength of the original economic justification of a proposed project. This can be complemented with a broader evaluation that includes a financial, environmental and social perspective.



# User guide

3

# 1 Introduction to CBA6

The *User Guide* provides system users with an authoritative understanding and instruction for using TMR's CBA6. An important part of the *User Guide* has been the inclusion of the case studies. The case studies have been carefully designed with the intention of assisting system users to undertake economic evaluations of road projects of different types within the CBA6 modules. The *User Guide* also provides an interpretation of the results generated by CBA6 and has an array of screenshots to demonstrate the application of the tool.

## 1.1 About CBA6

CBA6 is TMR's designated road project evaluation tool. CBA6 has the technical capability to undertake economic evaluations of TMR projects. CBA6 has been developed and tested by a diverse multi-disciplinary project team consisting of software developers, engineers and economists.

CBA6 was developed by TMR to make the CBA process as accessible and transparent as possible, and to provide an efficient means of processing a large volume of calculations that even small, simple projects entail. CBA6 is not always an all-encompassing tool for every road project; some projects may require the use of CBA6 in conjunction with spreadsheets or other software tools. Guidance is provided for more complex applications of CBA6.

The system user will have to exercise judgement when designing an evaluation. CBA6 is a tool used to assist in the evaluation process. It is necessary to define the problem, cost the potential solutions and gather traffic estimates, before using CBA6.

Input data for CBA6 needs to be acquired from sources such as ARMIS or SIDRA. The system user may be required to manually calculate some of the input data, such as traffic composition and traffic growth. CBA6 processes most of the benefit calculations that were such an onerous part of manual procedures set out in the previous manual. CBA6 has been designed to allow the system user to systematically conduct CBA.



### 1.1.1 Software description

CBA6 is a PC-based tool which automates the process of performing CBA for road infrastructure projects. It's a Windows application that runs stand-alone and has been developed by TMR using MS Visual Basic 6.0 and MSDE database environment.

### 1.1.2 History of CBA6

The *Cost-Benefit Analysis Manual for Road Projects* was first produced in 1993. At that time, QTMR CBA procedures relied almost exclusively on manual calculation. The introduction of computer software in 1994 largely eliminated the need for manual calculation and streamlined the CBA process.

The CBA manual produced in 1999 incorporated the use of software with the introduction of CBA4. This edition of the manual incorporates case studies based on the use of the current version of TMR's project evaluation tool CBA6.

Since the previous CBA manual was produced, there have been several significant developments in the field of road project evaluation. These developments include the release of the (2006) ATC material and the (2005) *Austroads Guide to Project Evaluation*. Substantial efforts have been made to harmonise CBA6 with other state-based project evaluation software models. Since 2005, TMR has focussed considerable efforts in harmonising the results generated in CBA6 with HDM-4. CBA6 has been updated to include the necessary calculations and features consistent with ATC guidelines.

### 1.1.3 Scope of CBA6

CBA6 has been developed with the capability to undertake economic evaluations for a wide range of road projects. The tool also has the capability to be used to undertake evaluations, or alternatively, partial evaluations of road links in urban environments, for example the Pacific Motorway in south-east Queensland. In these cases, system users will need to exercise caution, as the tool may not be suitable to operate in urban environments.

Some of the more complex rural project types that CBA6 is equipped to undertake, but is not limited to, include diversions, bypass projects and incremental projects. CBA6 is not equipped to undertake evaluations for rail projects or upgrades of other modal infrastructure. For these types of evaluations, system users will be required to obtain specialist advice from either the CBA Team or relevant experts.

## 1.2 Relationship with other software

This section aims to provide system users with some appreciation of other software tools that can be used in association with CBA6, and tools that prioritise road investment decisions on the basis of economic criteria. This section is not intended to provide system users with a detailed guide/explanation of these models, but to inform them of the available software models, and provide some information on their relevance with reference to the operation and use of CBA6 and road project evaluation.

### 1.2.1 ARMIS

ARMIS is essentially a system for collecting and storing road-related data, auditing its quality and currency, and presenting that data into information formats which assist decision making by TMR. ARMIS provides strategic and operational management information for the planning, design, construction, maintenance and management of the state's road network, and is fundamental to TMR in supporting the *Queensland Transport and Roads Investment Program*. The information supplied through ARMIS is a key input for road project evaluations using CBA6. ARMIS also incorporates a suite of presentation and analysis tools which are supported by a 'data warehouse' of roads information, the Roads Information Data Centre (RIDC). ARMIS data is summarised in the RIDC and integrated with a broad range of internal and external data sources. Presentation tools provided for accessing RIDC include ChartView, MapView, Roads Information Online (RIO), ARMIS GIS and any other Open Database Connectivity (ODBC) compliant tool, such as Microsoft® Excel or Access. ChartView is a useful tool when obtaining data and information to undertake a road project evaluation using CBA6.



### 1.2.2 DVR

TMR annually collects digital video data for the sealed road network from a network survey vehicle. Four directions are captured - forward, rear and both sides. Digital Video Road Viewer (DVR Viewer) is a viewer program that plays digital road videos so that they can be viewed on a PC screen. A system user can choose to simultaneously play any or all of the directional views and easily arrange their layout by dragging and dropping.

DVR Viewer also includes tools for taking measurements of features in the video image, adding text annotations, and attaching images to video frames.

The use of digital videos avoids cumbersome manual methods using video tapes, and opens the way to integration of the viewer with other applications. Currently, integrated applications include:

- SCENARIO
- ChartView

The different road video views can be analysed to collect information on road features for inventory purposes, and on the condition of the roads including defects such as cracks and pot-holes. DVR is a useful tool when obtaining data and information to undertake a road project evaluation using CBA6.

### 1.2.3 SCENARIO

SCENARIO is a decision support tool used by asset managers in developing maintenance strategies for road networks. It is a rule-based system, where system users have the freedom to develop their own rules or to adopt corporate rules. A corporate pavement condition deterioration model is also supplied, however system users have the freedom to create their own local model. SCENARIO's pavement management system analysis is complemented with reporting capabilities and budget constraint analysis. SCENARIO is predominantly used by RAM and gives the system user a detailed profile of maintenance expenditure of a predefined time. This is vital to include in the project analysis, especially for the accurate specification of the base case. SCENARIO calculates three economic criteria: NPV, BCR and IBCR.

### 1.2.4 HDM-4

HDM-4 is an internationally developed software tool which allows system users to evaluate alternative and competing maintenance strategies. The tool has been used by the World Bank primarily to conduct economic appraisals of maintenance strategies for rural roads in Indonesia and parts of South East Asia. The software model has been licensed and adapted for use in Australian conditions by ARRB. The inputs used in HDM-4 are quite complex and generally require the system user to possess an engineering background together with a detailed knowledge of pavement/asset management. HDM-4 software produces economic decision criteria, NPV and an IRR for each maintenance strategy. HDM-4 contains one module with the capability to undertake an economic appraisal of rural road projects.

For more information on the above software models, please contact Road Asset Management Branch, TMR.

### 1.2.5 SIDRA INTERSECTION evaluation and design

SIDRA INTERSECTION is an advanced micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models. SIDRA INTERSECTION is a renowned software package used worldwide for intersection capacity, level of service and performance analysis by traffic design, operations and planning professionals.

Using SIDRA INTERSECTION, the system user can evaluate and compare capacity, level of service and performance of alternative treatments involving signalised intersections, roundabouts, two-way stop and give way (yield) sign control, all-way stop sign control, single point urban interchanges, signalised midblock crossings for pedestrians, and all-in-one package. Intersections with up to eight legs, each as a two-way road, one-way approach or one-way exit, can be modelled with ease. SIDRA INTERSECTION is available from Akcelik & Associates Pty Ltd.

http://www.sidrasolutions.com/akcelik_company.htm

### 1.2.6 NIMPAC software tools

All road project evaluation software models in use in Australia are based on NIMPAC or its immediate predecessors and are equipped to calculate road user and travel time costs. NIMPAC is known as the NAASRA Improved Model for Project Assessment and Costing. Austroads was previously known as NAASRA. All NIMPAC-based software models have been harmonised with each other and with the international software HDM-4. Each of the NIMPAC-based models generates estimates of road user costs at an individual component level .

## 1.3 Installing CBA6

This section covers aspects of CBA6 installation from a system user's viewpoint. It explains how to acquire CBA6, who will install it, requirements by CBA6 on where it's installed and how, TMR Terms of Use, and for external system users the License Agreement. The chapter also describes what is installed and where, demo install, re-install and some housekeeping.

Software request and installation of CBA6 is very simple. After submitting a CBA6 software request form, the CBA Team will register a license in the Tracker system and provide an intranet link to the system user via email. The link enables a download of the CBA6 install package to anywhere on the TMR computer network. Local IT staff will download and install the software package onto a system user's PC.

### 1.3.1 How to request CBA6 installation

To provide ongoing updates to pricing models and maintain a consistent version of the tool, the CBA Team needs to maintain a contact register of current system users. The register will assist in planning ongoing training and communication in CBA-related topics. This is one of several reasons why system users need to fax or email their details in a software request form. The form is available from the CBA intranet site http://RAMS/CBA. The request form includes an acceptance of CBA6 Terms of Use, which outlines the terms under which the tool may be used at TMR for road evaluations.

External parties (e.g. contractors) who provide CBA for TMR may also request use of the tool. They can send a request through the region, who will contact the CBA Team by email and submit the request form. External parties are also subject to the Terms of Use plus a License Agreement as a condition for use. As a general rule, external parties and consultants need to be pre-qualified in economic studies.

The process for obtaining pre-qualification is detailed in *Manual - Consultants for Engineering Projects* available through Contracts and Standards Branch, TMR. Policy information is available on TMR's intranet site.

System users who just want to try out the tool, can request local IT support to download and install the demo install from the CBA intranet website. The demo install is fully functional, but limited to 30 days before it expires.



### 1.3.2 License and registration

When the 30-day period of a demo install expires, CBA6 will ask for license and registration code. A demo install can then continue if such details are obtained and entered, but this is not the usual approach for the majority of system users.

Instead, a CBA6 install requested as described in 1.3.3, will not require the system user to register or enter any license details. The license code registration is built in and automatic, and each system user is registered when a request form is submitted.

Registration credentials are checked automatically each time a system user logs into CBA6, since each license has an expiry date, typically one year. After expiry, the system user needs to contact the CBA Team and request renewal, which is easily done by email to CBATeam@tmr.qld.gov.au.

### 1.3.3 Installation requirements

In summary, CBA6 will install on any standard TMR PC without any additional requirements.

CBA6 needs to be installed on a Windows PC with the TMR Standard Operating Environment (SOE) i.e. a PC supplied and maintained by TMR. This is currently a Windows XP sp3 environment with MS Office 2003. There are no other specific requirements, however CBA6 runs a local database, and it's advisable to have at least 1 Gb RAM (Random Access Memory).

CBA6 has only been tested on Windows XP. It has not been tested, and is not supported, on Windows PC operating systems that are later than Windows XP.

The PC may be a laptop, and the install as well as the using of CBA6 can be without continuous access to the TMR computer network.

Downloading the install package requires access to TMR's intranet network i.e. using a location of http://rams/cba brings up a TMR web page. If there is no such access, an installation CD needs to be supplied by the CBA Team.

CBA6 has not been tested to run on a PC that has a database management system later than MSDE 8.00 SP3. For instance a PC with other software, that uses the later version of Microsoft SQL Express, may install and work but is not supported. This can sometimes be the case with non-departmental PCs.

Finally, as also noted in the instructions displayed during the install, the Windows configuration setting found at Control Panel—Administrative Tools—Services—Server needs to be enabled and started during the installation, after which it may be restored to the previous setting.

### 1.3.4 Install process

Only software available for installation via the Novell Windows can be installed by system users themselves. CBA6, for technical reasons, has to be installed by IT support with administrative rights on the PC.

For re-installs, the system user must first ensure that any existing CBA6 evaluations are first exported, as the re-install will delete existing databases.

### 1.3.5 Installation for TMR staff

The following steps will be used in the install for TMR staff.

1. The system user visits the CBA intranet website, downloads the CBA software request form and reads the CBA Terms of Use document.

2. The system user fills in the request form and sends a fax (ref. intranet website or departmental phone book) or scan/email to the CBATeam@tmr.qld.gov.au.

3. The CBA Team registers a license for the system user using the RAMS Tracker registration interface and distributes the install package. The install will appear as a compressed file on the TMR intranet, accessible through a network link which is emailed to the system user.

4. The system user, or local IT support, downloads and decompresses the package file from TMR's intranet using the supplied download link.

5. Local IT support will use the information contained in the CBAInstallationReadMe.htm file, found in the downloaded compressed file, to install CBA6.

6. Additional support is available during the installation from the CBA Team.

### 1.3.6 Installation for non-TMR staff

CBA6 is sometimes made available to non-TMR staff such as contractors.

Non-TMR staff and consultants need to be pre-qualified in economic studies, to ensure consistency of use and approach in the selection of data, subjective definitions and non-automated steps of a CBA when using CBA6.

The process for obtaining pre-qualification is detailed in *Manual - Consultants for Engineering Projects* available through TMR's Contracts and Standards Branch.

The following steps should be used to install CBA6 for non-TMR staff:

1 The system user emails CBATeam@tmr.qld.gov.au requesting a CBA6 request form, Terms of Use document and License Agreement. The request form is then returned by fax or scan/email, to the same email address.

2 The CBA Team registers a license for the system user for the requested period using the RAMS Tracker registration interface, distributes the install package and writes the package to a CD. The CD is then sent to the system user.

3 The local IT support for the system user, or a person with administrative PC rights, will use the information contained in the CBAInstallationReadMe.htm file (found in the downloaded compressed file), to install CBA6.

Non-TMR staff will need to accept and adhere to both the Terms of Use and a License Agreement which specify conditions and limitations covering TMR's provision of access to CBA6. The process for this and the acceptance of these agreements are detailed in the CBA request form.

(the CBAInstallationReadMe.htm file, as viewed by MS Internet Explorer)

### 1.3.7 What will be installed?

The installation process will install and register several Windows components that will be located at C:\Program Files\CBA in directories under this location.

The main files will be the CBA program, some additional linked modules, export template file, crystal report template, a CBA Windows help file and two databases represented by two pairs of files: CBAProj_cases.mdf, CBAProj_cases.ldf, DMR.mdf and DMR.ldf.

The DMR files contain the TMR pricing data, road types and other common parameters for calculations such as deterioration values, accident costs, etc.

The CBAProj_cases files constitute the database for the system user's evaluation data.

### 1.3.8 Demo installation

The Demo CBA6 is a full version of CBA6 available from TMR's intranet site http://rams/cba under downloads. It will expire 30 days after installation and is to be used for evaluating CBA6. Once downloaded, the installation is identical to the licensed version. The installation steps are the same, starting at point 4 for TMR (1.3.5).

## 1.4 Housekeeping and updates

Approximately every second year, the CBA Team will distribute an update of the DMR to registered system users. This will keep pricing and variables such as fuel costs, oil, tyres etc. up to date.

The system user will update simply by replacing the existing two DMR files at C:\Program Files\CBA\Databases with those contained in the compressed distributed file.

The system user needs to do frequent backups of evaluation data, typically after major work has been entered. Departmental PCs have a network file location, the H: drive, where system users normally store data that should be secured through system backups. Using the H: drive will ensure that the data is covered by the system backup process, and can be restored in case of catastrophic failure of software or hardware.

The exported files of evaluations can be compressed and emailed when interacting with the CBA Team.

During the re-install, the existing user data will be lost and the system user will need to import their saved exported evaluations. Details about updates and new releases will be communicated through the CBA6 intranet website and newsletter.

## 1.5 Help and support

The CBA Intranet website http://RAMS/CBA is kept up to date with the latest information on CBA6, and maintains a regular newsletter.

The CBA Team is a dedicated support team for CBA work on TMR projects and the installation of CBA6, as well as ongoing support and advice regarding CBA issues. The team can be contacted by email on CBATeam@tmr.qld.gov.au.

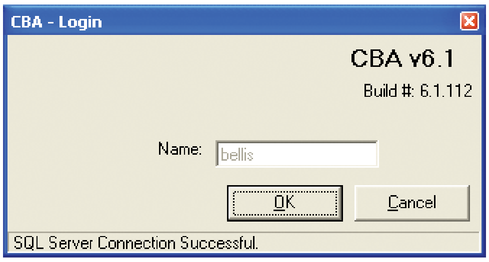
## 2 CBA6 settings and features

This section examines the use of CBA6 including general software design and user settings. This section will outline the system settings that are used to configure CBA6 for project evaluation.

## 2.1 CBA6 logon and workspace

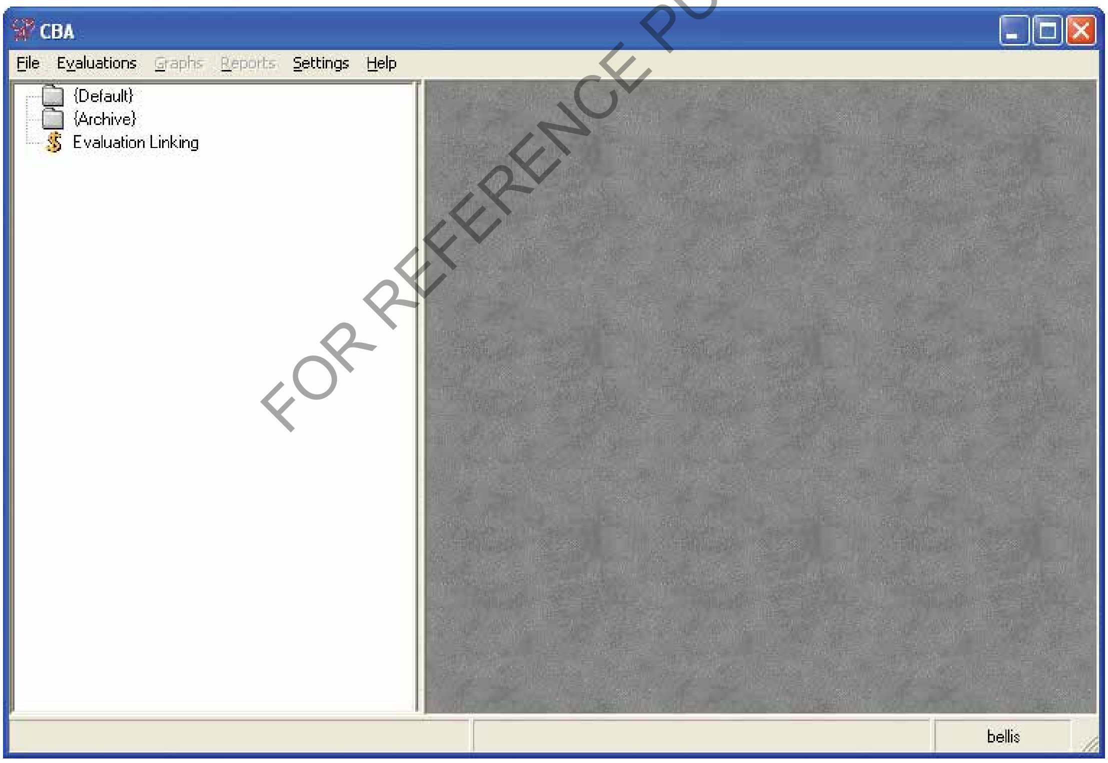
CBA6 is available in the Windows start menu or located via an icon on the desktop. The login screen displays the tool version number and user name. Once the login screen appears, CBA6 will automatically fill in the system user's Windows ID.

*Figure 1: CBA6 login screen*




Once the tool starts, the CBA6 workspace will appear and the tool is ready for use. Figure 2 shows the workspace and associated menu structure. The interface consists of a series of drop-down menus which display a list of options when highlighted. The workspace also consists of two empty folders '{Default}' and '{Archive}' and an 'evaluation linking' option. Some menu options are only available when a 'project' has been created. An explanation of each menu item and the workspace is shown below.

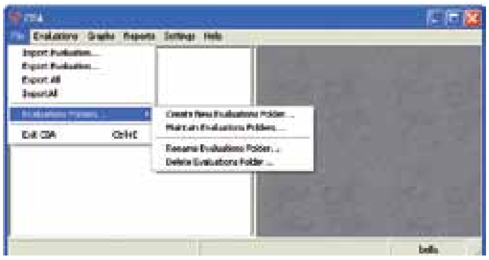
*Figure 2: CBA6 workspace*



## 2.2 File menu

The file menu is used for importing and exporting individual projects, database backups, creating and editing evaluation folders and exiting CBA6, see Figure 3. The remainder of Section 2.2 will discuss each of the drop-down menu options.

*Figure 3: CBA6 file menu*



### 2.2.1 Import/export evaluation files

CBA6 allows the user to export completed evaluation files to other directories, or import externally stored files into the tool for further assessment.

#### 2.2.1.1 Export evaluation

For security purposes, all evaluation files should be exported and stored in a safe location. Reducing the number of evaluation files stored in the tool may also increase performance of the tool. The CBA6 tool can be used to export individual evaluation files or back up all evaluation files stored in the tool. The evaluation export screen is shown in Figure 4.

*Figure 4: Exporting an individual evaluation*

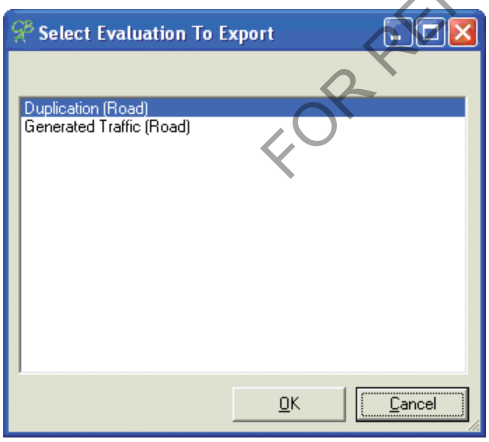
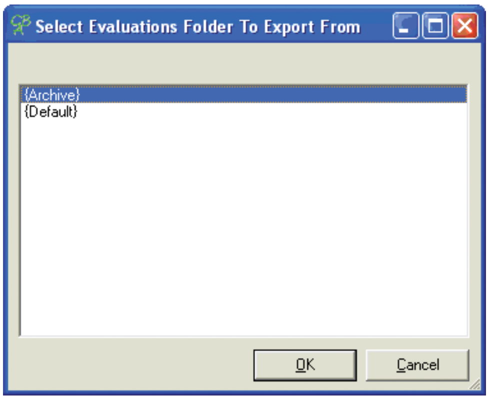



Figure 4 indicates two evaluation files to be exported. The system user selects one of these files and saves it to a secure location.

Alternatively, system users can export all projects that have been created. This form of backup is used to store completed evaluation files in a safe location. To back up completed road projects, proceed to the file menu then select 'export all' (from Figure 3), choose the evaluations folders that all projects will be exported from and select 'ok'. In Figure 5 the system user can back up evaluation files created in either the '{default}' or '{archive}' folders. The backed up valuation will now be stored in the chosen directory (file extension *.cba).

*Figure 5: Back up completed evaluation files from project folder*

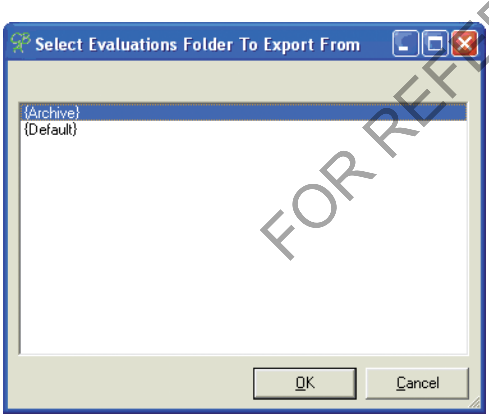





### 2.2.1.2 Import evaluation

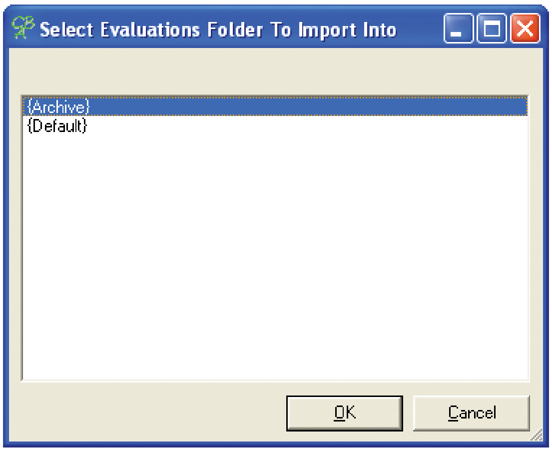
System users are able to import project files from external locations using the 'import evaluation' option from the file menu, see Figure 6.

*Figure 6: Import individual evaluation files*



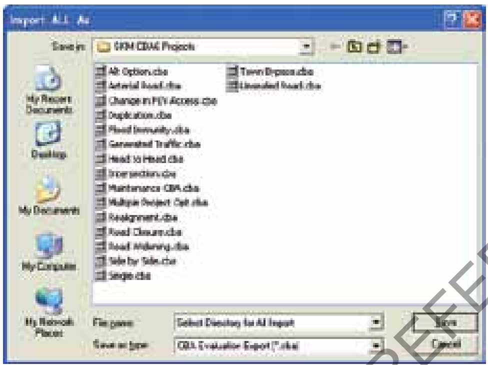

System users then select the project folder location for the imported CBA file from the CBA6 workspace, see Figure 7.

*Figure 7: Import completed evaluation files to project folder*




To import a number of backed up projects, the system user selects the ‘import all’ option. All files from a directory can then be imported into a project folder, see Figure 8.

*Figure 8: Import all evaluation files*



## 2.2.2 Evaluations folders

The evaluations drop-down menu can be used to create new evaluations folders, maintain the evaluations folders and rename or delete the evaluations folders.

### 2.2.2.1 Create new evaluations folder

CBA6 contains two folders for storing projects, the '{Default}' and '{Archive}' folders, see Figure 2. System users can add additional evaluations folders to store projects, see Figure 9.

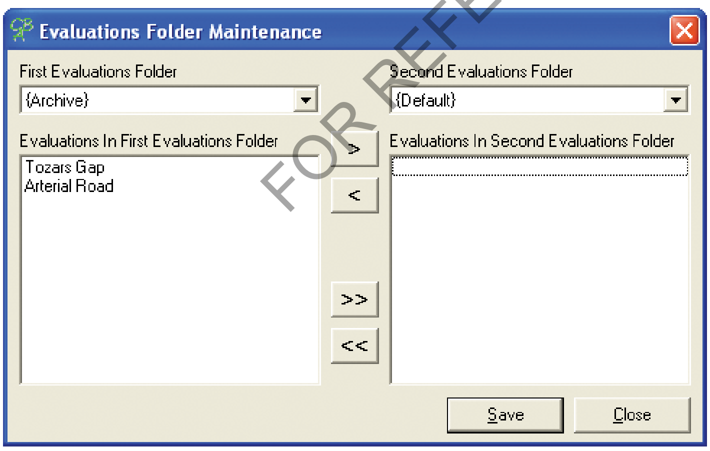
*Figure 9: Create new evaluations folder*


System users may wish to create their own evaluations folder to store common projects. For example a system user could create a project folder entitled 'Bruce Highway' and store all project evaluation files undertaken on the Bruce Highway under this folder.

### 2.2.2.2 Maintain evaluations folder

Evaluations folder maintenance enables the transfer of evaluation files between project folders. In Figure 10 the 'duplication' evaluation could be transferred from the '{Default}' project folder to the '{Archive}' evaluations folder.

*Figure 10: Evaluations folder maintenance*



### 2.2.2.3 Rename evaluations folder

To rename an evaluations folder ensure a user created folder is highlighted and select the 'rename evaluations folder' option from the file menu, see Figure 11.

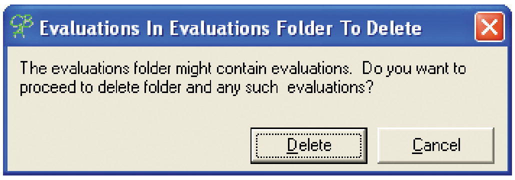
*Figure 11: Rename evaluations folder*


Note: The '{default}' and '{archive}' folders cannot be renamed.

### 2.2.2.4 Delete evaluations folder

To delete a user created evaluations folder select the 'delete evaluations folder' option from the file menu. A warning message will appear before the evaluations folder is deleted, see Figure 12.

*Figure 12: Delete evaluations folder*

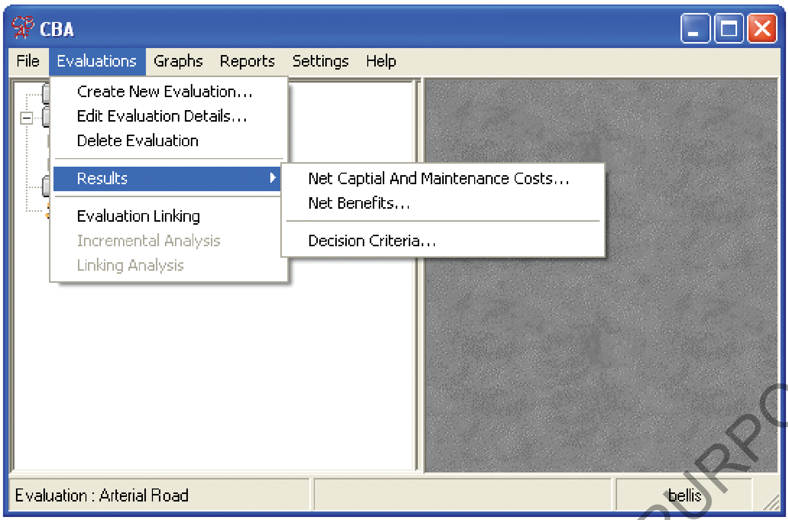



Note: The '{default}' and '{archive}' folders cannot be deleted.

## 2.3 Evaluations menu

The evaluations menu is used to create an evaluation of a proposed road project, see Figure 13. This menu can also be used to view results of the economic evaluation of a specific project or to link several projects together using an incremental or linking analysis. The evaluations menu is explained in detail in Section 3.

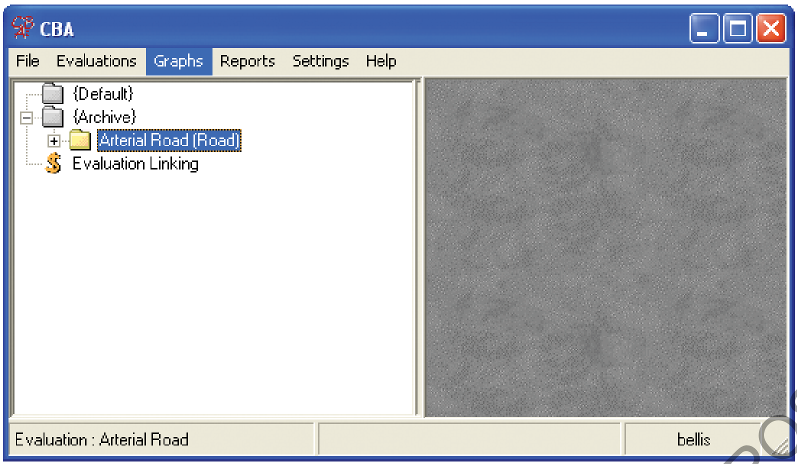
*Figure 13: CBA6 evaluations menu*



## 2.4 Graphs menu

The graphs menu is shown in Figure 14. Line or bar graphs of project results data can be created through the graphs menu. Graphing is discussed further in Section 4.8.

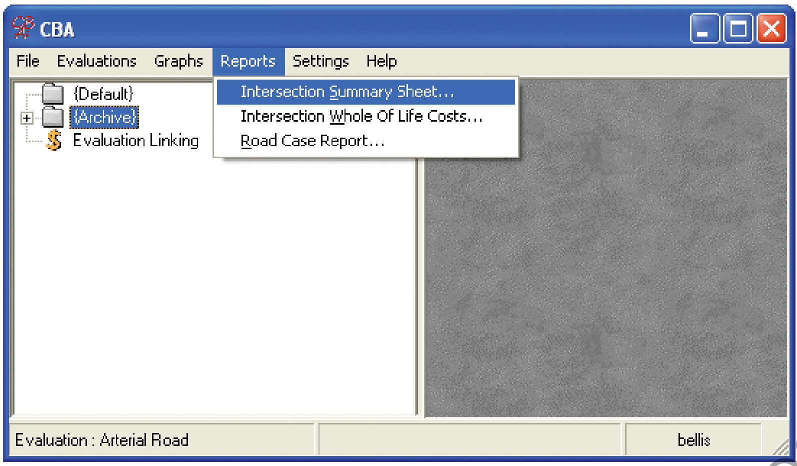
*Figure 14: Graph menu*



## 2.5 Reports menu

Various reports detailing the results from the CBA can be viewed and printed through the reports menu, see Figure 15. For further information on reports, see Section 4.6.

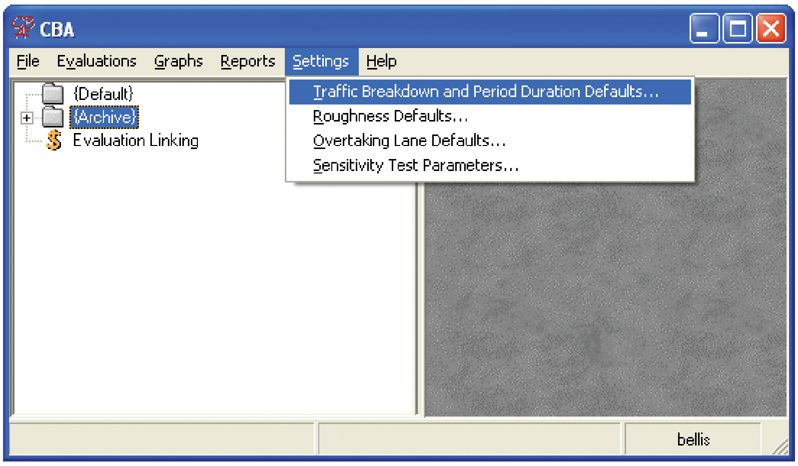
*Figure 15: Reports menu*



## 2.6 Settings menu

The settings menu enables the system user to alter the system default data to a user-specified range, see Figure 16.

*Figure 16: Settings menu*

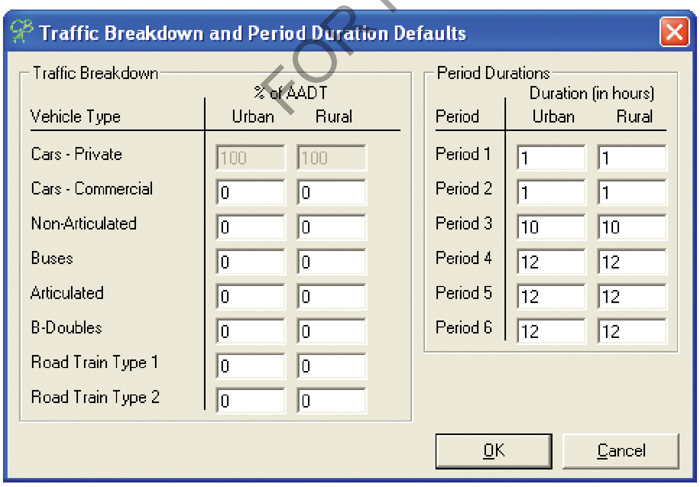



### 2.6.1 Traffic breakdown and period duration defaults

While undertaking an evaluation, the system user is required to enter traffic details including AADT, growth and traffic composition. The traffic breakdown and period duration defaults screen settings enable the user to enter project-specific values for more than one project at a time.

The design of CBA6 allows the system user to enter values for traffic composition in both rural and urban environments that can be used in multiple evaluations. This feature allows the system user to use the same settings on new evaluations which are located on the same link or corridor.

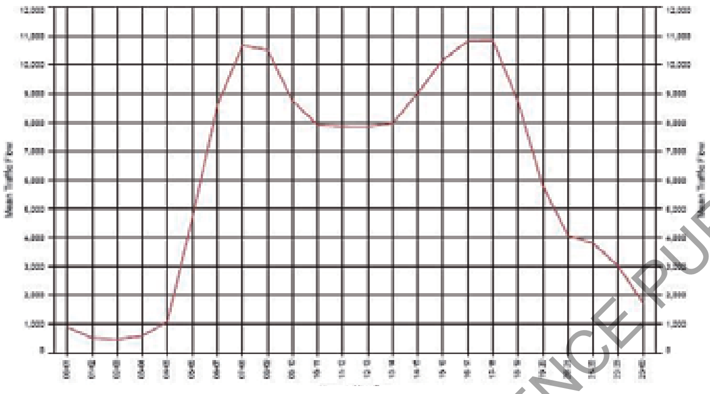
*Figure 17: Traffic breakdown and period duration screen*



Period durations are used to quantify road user costs within the intersection module of CBA6. Period duration defaults can be changed to reflect peak spreading or increases in total peak durations.

- Period 1 – morning peak
- Period 2 – afternoon peak
- Period 3 – non-peak
- Period 4 – night
- Period 5 – weekend day
- Period 6 – weekend night

*Figure 18: Description of peak periods*



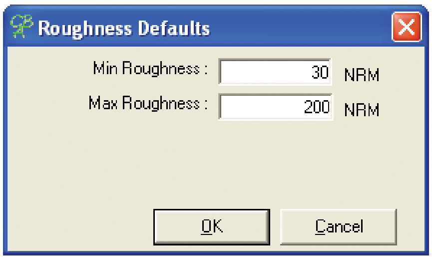
Note: The total of periods 5 and 6 should add to reflect the daily weekend duration, while periods 1 to 4 should cumulatively add to 24 hours, to reflect weekday durations.



### 2.6.2 Roughness defaults

The CBA6 tool allows the advanced user to change the default road roughness limits, see Figure 19. It is recommended that specialist engineering advice be sought before altering the roughness default settings.

*Figure 19: Roughness defaults*

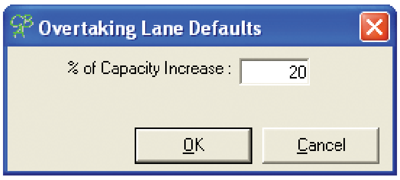



Note: Road roughness is displayed in NRM and can be converted from IRI using a simple conversion factor (see Appendix F of the *Technical Manual*).

### 2.6.3 Overtaking lane defaults

CBA6 uses a default increase in capacity after construction of the overtaking lane. The design of the tool assumes that the downstream area has an increased capacity after construction of the overtaking lane. The system user can alter the default settings. See Section 4.4 for further information on the significance of the downstream area.

*Figure 20: Overtaking lane defaults – downstream area*




### 2.6.4 Sensitivity test parameters

CBA6 contains an inbuilt sensitivity analysis within the road case report. Sensitivity analysis provides the decision maker with alternative CBA6 results based on plausible changes to key parameters in the project data inputs. The sensitivity analysis alters the fixed parameters by a default percentage and reports the resulting changes. The fixed sensitivity paramaters and the default ranges are:

- Capital Costs ± 20%
- TTC ± 40%
- VOC ± 20%
- Accident Costs ± 20%

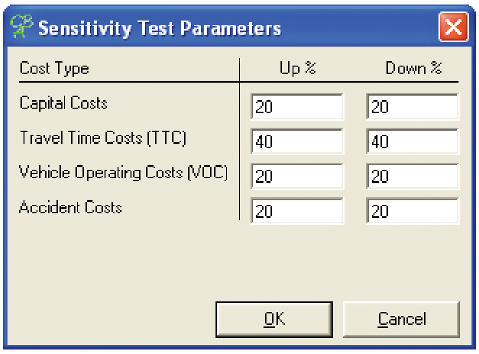
The system user may modify these ranges, using user options, to suit project-specific characteristics or to highlight the sensitivity of a particular input, e.g. capital.

As an example, TTC savings can be subject to more stringent sensitivity testing by setting the lower and upper bounds to 40%.

See Section 1.8.3 of the *Theoretical Guide* for further information on sensitivity testing.



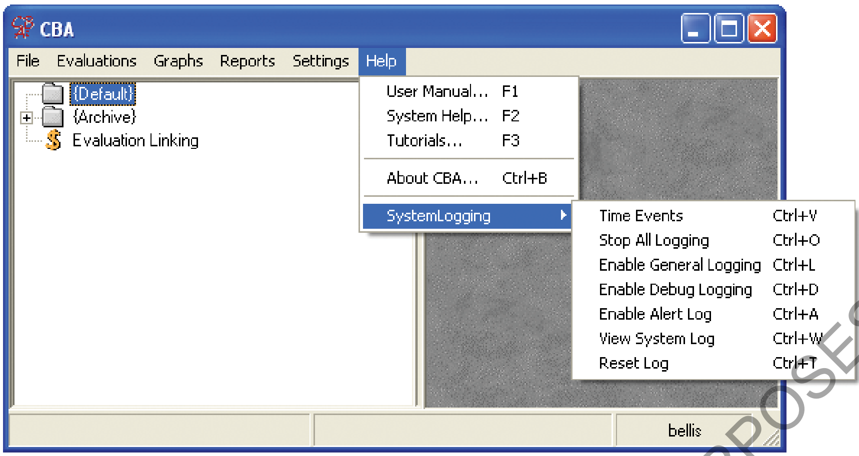
*Figure 21: Sensitivity test parameters*



## 2.7 Help menu

The help menu provides a link to the CBA6 help file. The help file contains theoretical help, system help and tutorial sections. The help menu also provides a system log which can be viewed and/or sent to the CBA Team for debugging purposes, see Figure 22.

*Figure 22: CBA6 help menu*






### 2.7.1 CBA6 help

CBA6 help is a free-flowing help file created in html format that gives basic guidance and advice from within CBA6, see Figure 23. As with most help files, CBA6 help facilitates a search function, allowing the user to search by keyword for their topic of interest. Access to the CBA6 help file is available through the CBA6 desktop interface, listed under the help menu, and can be accessed through the drop-down lists. Alternatively the help file can be accessed through keyboard shortcuts following the section layout as follows:

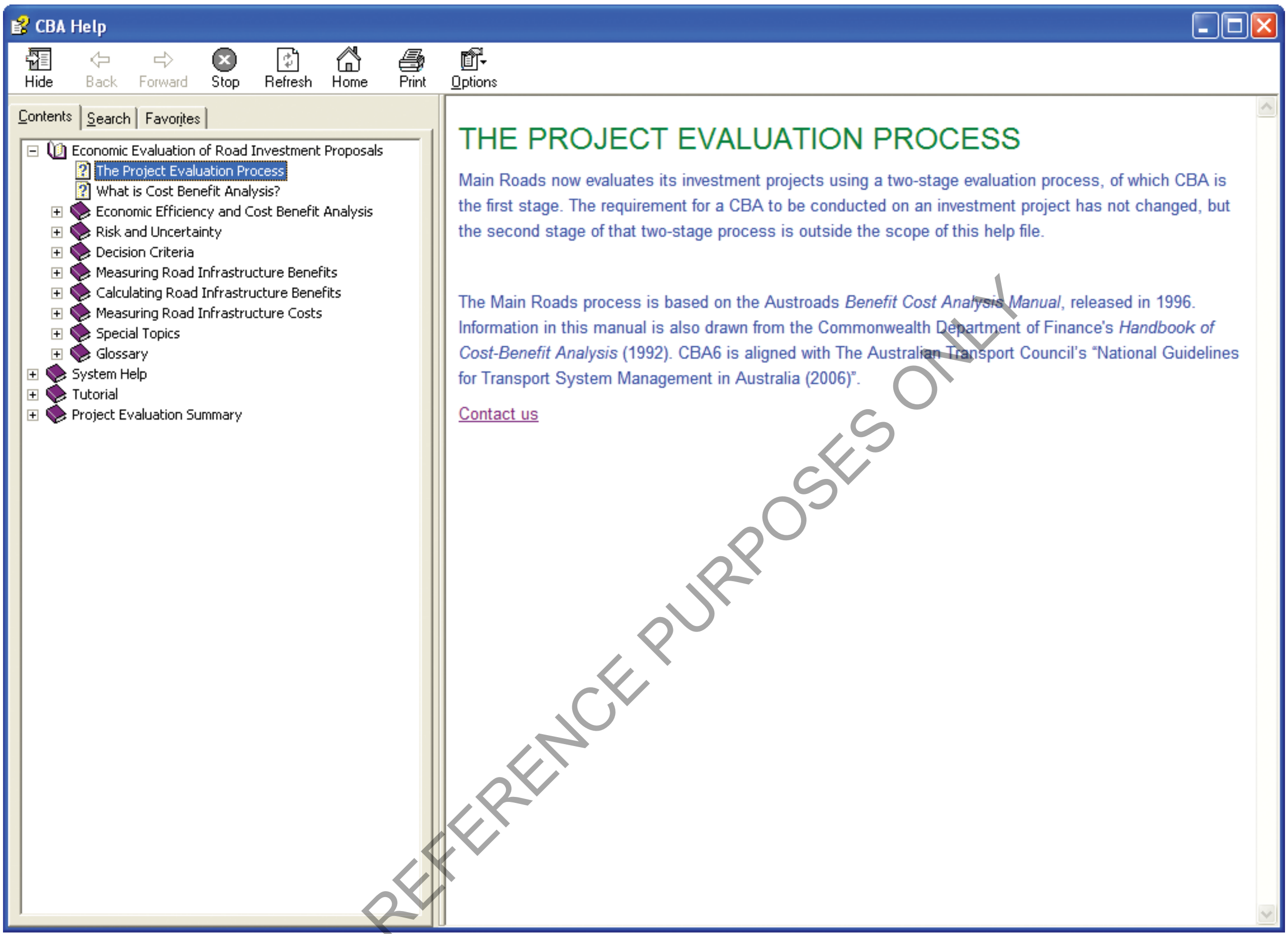
- F1 – economic evaluation of road investment proposals
- F2 – system help
- F3 – tutorials

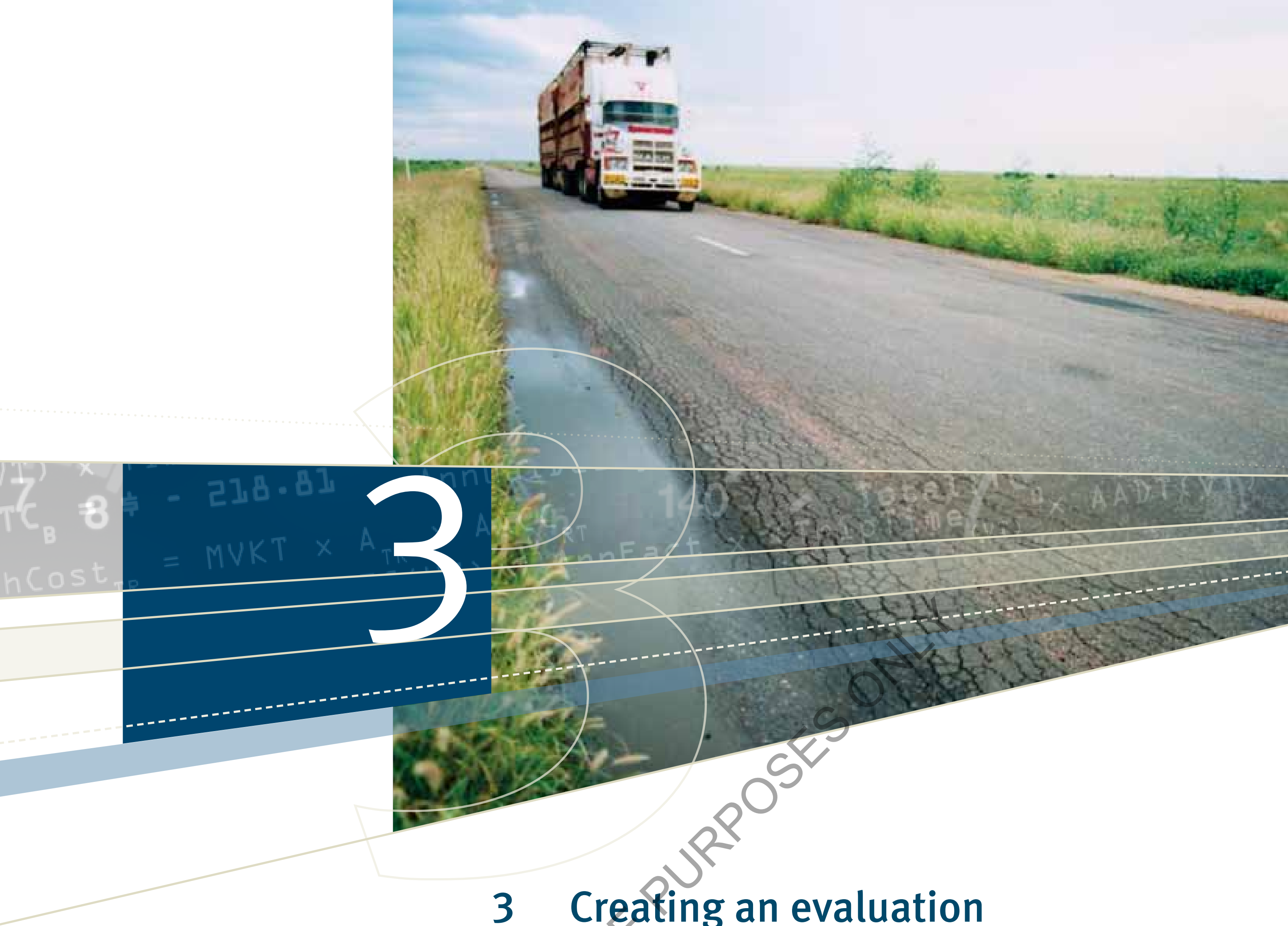
The help file provides the user with multiple topics of interest including a brief overview of the background of CBA and its role in evaluating road project investment.

The system help provides the user with an overview of the basic operations of the CBA6 tool including creation of basic evaluation files and explanations of the functional operation.

The tutorials section of the help file enables the user to follow systematic instructions on various types of projects available for evaluation in the CBA6 tool. Tutorials in the help file are also covered in Section 5.

*Figure 23: CBA6 help*





# 3 Creating an evaluation

This chapter of the *User Guide* identifies and describes the inputs required to create a standard evaluation. It is essential that system users be familiar with the processes described in this chapter as it is the platform for further project evaluation work while using CBA6. Processes common to all types of project evaluation are covered in this chapter.

This section outlines the process required, including when and how inputs are to be specified within CBA6, to create project evaluation files.

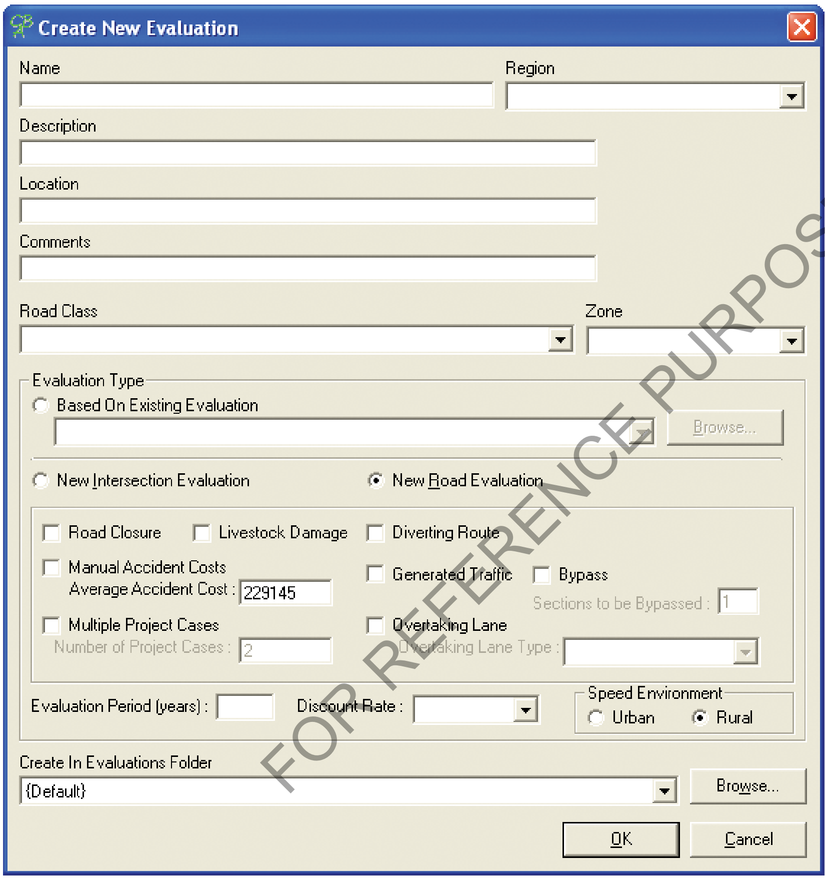
## 3.1 Create new evaluation

To begin a road project evaluation it is important that the system user has all the required information. This includes all basic entered data and a detailed understanding on the type of project the system user is attempting to evaluate (including relevant issues and method development). Once this information and understanding is attained, the system user will then be ready to undertake a new evaluation.

To create a new evaluation, go to the evaluations menu and select 'create new evaluation', see Figure 24.

Sections 3.1.1 to 3.1.12 explain the features of the 'create new evaluation' screen.

*Figure 24: Create new evaluation screen*






### 3.1.1 Name

Enter the name of the new project into this field. There is a 20-character limit. For example, '85-10c-42' or 'overtaking lane upgrade'.

### 3.1.2 Region

System users should select the region where the project is geographically located from the drop-down menu. These regions are:

- Central West
- Darling Downs
- Far North
- Fitzroy
- Mackay/Whitsunday
- Metropolitan
- North Coast
- Northern
- North West
- South Coast
- South West
- Wide Bay/Burnett.

Note: The selection of region has no bearing on the results of the CBA.

### 3.1.3 Description

The description of a new project, including the type, is entered into the 'description' field. For example, '2 km head-to-head overtaking lane' or 'timber bridge replacement'.

### 3.1.4 Location

This field enables the system user to provide more specific information on the location of a project. For example, '2 km west of Bundaberg' or alternatively, the chainage of the road could be used.

### 3.1.5 Comments

The system user can use the 'comments' field to provide generic information about a project or any other relevant information that needs to be mentioned. For example, 'this project involves several overtaking lanes'.

### 3.1.6 Road class

There are four categories of functional road class. The corresponding class of a project should be selected from:

- national
- state strategic
- regional
- district.

### 3.1.7 Zone

The four types of zones that can be selected in the drop-down menu are:

- dry reactive
- dry non-reactive
- wet reactive
- wet non-reactive.

These zones reflect soil types and weather conditions within a project section. The selected zone alters the deterioration rates of pavement types. Pavement deterioration is covered in further detail in Section 5.1.

### 3.1.8 Evaluation type

A new evaluation can be created from the following options:

- based on existing evaluation
- new intersection evaluation
- new road evaluation.

#### 3.1.8.1 Based on existing evaluation

When system users select the 'based on existing evaluation' option, CBA6 will re-create an existing evaluation of their choice. It may be useful to re-create an existing evaluation to test the CBA results when changing an input variable, such as traffic volumes, see Section 4.6.3.

#### 3.1.8.2 New intersection evaluation

CBA6 can be used to create intersection evaluation files. Intersection evaluations are shown in detail in Section 5.5.

#### 3.1.8.3 New road evaluation

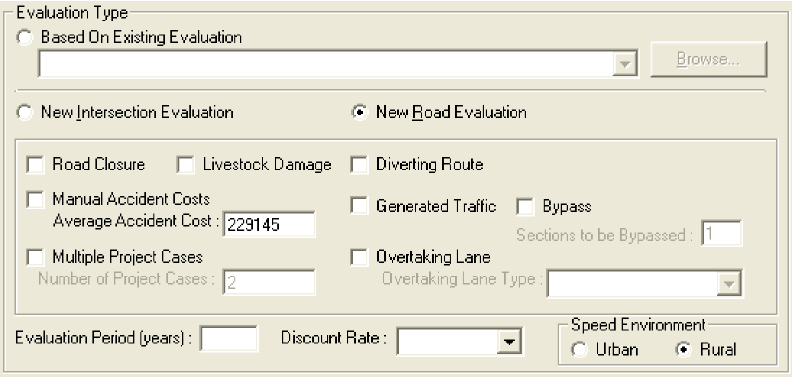
The new road evaluation option allows the system user to assess a range of road evaluation types, other than intersection evaluation. These CBA6 project modules include:

- road closures
- livestock damage
- diverting routes
- manual accident costs – detailed safety analysis
- generated traffic
- bypasses

- multiple project cases
- overtaking lanes.

Each of these modules is discussed in Section 4.6.3.

*Figure 25: Evaluation type options*




### 3.1.9 Evaluation period

The evaluation period includes the initial period of capital investment and the subsequent period over which the benefits of the project accrue. The evaluation period entered into this field should allow sufficient time to include design and implementation. For further detail or clarification on the evaluation period, see Section 4.1.1 of the *Theoretical Guide*.

### 3.1.10 Discount rate

The discount rate can be set at the appropriate rate required by the decision maker.

Note: When the system user selects 'road class' from the drop-down option, a default rate will be selected in the 'discount rate' field. The default for a national highway is 7% while state strategic, regional and district road classes are defaulted to 6%. Please seek specialist advice on the choice of discount rate. See Section 1.5 of the *Theoretical Guide* for further information.



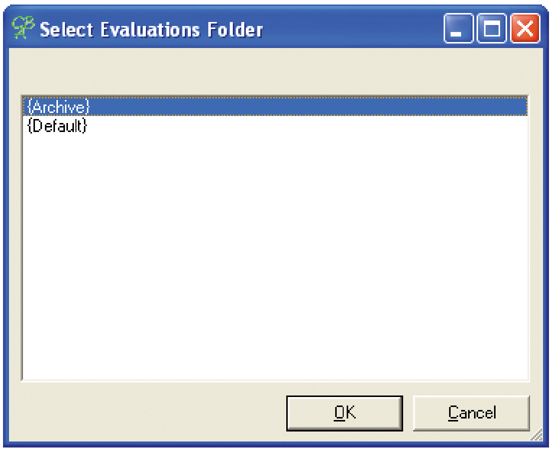
### 3.1.11 Speed environment

CBA6 allows the system user to choose between a rural or urban speed environment. This selection of speed environment only alters the TTC and the average accident cost to reflect the classification; it does not provide any additional measures to quantify urban evaluations.

### 3.1.12 Create in evaluations folder

The 'create in evaluations folder' option enables the system user to save the newly created evaluation in a folder of their choice. System users can browse through the default folder options and also user created folders, see Figure 26.

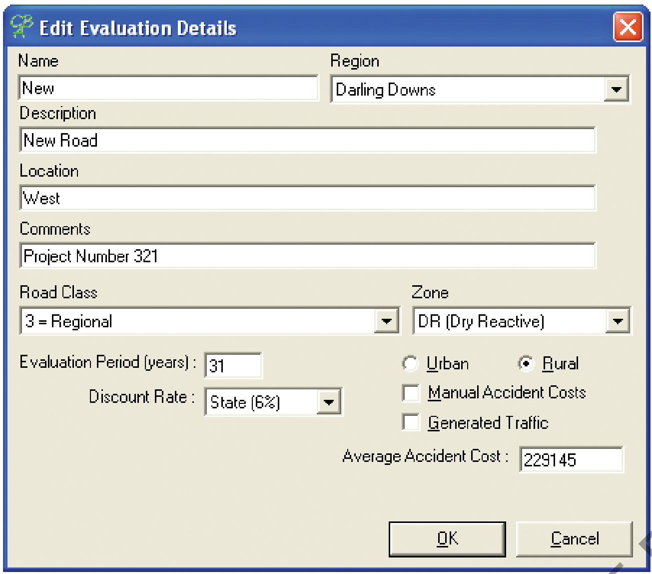
*Figure 26: Create in evaluations folder*



## 3.2 Edit evaluation

The 'edit evaluation' feature is found in the evaluations menu. To change minor details originally selected in the 'create new evaluation' screen during the evaluation, the system user is able to use the 'edit evaluation' function within the CBA6 tool, see Figure 27.

*Figure 27: Edit evaluation*




Note: Many of these changes will have no bearing on data already entered into the evaluation. However, editing the evaluation period, environmental zone, discount rate, speed environment, average accident cost and inclusion of manual accident costs will delete much of the previously entered data.

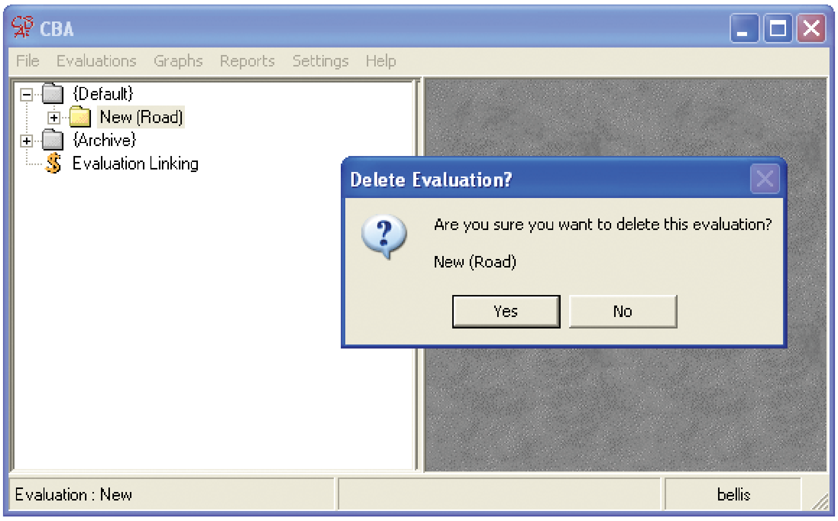
The 'edit evaluation' screen for overtaking lanes shows the type of overtaking lane used in the evaluation, see Figures 87, 97 and 106.

### 3.2.1 Delete evaluation

To delete an evaluation, highlight the appropriate evaluation and select 'delete evaluation' from the evaluation menu. Select 'yes' and the evaluation will be removed from the workspace, see Figure 28.

Note: Both edit and delete evaluation functions can be accessed through right clicking the mouse on the selected evaluation as displayed in the node tree and then selecting the function.

*Figure 28: Delete evaluation*



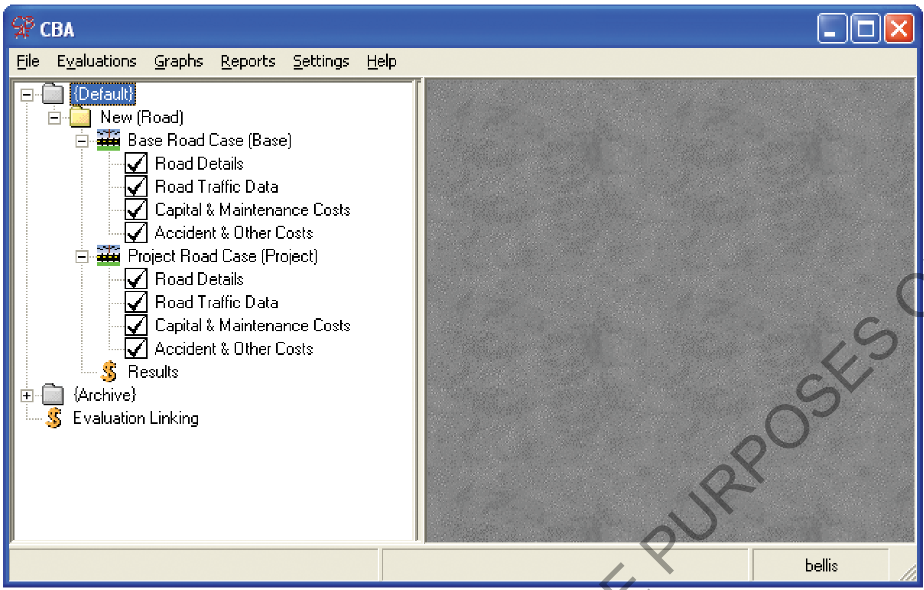

### 3.2.2 Evaluation linking

CBA6 can be used to link a number of individual project evaluation files. For information on how to link evaluation files, see Section 4.5.1.

## 3.3 CBA6 workspace

The CBA6 workspace is designed for user-friendly operation, identifying all current evaluation files and encompassing a visual navigation pane on the left hand side of the interface. This navigation pane allows quick access to system user projects and provides access to individual evaluation tasks, see Figure 29.

*Figure 29: CBA6 workspace with new evaluation*






The base and project case details can be found in the navigation pane under the title of the evaluation. The node tree structures show all components of the evaluation, see Figure 29. The components are:

- road details
- road traffic data
- capital and maintenance costs
- accident and other costs.

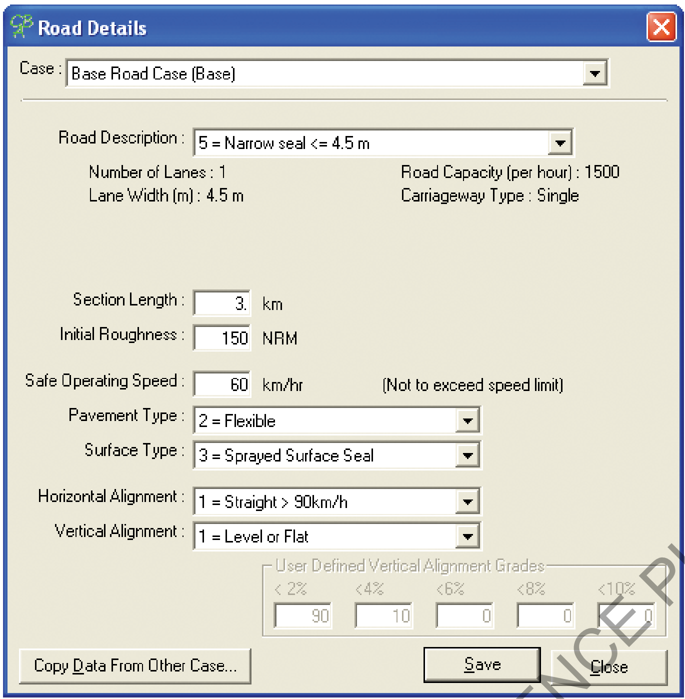
The details of each component screen are discussed further in Sections 3.4 to 3.7. For more advanced modules there will be additional input components to those mentioned above. Advanced modules are discussed in Section 5.

Note: Once these components are completed for both the base and project cases, a tick will appear to mark the completion of each component. Upon start-up of a new evaluation only the 'road details' and 'road traffic data' components will be available. After the system user has provided the necessary input in these fields, the other components will become available.

## 3.4 Road details screen

The ‘road details’ screen requires the system user to enter road project data characteristics for the base and project cases.

*Figure 30: Road details screen*






### 3.4.1 Case

The case drop-down menu is used to toggle between the base case and project case. Prior to switching between the base and project cases, ensure all input data has been saved.

### 3.4.2 Road description (model road state)

When undertaking an evaluation, the system user should select the appropriate road description for both base and project cases. The selection is based on model road state categories, which are identified in Appendix G of the *Technical Guide*. Model road state or MRS is used to categorize a specific road type. For example, in CBA6 a single carriageway two-lane road with a seal width of 7.4 metres is defined as MRS10. The MRS used in ARMIS and other sources may not always be consistent with CBA6. In the first instance, system users should set the road description and MRS in CBA6 to the seal width of the current road or project.

The model road state is used to determine the capacity of the road and is therefore an input variable used to calculate the congestion level and operating speed of the fleet.

### 3.4.3 Section length

The section length represents the full length of both base and project cases in kilometres. In some instances the base case and project case section length may differ. For example, a realignment project may reduce the section length of the road, see Section 4.5.4.

### 3.4.4 Initial roughness

Roughness is the measure of the unevenness of a road surface. It is a useful term for the condition of a pavement, because it is a condition directly experienced by motorists. It is commonly reported in Australia by either the NAASRA Roughness Measurement (NRM) method (Austroads 2000), which is measured using the NAASRA Roughness Car, or by the International Roughness Index (IRI), which is calculated by applying an analytical 'quarter car model' to road profile data collected via laser profilometer. NRM can be reliably converted to IRI by a linear equation, and vice versa, where required. See Appendix H of the *Technical Guide*.

Historically, TMR has collected NRM using the Roughness Car, a dynamic response type device, and reported both NRM and IRI. NRM is the most readily used. For further information on this topic, see the QUT paper *Roughness Deterioration of Bitumen Sealed Pavements* (P Hunt and JM Bunker).

*Table 1: Description of roughness values NRM(IRI)*

| Descriptive Condition | Ride Quality | Roughness Value NRM counts/km (IRI) |
|---|---|---|
| Excellent | Very smooth ride. | <40 (1.46) |
| Good | Some minor bumps encountered. | 40 to 80 (2.97) |
| Fair | Constant small up and down movement, but reasonably comfortable driving. | 80 to 110 (4.10) |
| Poor | Constant up and down and/or sideways movement. Can feel very rough in Trucks. Modern cars suspension makes car driving bearable, but with low comfort. | 110 to 140 (5.23) |
| Very Poor | Uncomfortable rideability experiencing severe up/down and/or sideways movement. Drivers must maintain good control of steering and reduce speed in some circumstances. | >140 (5.23) |

See Appendix H of the *Technical Guide* for conversion factors.



### 3.4.5 Safe operating speed

Operating speed reflects the safe operating speed for the fleet. Also known as posted speed, it is not to be confused with 'actual' vehicle operating speed, calculated separately, see Section 4 of the *Technical Guide*. Operating speed is deemed the maximum safe operating speed a vehicle should travel along a project route. CBA6 does not allow the fleet to travel any faster than this operating speed, therefore the posted or signed speed limit should be used.

### 3.4.6 Pavement type

There are three types of pavements used in CBA6. These are unpaved, flexible and rigid. Usually the pavement type will be defaulted to a corresponding classification as defined by the MRS. For example the default pavement type for MRS10 is a flexible pavement. The selection of pavement type affects the associated roughness deterioration profiles of the road.

### 3.4.7 Surface type

CBA6 has four choices of surface type: unsurfaced, primer seal, sprayed surface seal or asphaltic concrete. Usually the surface type will be defaulted based on the corresponding MRS. For example the default surface type for MRS10 is a 'sprayed surface seal'.

The sprayed surface seal will be the appropriate option for the majority of rural road projects. Concrete surface types, although used less often, are mainly used for national highways and motorways. Primer seals are used infrequently, generally for low-use roads, and provide a basic seal for the road surface. Road deterioration is also influenced by the selection of surface type.

### 3.4.8 Curvature

This option broadly defines the horizontal geometry of the road. CBA6 has three categories to select the curvature of the project site:

- straight
- curvy
- very curvy.

As an estimated guide for selecting the appropriate alignment category for a project site, apply the following:

- If AHSPD ≥ 90 km/h or less than 15% of the section is in a curve, the curvature = straight.
- If 90 km/h ≥ AHSPD ≥ 75 km/h or if 15% to 75% of the section is in a curve, the curvature = curvy.
- If AHSPD ‹ 75 km/h or if more than 75% of the section is in a curve, the curvature = very curvy.

Where:

- AHSPD = speed numeric reflecting the weighted average of curve design speed in a road section

Selection of the horizontal alignment of the road aspect will impact the road user costs, notably the operating speed of the fleet and tyre costs. For more information on tyre wear costs, refer to Section 4.3 of the *Technical Guide*.

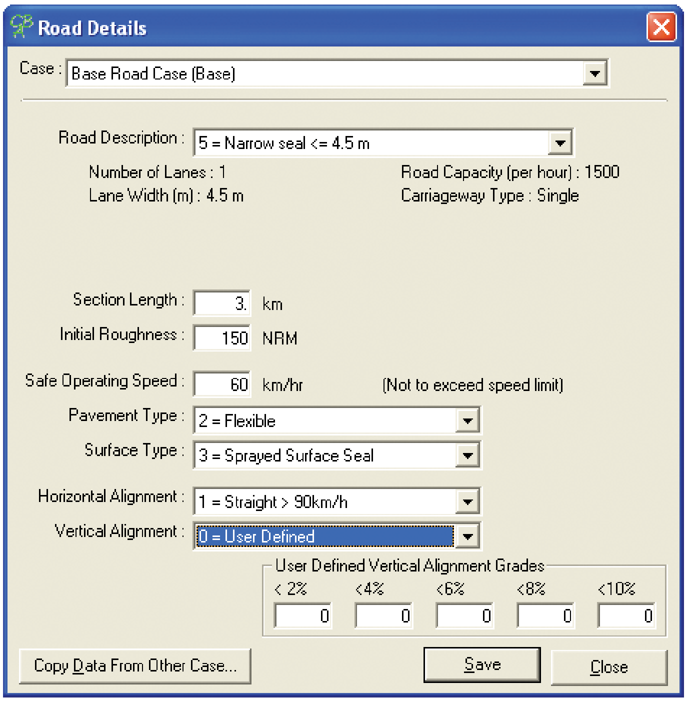
### 3.4.9 Vertical alignment

The vertical alignment refers to the proportions of current and proposed grade of the road section. The vertical alignment selection in CBA6 can be modified for project specific gradients (user defined) or from predetermined default selections. Selection of horizontal and vertical alignments will result in associated changes in operating speeds (see Section 3.1 of the *Technical Guide* for information on the effect the vertical gradient has on traffic volume measurements). The selection options for vertical alignment are:

- level or flat
- rolling or undulating
- mountainous
- user defined, see Figure 31.

When the predefined gradient proportions are unsuitable for a particular road segment and defined vertical alignment data is available, the system user can select 'user defined', located below the default alignments, to select the suitable alternative gradient specifications. The input fields represent the percentage of road which falls into the respective gradient categories, see Figure 31. These entered grades must equal 100%.

*Figure 31: User defined alignment*



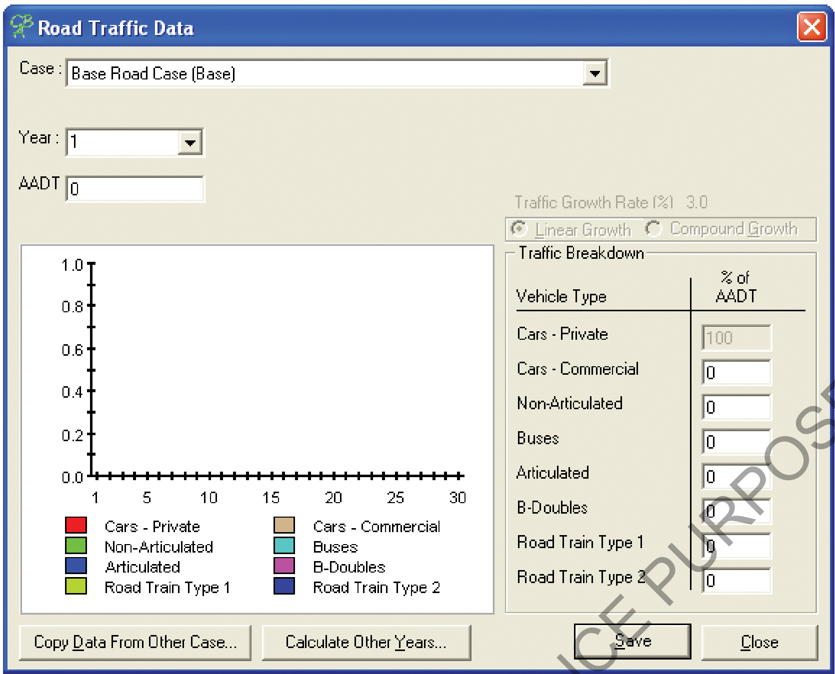

## 3.4.10 Copy data from other case

This option is used to quickly copy data from one case to another. For example a system user can copy base case data into the project case input screen. This option is useful when there are only a few changes in the CBA6 inputs between the base and project cases, see Section 3.8.

# 3.5 Road traffic data screen

The ‘road traffic data’ screen identifies the traffic flow, composition and growth over the life of a project, see Figure 32. Sections 3.5.1 to 3.5.4 explain the features of this screen.

*Figure 32: Road traffic data screen*




## 3.5.1 Case

The case drop-down menu is found in a number of CBA6 input screens and used to toggle between the various base and project cases traffic data.

## 3.5.2 Year

The year drop-down menu gives the system user access to individual years of the evaluation. System users can manually input or change traffic data for a given year.

Note: The number of years in the evaluation is specified in the ‘create new evaluation’ screen, see Section 3.1.9.

## 3.5.3 AADT and traffic breakdown

AADT refers to annual average daily traffic. This is a measure of road use by all vehicles at a daily equivalent rate. Typically, traffic data is gathered over a period of time using surveys and traffic counting devices. Where AADT volumes are not available for a given road segment, it is recommended that project-specific surveys are undertaken to provide basic data.

In the ‘road traffic data’ screen, CBA6 provides the system user with the following options for input:

- manually entering AADT for each year, see Section 3.5.3.1

- calculating other years function (using a linear or compound growth rate), see Section 3.5.3.2
- combining both, see Section 3.5.3.3.

Once AADT volumes have been sourced for a project, they must be disaggregated for use in CBA6. There are eight vehicle types used in CBA6, which correspond with Austroads vehicle clarifications, see Appendix E.

The vehicle types used in CBA6 are:

- cars – private
- cars – commercial
- non-articulated
- buses
- articulated
- B-doubles
- road train type 1
- road train type 2.

If AADT is given in vehicle numbers, then the percentage breakdown per vehicle type must be calculated prior to entry into CBA6.

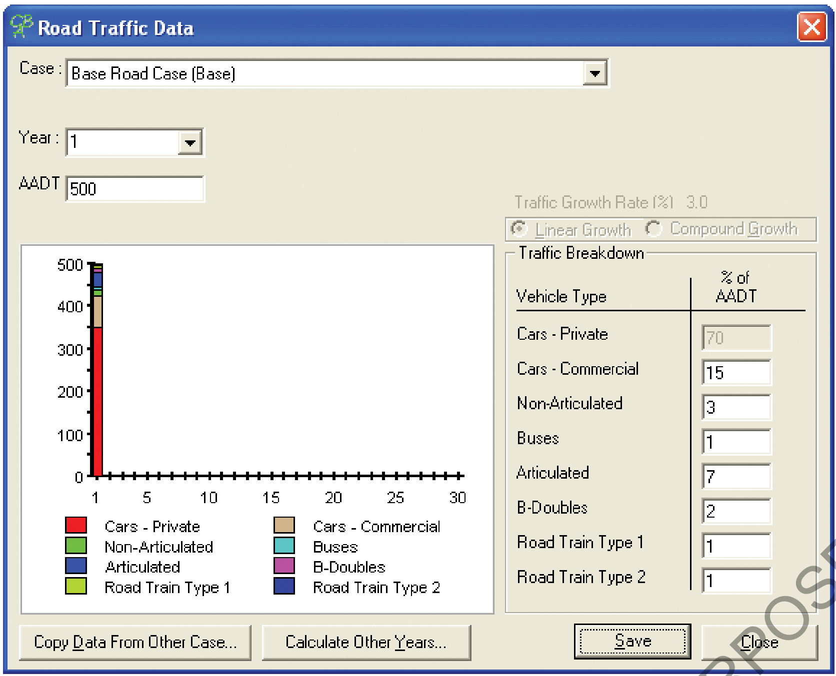
Note: CBA6 automatically generates the private vehicle composition as the residual of the total AADT once other vehicle types are entered. The traffic breakdown screen is also the input source for livestock damage. For further information on livestock, see Figure 53.



### 3.5.3.1 Manual input

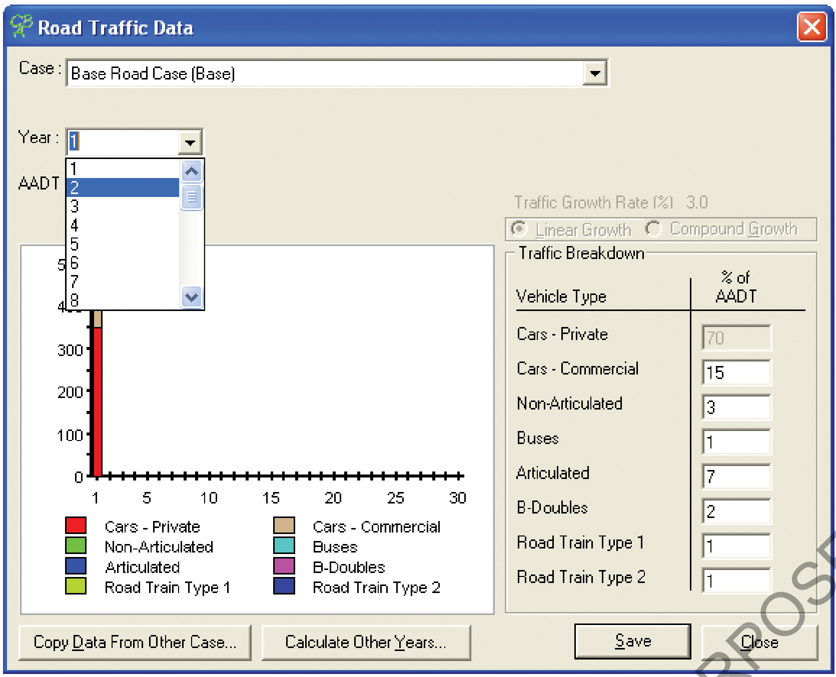
CBA6 will automatically generate traffic given an initial AADT and growth rate. To manually enter traffic data for each year, the sytem user enters AADT and a traffic breakdown, see Figure 33.

*Figure 33: Manual traffic data entry – year 1*




As shown in Figure 34, system users then select year 2 from the drop-down menu and input the relevant data for this year. This process is continued until all years of the evaluation period have been populated.

*Figure 34: Manual traffic data entry – year 2*

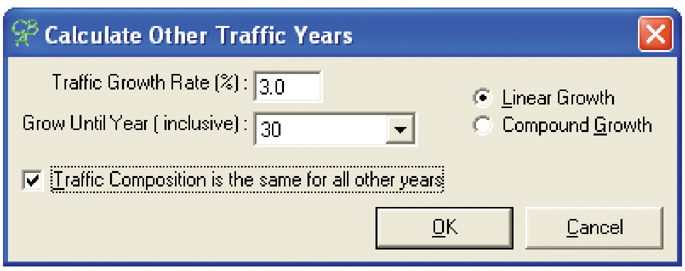



### 3.5.3.2 Calculate other years

To automate the population of traffic data over the entire evaluation period, CBA6 allows the system user to choose a simple linear growth rate or a compound rate to forecast future traffic growth, see Figure 35.

Note: Future predictions of traffic flows and subsequent growth are usually site specific and can be derived from future land use and road network projections. Growth rates can vary in complexity, but are often simply modelled from regional population growth forecasts.

*Figure 35: Calculate other traffic years*



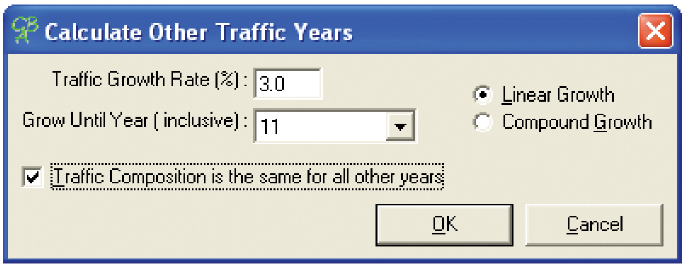

The base and project cases usually have the same traffic data inputs, however the provision of new infrastructure can lead to new or generated traffic, increasing the expected demand in the project case.

Note: If a road project is likely to change the traffic demand or breakdown between the base case and the project case, system users must use the 'generated traffic' or 'change in MCV' methodology where appropriate, see Figures 54 and 55.

### 3.5.3.3 Change in growth or breakdown

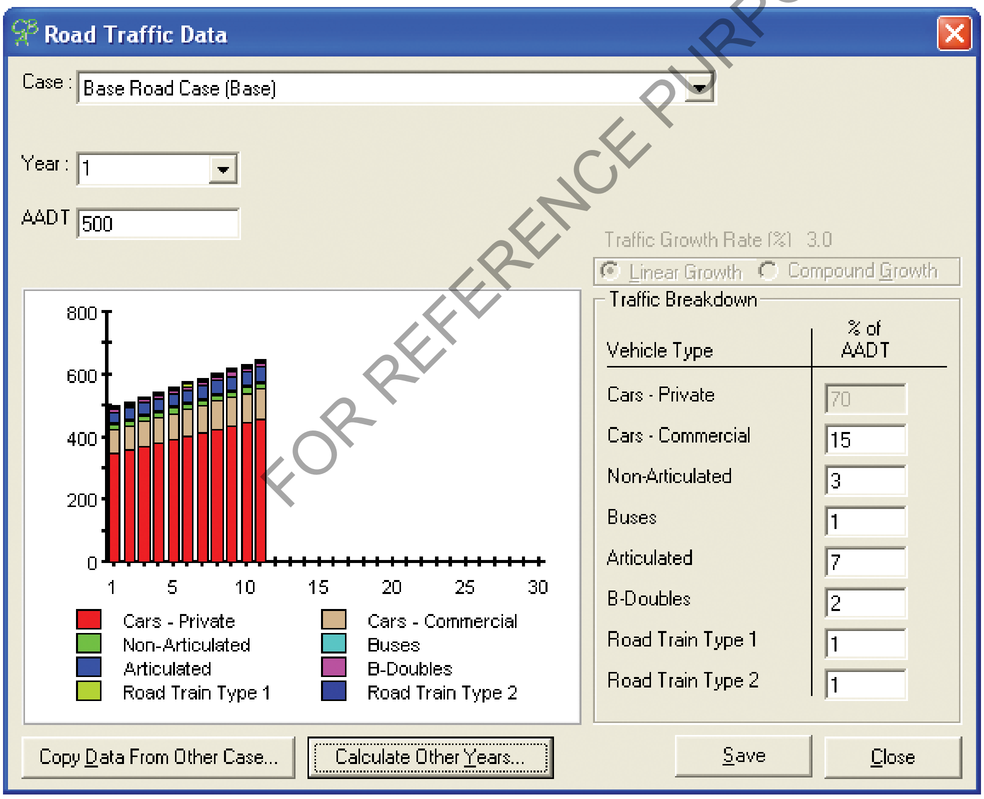
In some circumstances, traffic growth may change in future years given the influence of external factors. For example, a new mine may open causing an increase in the number of heavy vehicles using the road. CBA6 can be used to account for this change in traffic growth, see Figure 36.

*Figure 36: Traffic growth from year 1 to year 11*




Traffic grows at 3% linear from year 1 to year 11, see Figure 37.

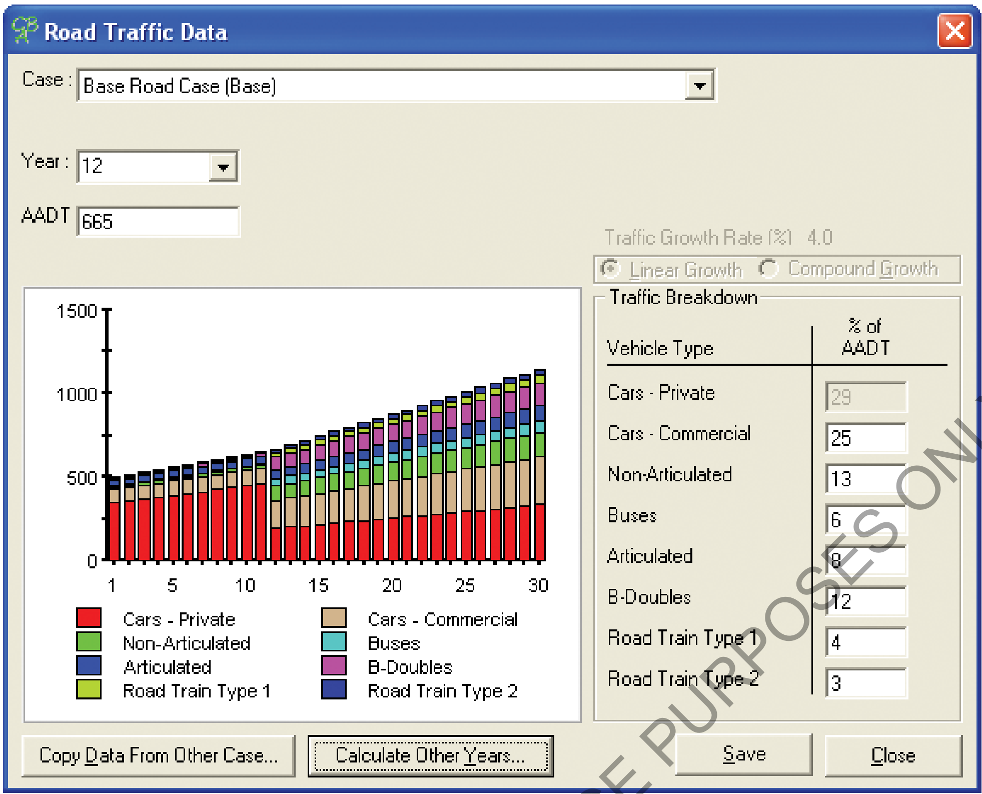
*Figure 37: Traffic AADT from year 1 to year 11*






From year 12, the traffic composition and growth rate changes. The remaining years of the evaluation are forecast as shown in Figure 38 using the 'calculate other years' function starting from year 12.

*Figure 38: Traffic from year 12 to year 33*




## 3.5.4 Copy data from other case

Traffic data can be copied from the base case to the project case using the 'copy data from other case' feature, see Section 3.8.

## 3.6 Road capital and maintenance costs screen

The 'road capital and maintenance costs' screen in CBA6 shown in Figure 39 is used to capture whole-of-life costs. In the base case, the anticipated costs in the absence of a project should be included over the life of the evaluation, while in the project case, costs should include any additional costs or savings in maintenance borne by a project. Typically, projects such as road widening works may require additional maintenance costs (i.e. due to increased surface area), however new technology or pavement designs may reduce extensive rehabilitation costs, effectively creating a whole-of-life maintenance saving.

The *Department Asset Management Guidelines* (2002) categories of pavement maintenance are:

- routine maintenance
- programmed maintenance – road resurfacing and/or bulk routine maintenance
- rehabilitation.

Inflation should be excluded from all maintenance costs entered into CBA6, i.e. include only real costs of maintenance. For an example of increasing real costs of maintenance, see Section 3.6.7.

*Figure 39: Project case capital and maintenance cost screen*

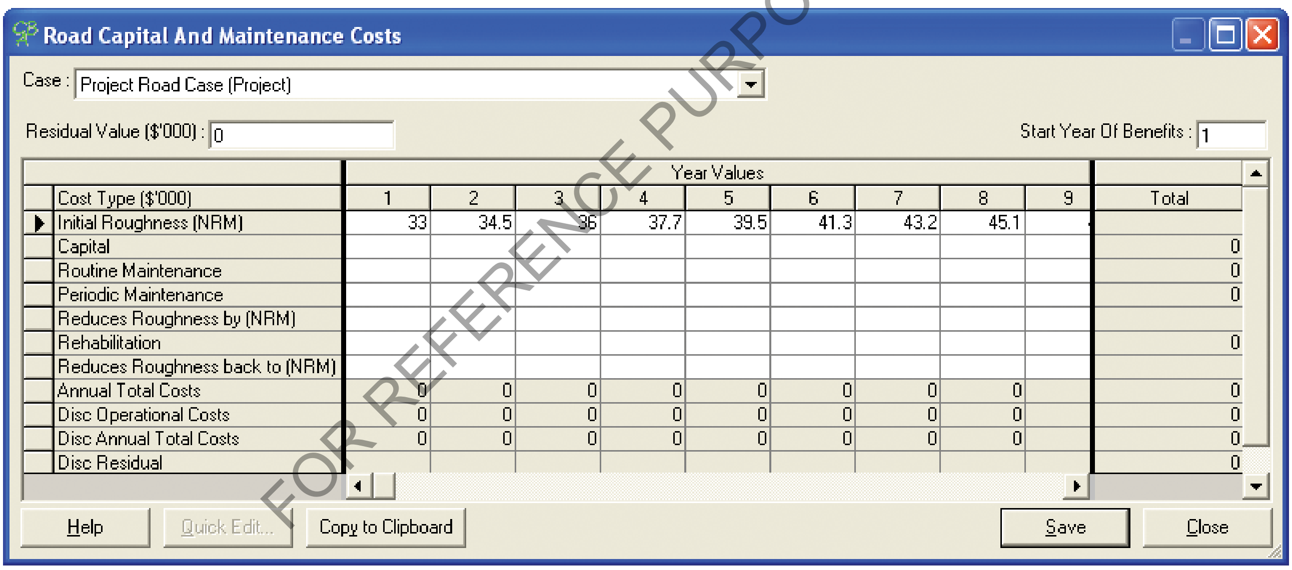
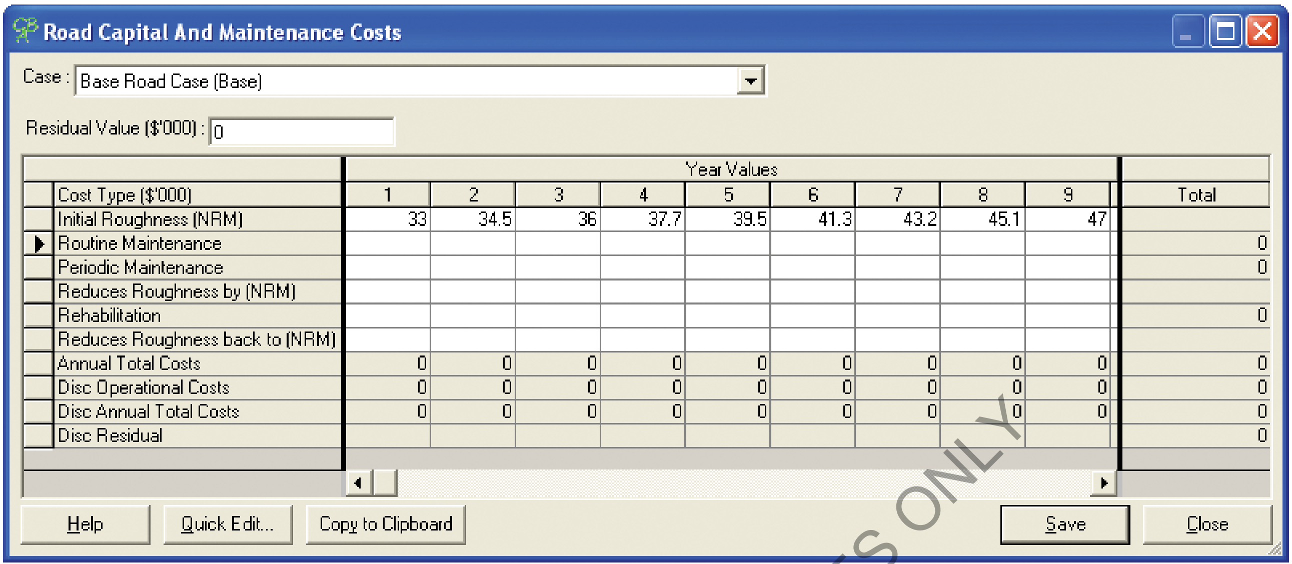


*Figure 40: Base case capital and maintenance cost screen*




## 3.6.1 Capital

Capital costs are the initial outlay or one-off investment costs needed to set up a project. These are the start-up costs required to build the road infrastructure, including any labour costs used in construction of a project.

Note: Depreciation is excluded from the analysis as the full cost to the community of the asset is determined at the time of consumption. To include depreciation would therefore distort the assumption behind the discount rate.

## 3.6.2 Routine maintenance

Routine maintenance preserves the shape or profile of the pavement and amenities of the road corridor. Routine maintenance has no impact on road roughness.

## 3.6.3 Periodic maintenance

Programmed maintenance is referred to as 'periodic maintenance' in CBA6. Periodic maintenance can have an impact on road roughness and usually reduces roughness by a factor of NRM. For example, periodic maintenance reduces roughness by 5 NRM. Periodic maintenance usually occurs at 5 to 10-year intervals.

## 3.6.4 Rehabilitation

Rehabilitation refers to the full reconstruction of the road surface and usually occurs at longer intervals than other types of maintenance. Rehabilitation works usually return the road to its original design roughness. For example rehabilitation reduces roughness back to 55 NRM.

## 3.6.5 Residual value

A residual value can be entered for both the base case and project case. The residual value is used to incorporate the additional value of the asset after the end of the evaluation period. For example, a road asset may have a useful life of 50 years, however the evaluation is undertaken over a 30-year period. To account for the remaining 20 years of useful life, a residual value is incorporated in the CBA. See Section 9.7 of the *Technical Guide* for residual value calculation.

### 3.6.6 Start year of benefits

The 'start year of benefit' field specifies the completion and commission date of a project. For example, if a project takes 3 years to build, the start year of benefits will be year 4.

### 3.6.7 Quick edit

The predominant use of the 'quick edit' function is as an alternative to manually entering maintenance costs. The 'quick edit' function allows the system user to extrapolate yearly maintenance costs over the life of the evaluation or in the years in which it occurs. To use the 'quick edit' function:

1 select relevant maintenance category (routine, periodic or rehabilitation)

2 click 'quick edit'

3 select 'start year' and 'end year'

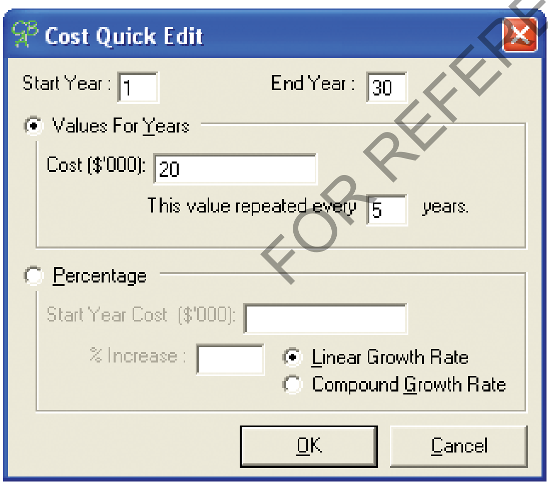
4 select either 'constant yearly value' or 'percentage' (growth function)

5 enter values

6 select 'ok'.

Figure 41 provides an example of $20 000 in maintenance costs spent every 5 years. To incorporate annual costs the system user would enter '1' in the appropriate field.

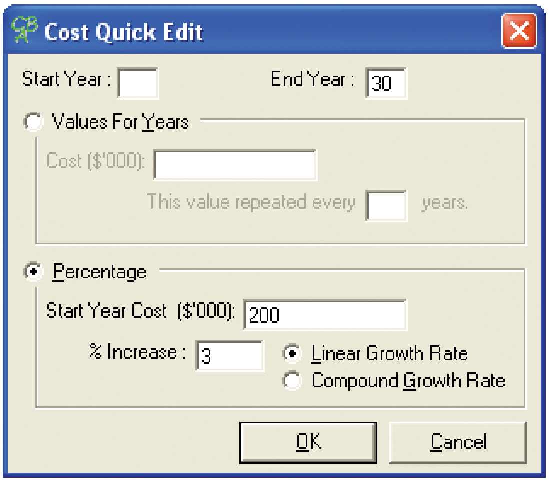
*Figure 41: Cost quick edit constant value*






To account for a change in costs each year the system user can incorporate a growth factor to the maintenance cost estimates. In Figure 59, $200 000 in costs is expected to increase by 3%. This may be warranted to maintain the road at its current roughness standard given future increases in traffic volumes.

*Figure 42: Cost quick edit percentage increase*




The 'quick edit' function also allows the system user to assign a consistent roughness modifier resulting from the associated maintenance costs. To quick edit the roughness modifier for periodic and rehabilitation maintenance categories:

1 select 'roughness modifier' (periodic and rehabilitation categories only), 'reduces roughness by' (NRM), or 'reduces roughness back to' (NRM)

2 select 'quick edit'

3 select 'start year' and 'end year'

4 input roughness modifier ('reduce roughness by' or 'reduces roughness back to')

5 enter repetition frequency

6 select 'ok'.

Figure 43 shows the 'quick edit' function for periodic maintenance.

*Figure 43: Periodic roughness quick edit*

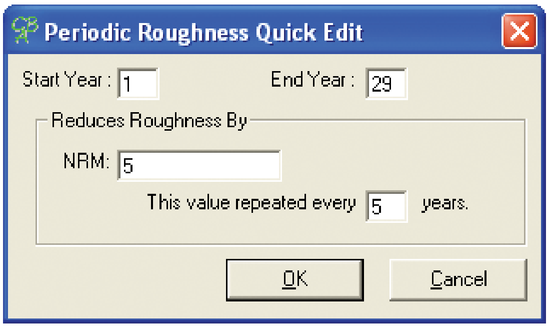
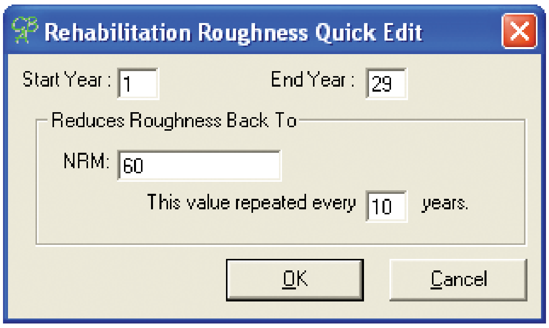


Figure 44 shows the function for rehabilitation.

*Figure 44: Rehabilitation roughness quick edit*



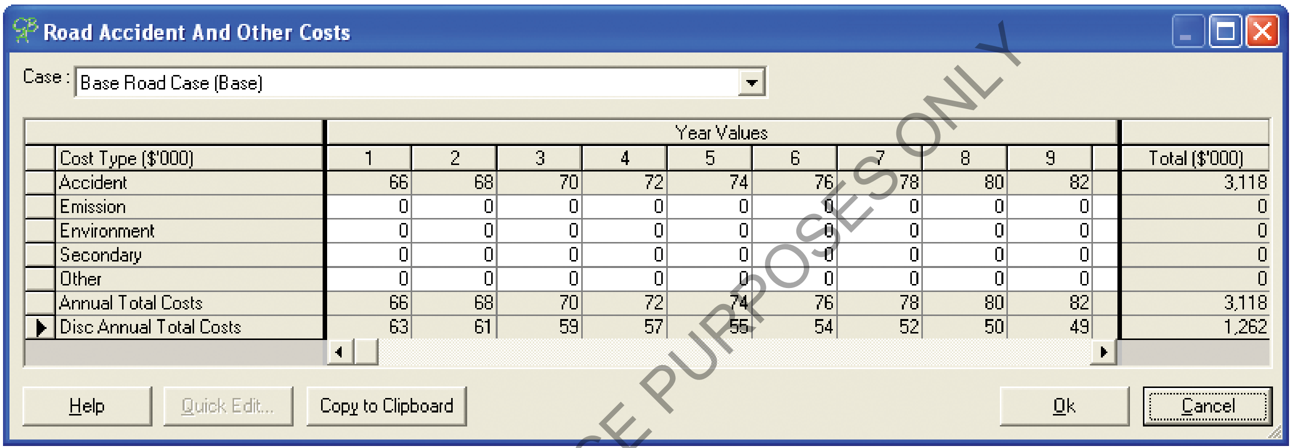

Note: Timing of the roughness reduction quick edit must match the timing of costs. For example, if costs occur in year 5, the 'reduces roughness' field must coincide with costs in year 5.

## 3.7 Road accident and other costs

The final input screen for a road evaluation is the 'road accident and other costs' screen, see Figure 45. CBA6 will automatically calculate the accident costs unless the system user specifies manual accident costs in the 'create new evaluation' screen. For more information on the manual calculation of accident costs, see Section 6 of the *Technical Guide*.

In this screen, system users are able to add additional costs that need to be included in the evaluation. These are usually externalities costs such as noise and emissions. For more detail on deriving user-defined externality costs, see Section 7 of the *Technical Guide*.

*Figure 45: Road accident and other costs*




| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
| Accident | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 3,118 |
| Emission | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Environment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Secondary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual Total Costs | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 3,118 |
| Disc Annual Total Costs | 63 | 61 | 59 | 57 | 55 | 54 | 52 | 50 | 49 | 1,262 |

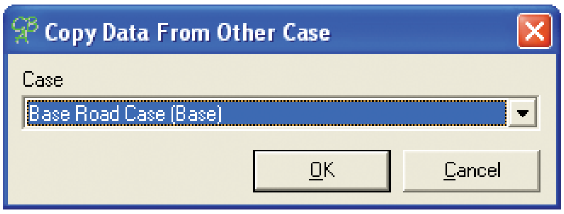
## 3.8 Copy data from other case

The 'copy data from other case' function, located at the bottom of both the road details and road traffic data screens of CBA6, allows the system user to directly copy all details from one case to another, i.e. base to project or project to base. This function is useful in scenarios where composition, volume and growth remain the same in both base and project cases. To copy data from one case to another:

- select case and screen to copy data to
- click 'copy data from other case'
- select 'case' to copy data from
- click 'ok'.

Note: To enable this function, one case (base or project) must be completed. The 'copy data from other case' screen can be seen in Figure 46.

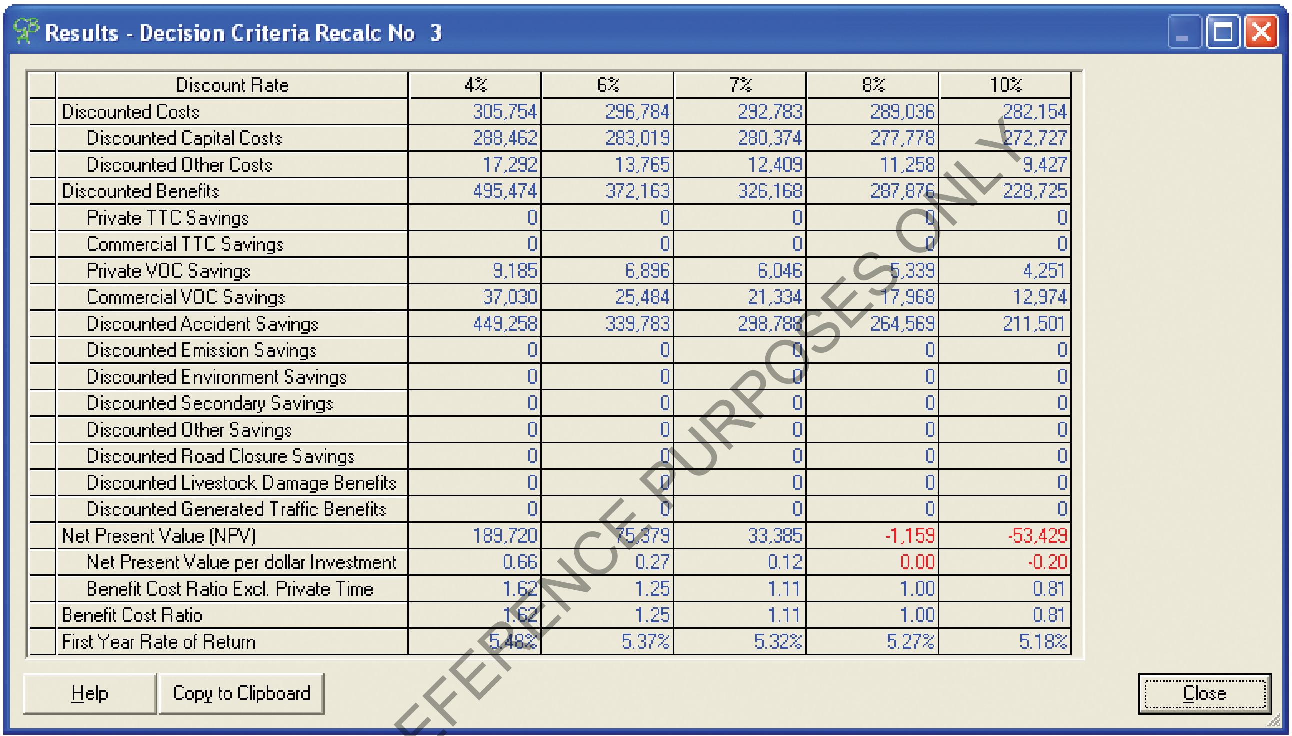
*Figure 46: Copy data from other case*



## 3.9 Copy to clipboard

The 'copy to clipboard' function allows the system user to copy data shown by CBA6 into other applications. The 'copy to clipboard' button is located in the capital and maintenance, accident and other costs, travel time, VOC and the results screens (see Figure 47). Once the data is exported, the system user is able to manipulate the format and presentation as necessary to suite any further analysis (e.g. manual amalgamation of multiple evaluation files) or reporting requirements.

*Figure 47: Copy to clipboard – decision criteria*




| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 305,754 | 296,784 | 292,783 | 289,036 | 282,154 |
| Discounted Capital Costs | 288,462 | 283,019 | 280,374 | 277,778 | 272,727 |
| Discounted Other Costs | 17,292 | 13,765 | 12,409 | 11,258 | 9,427 |
| Discounted Benefits | 495,474 | 372,163 | 326,168 | 287,876 | 228,725 |
| Private TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Commercial TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Private VOC Savings | 9,185 | 6,896 | 6,046 | 5,339 | 4,251 |
| Commercial VOC Savings | 37,030 | 25,484 | 21,334 | 17,968 | 12,974 |
| Discounted Accident Savings | 449,258 | 339,783 | 298,788 | 264,569 | 211,501 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 189,720 | 75,379 | 33,385 | -1,159 | -53,429 |
| Net Present Value per dollar Investment | 0.66 | 0.27 | 0.12 | 0.00 | -0.20 |
| Benefit Cost Ratio Excl. Private Time | 1.62 | 1.25 | 1.11 | 1.00 | 0.81 |
| Benefit Cost Ratio | 1.62 | 1.25 | 1.11 | 1.00 | 0.81 |
| First Year Rate of Return | 5.48% | 5.37% | 5.32% | 5.27% | 5.18% |

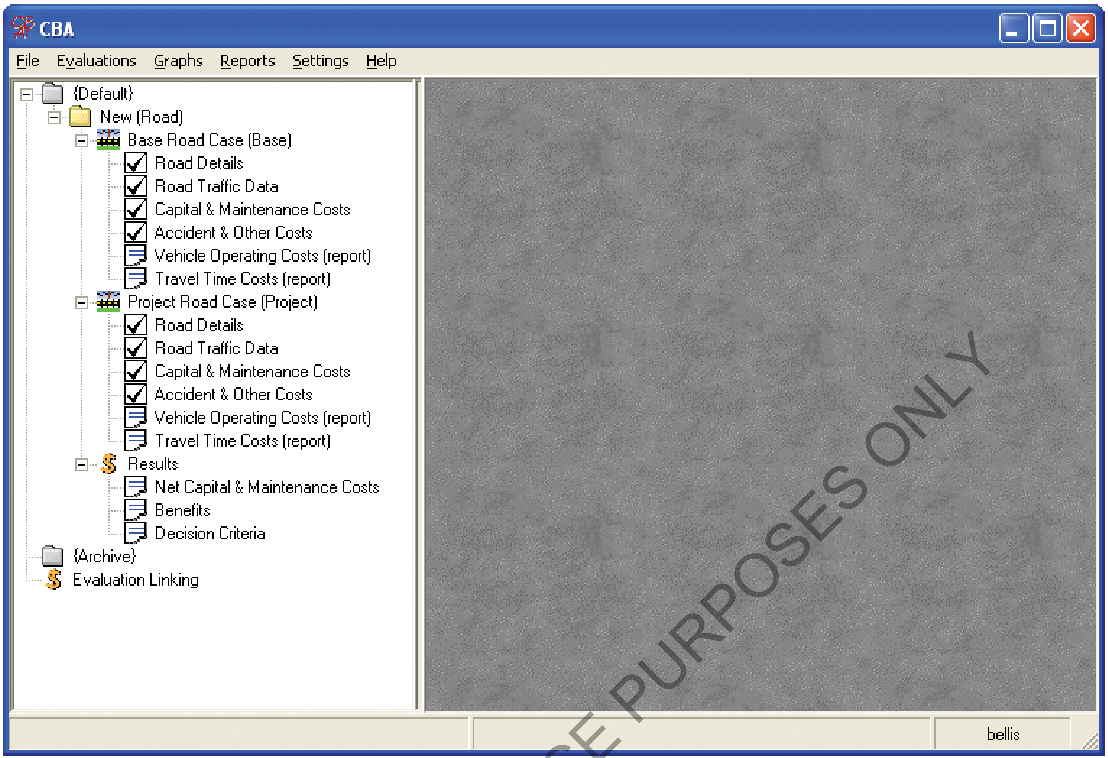
This function is also available within the detailed road case report to allow the system user to copy the disaggregated VOC (fuel, tyres, oil, repairs and depreciation) see Figure 25.

# 4 Results and reports

It is important that the results of a project evaluation are appropriately documented. CBA6 provides reports for VOC, TTC, net capital and maintenance costs, benefits and decision criteria, see Figure 48. CBA6 presents its results in two ways: online screen displays and reports. This chapter covers the display screens and reports produced by CBA6.

A thorough understanding of the results shown in CBA6 is required in order to provide informed recommendations on a project's economic justification. This chapter will ensure system users can make appropriate interpretation of the results calculated in CBA6. This chapter will also provide system users with an overview of the CBA6 results and explain how to cross-check evaluation inputs with outputs.

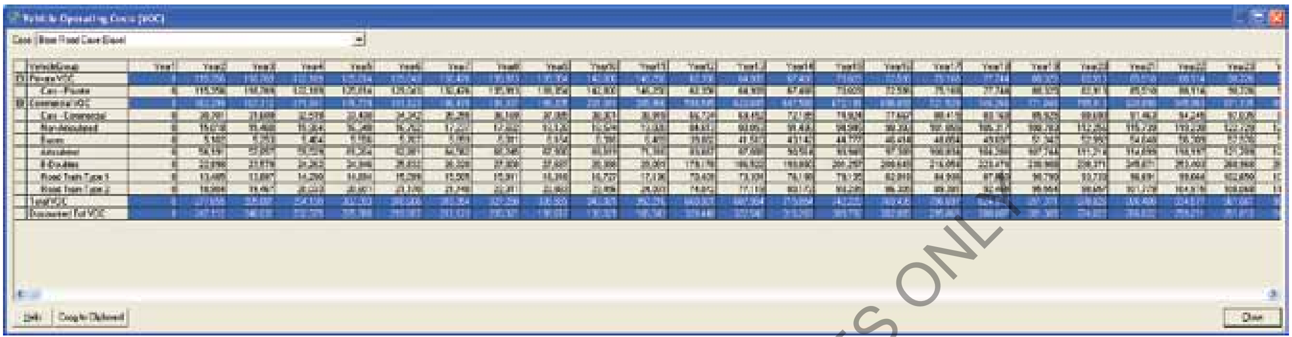
*Figure 48: CBA6 reports*



## 4.1 Vehicle operating costs

The 'VOC' screen allows the system user to view project VOC savings in discounted and undiscounted values. The data is displayed on an annual basis and is disaggregated by vehicle type. The results displayed on this screen form a direct link with the decision criteria report. The system user can switch between the base and project cases to compare the change in cost. See Section 4 of the *Technical Guide* for further information on VOC.

*Figure 49: Vehicle operating costs (VOC) screen*

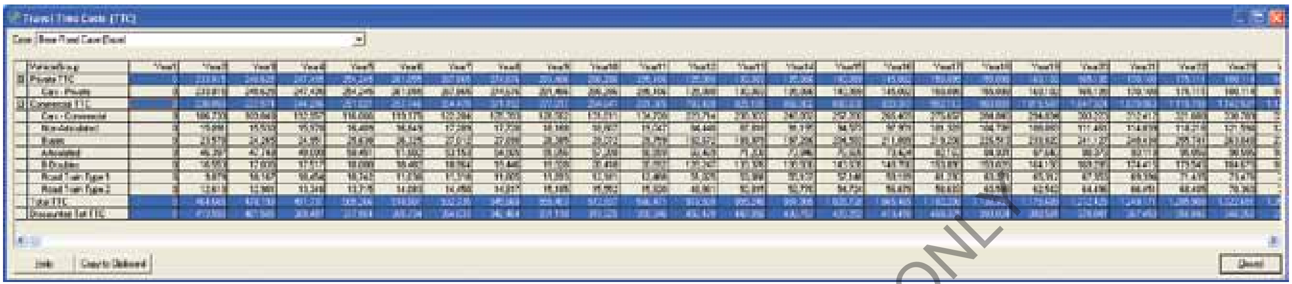


Note: This screen does not display individual costs on a per-vehicle basis but rather costs for the entire fleet.

## 4.2 Travel time costs

The 'TTC' screen allows the system user to view project TTC savings in discounted and undiscounted values. The data is displayed on an annual basis and is disaggregated by vehicle type. The results displayed in this screen form a direct link with the decision criteria report. The system user can switch between the base and project cases to compare the change in cost. See Section 4 of the *Technical Guide* for further information on vehicle TTC.

*Figure 50: Travel time costs screen*



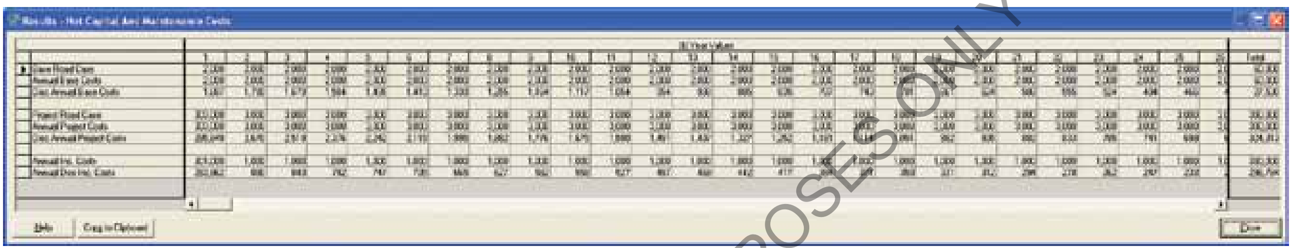
Note: This screen does not display individual costs on a per-vehicle basis but rather costs for the entire fleet.

## 4.3 Net capital and maintenance costs

The ‘net capital and maintenance costs’ screen displays an aggregate summary of annual capital and maintenance costs over the life of a project. CBA6 aggregates both base case and project case costs, providing the system user with an overarching cost summary.

Figure 51 shows the net capital and maintenance costs for a project. In this figure, ongoing and recurrent maintenance costs occur throughout all years in the base case with periodic maintenance occurring in Year 8. In the project case, capital costs occur from Years 1 to 3. As the same routine maintenance occurs in both the base and project cases, the incremental costs from Years 4 to 7 are zero. The negative incremental cost in Year 8 is a result of periodic maintenance costs which occur in the base case but do not occur in the project case. The annual discounted costs in both cases are represented by the selected discount rate at the start of the evaluation.

*Figure 51: Net capital and maintenance costs screen*

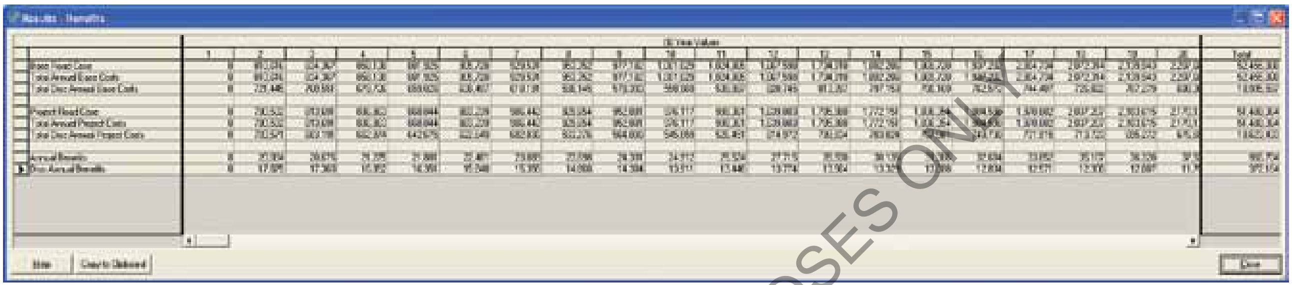


## 4.4 Benefits

Benefits results are similar to net capital and maintenance costs and summarise the aggregate road user benefits of a project in both base and project cases. Benefits calculations are based on aggregated estimates of road user costs including TTC, VOC and accident costs.

Figure 52 shows that there are two years of capital costs with benefits of a project commencing in Year 3, see Section 3.6.6. From the figure, it can be seen that from Year 3, total base case costs exceed costs in the project case, deriving an annual benefit which is totalled at a discounted value of $890 000.

*Figure 52: Benefits screen*



## 4.5 Decision criteria

The economic decision criteria created by CBA6 are a set of indicators which allow system users to understand possible economic outcomes of projects. The economic decision criteria identified here allows useful economic comparisons between discounted benefits and costs.

The economic decision criteria generated in CBA6 includes:

- BCR
- NPV per $ investment
- NPV
- FYRR.

Each criterion is discussed in detail in Sections 4.5.1 to 4.5.4. For further information on the theoretical assumptions of the decision criteria used in CBA6, see Section 1.7 of the *Theoretical Guide*. For further information on the formulas used to calculate the decision criteria used in CBA6, see Section 9 of the *Technical Guide*.



### 4.5.1 Benefit-cost ratio

The BCR is the most widely used measurement of project performance within TMR. A BCR greater than 1 indicates that a project is economically viable i.e. the benefits outweigh the costs.

The decision criteria example in Figure 52 displays the output from CBA6. At the 7% discount rate, the BCR for the project is 2.48. This indicates that the benefits exceed the costs, and the project is economically viable.

### 4.5.2 Net present value per $ investment

This is a ratio of NPV divided by the present value of capital costs. It indicates the increase in economic value to the community relative to the amount of capital invested. If two projects generate the same NPV but have different capital efficiency ratios, the project with the higher capital efficiency factor is considered the superior investment.

### 4.5.3 Net present value

The NPV of a project is the difference between the discounted stream of benefits and the discounted stream of costs. Ultimately the NPV should be used to value the initiative and the BCR should be used to rank viable projects. The NPV shown in Figure 52 at the 6% discount rate is $12.9 million.

### 4.5.4 First year rate of return

The FYRR is a ratio of first year of benefits to the capital costs of a project. FYRR indicates whether a project's optimal implementation time is in the past or in the future, and can indicate whether deferral is warranted (ATC 2007).

*Figure 53: Results – decision criteria screen*

**Results - Decision Criteria Recalc No 3**

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 305,754 | 296,784 | 292,783 | 289,036 | 282,154 |
| Discounted Capital Costs | 288,462 | 283,019 | 280,374 | 277,778 | 272,727 |
| Discounted Other Costs | 17,292 | 13,765 | 12,409 | 11,258 | 9,427 |
| Discounted Benefits | 495,474 | 372,163 | 326,168 | 287,876 | 228,725 |
| Private TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Commercial TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Private VOC Savings | 9,185 | 6,896 | 6,046 | 5,339 | 4,251 |
| Commercial VOC Savings | 37,030 | 25,484 | 21,334 | 17,968 | 12,974 |
| Discounted Accident Savings | 449,258 | 339,783 | 298,788 | 264,569 | 211,501 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 189,720 | 75,379 | 33,385 | -1,159 | -53,429 |
| Net Present Value per dollar Investment | 0.66 | 0.27 | 0.12 | 0.00 | -0.20 |
| Benefit Cost Ratio Excl. Private Time | 1.62 | 1.25 | 1.11 | 1.00 | 0.81 |
| Benefit Cost Ratio | 1.62 | 1.25 | 1.11 | 1.00 | 0.81 |
| First Year Rate of Return | 5.48% | 5.37% | 5.32% | 5.27% | 5.18% |

Help | Copy to Clipboard | Close

## 4.5.5 Incremental and linking decision criteria

The 'decision criteria' screen can also be populated for linking evaluation files and comparing project options through the incremental analysis. For further information on using incremental analysis and linking, see Sections 5.12 and 5.13.

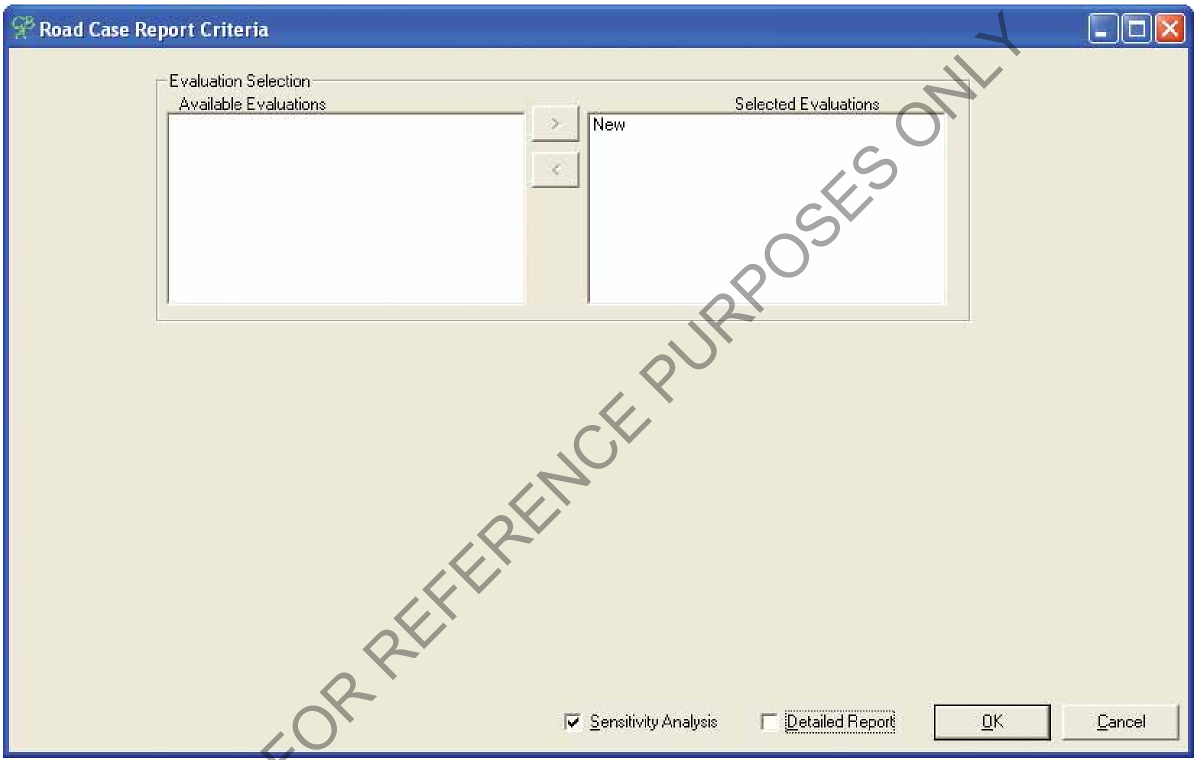
## 4.6 Producing and understanding CBA reports

CBA6 produces output reports in detailed forms for all project types available in the tool. These reports provide system users with disaggregated results which can be used in a variety of report presentation formats.

### 4.6.1 Producing road case reports

The road case report is the most significant report created by CBA6. The road case report is created to provide system users with a detailed assessment of all components of a project. When the system user creates a road case report, the tool will identify a number of user options for selection. A simple report can be created, see Figure 54.

*Figure 54: Simple report*



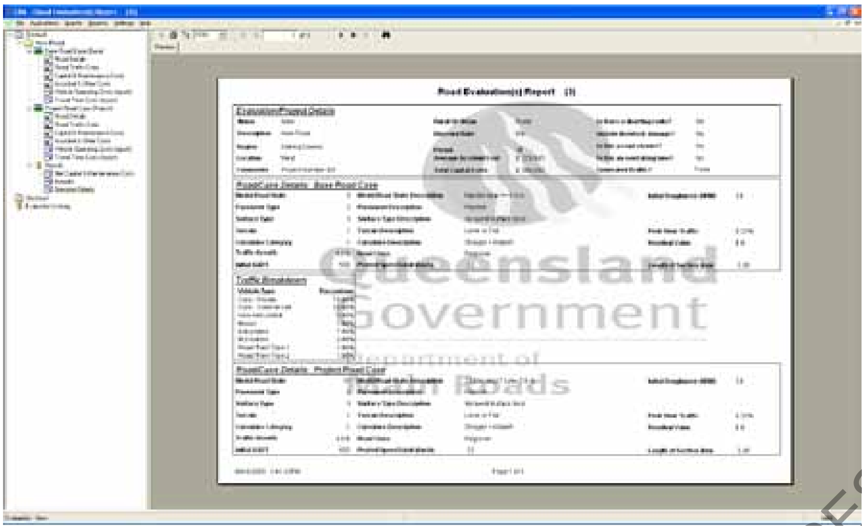



The standard road case report summarises the CBA and includes the following components:

- evaluation/project details
- road details – base case
- road details – project case
- decision criteria
- sensitivity analysis.

The road case report screen is shown in Figure 55.

*Figure 55: Road case report*

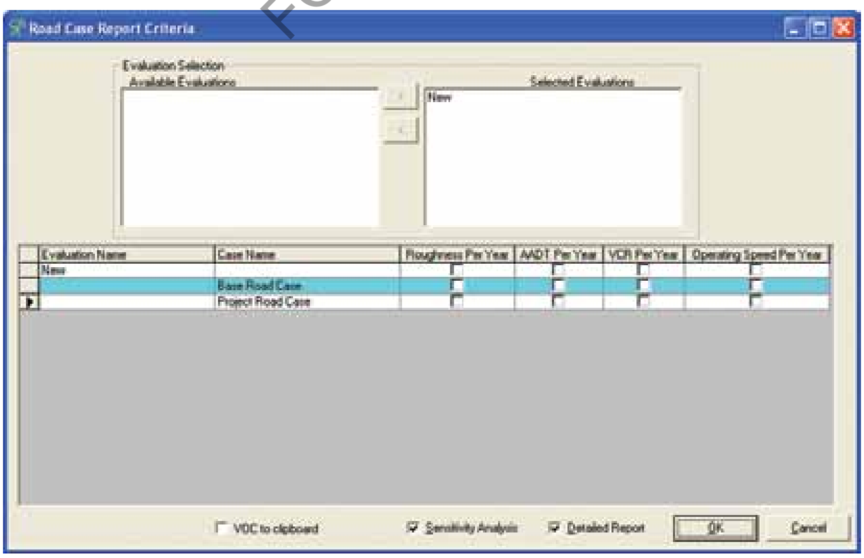


To create a detailed CBA report the system user can select the ‘detailed report’ option. From Figure 55 there is now a number of additional outputs that can be included in the report. The system user can select the following additional reporting options:

- roughness per year
- AADT per year
- VCR per year
- operating speed per year.

These additional outputs can be selected by individual case option (base or project) or for the whole project.

*Figure 56: Detailed report*




Note: Printing the detailed CBA report may only be required when, for example, being used as an appendix to a funding submission. The report will produce a number of pages that may otherwise not be needed.

### 4.6.2 Vehicle operating costs to clipboard

The 'VOC to clipboard' function is generically quite similar to the 'copy to clipboard' function, but is only available after the system user has generated a detailed road case report. When creating a detailed road case report, the system user is given an option to 'copy VOC to clipboard', see Figure 55. The function will then allow the system user to copy all VOCs of the evaluation to a spreadsheet for further analysis. This function allows the system user to acquire disaggregated VOC, unavailable in the other reports.

### 4.6.3 Sensitivity analysis

The sensitivity analysis presented within the road case report is designed to measure the uncertainty of inputs within an evaluation. For a given road project evaluation, CBA6 performs sensitivity analysis on a number of parameters. The sensitivity test range can be changed by the system user, see Section 2.6.4.

The sensitivity analysis undertaken in the road case report is shown in Figure 57. For example, if private TTC savings are a large proportion of total project benefits, the system user may wish to consider public transport options as opposed to road infrastructure.



*Figure 57: Sensitivity analysis*

***Sensitivity Analysis***

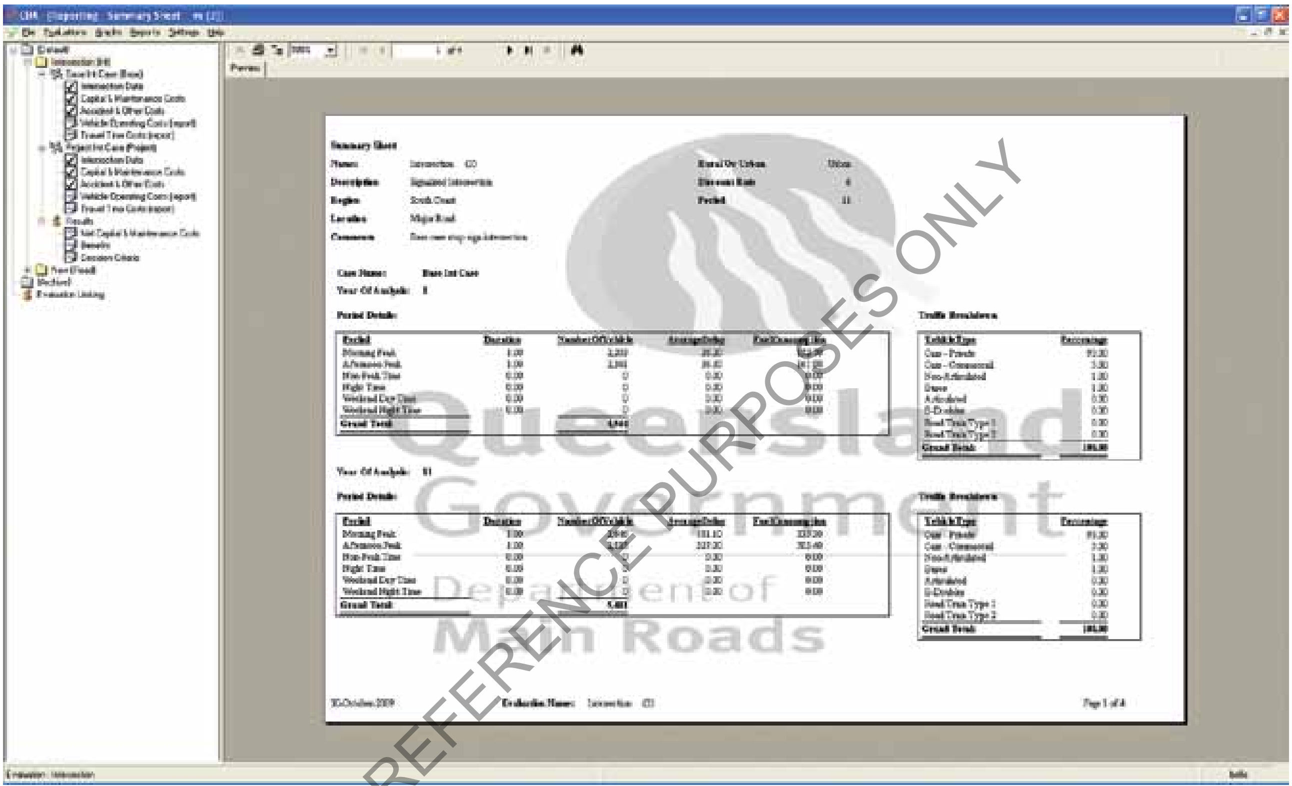
**New**

| Sensitivity Change | 4% | | | 6% | | | 7% | | | 8% | | | 10% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NPV | BCR | FYRR | NPV | BCR | FYRR | NPV | BCR | FYRR | NPV | BCR | FYRR | NPV | BCR | FYRR |
| Normal | 189,720 | 1.62 | 5.48 | 75,379 | 1.25 | 5.37 | 33,385 | 1.11 | 5.32 | -1,159 | 1.00 | 5.27 | -53,429 | 0.81 | 5.18 |
| Capital Costs Up 20% | 132,028 | 1.36 | 4.56 | 18,776 | 1.05 | 4.48 | -32,690 | 0.93 | 4.44 | -56,715 | 0.84 | 4.39 | -107,975 | 0.68 | 4.31 |
| Capital Costs Down 20% | 299,289 | 2.53 | 6.84 | 173,278 | 1.87 | 6.72 | 126,687 | 1.64 | 6.65 | 88,170 | 1.44 | 6.59 | 29,397 | 1.15 | 6.47 |
| Travel Time Costs Up 40% | 189,720 | 1.62 | 5.48 | 75,379 | 1.25 | 5.37 | 33,385 | 1.11 | 5.32 | -1,159 | 1.00 | 5.27 | -53,429 | 0.81 | 5.18 |
| Travel Time Costs Down 40% | 189,720 | 1.62 | 5.48 | 75,379 | 1.25 | 5.37 | 33,385 | 1.11 | 5.32 | -1,159 | 1.00 | 5.27 | -53,429 | 0.81 | 5.18 |
| Vehicle Operating Costs Up 20% | 198,963 | 1.65 | 5.52 | 81,855 | 1.28 | 5.42 | 38,861 | 1.13 | 5.37 | 3,502 | 1.01 | 5.32 | -49,984 | 0.82 | 5.22 |
| Vehicle Operating Costs Down 20% | 180,477 | 1.59 | 5.43 | 68,904 | 1.23 | 5.33 | 27,909 | 1.10 | 5.28 | -5,821 | 0.98 | 5.23 | -56,874 | 0.80 | 5.13 |
| Accident Costs Up 20% | 279,572 | 1.91 | 6.72 | 143,336 | 1.48 | 6.59 | 93,143 | 1.32 | 6.53 | 51,755 | 1.18 | 6.47 | -11,129 | 0.96 | 6.35 |
| Accident Costs Down 20% | 99,868 | 1.33 | 4.24 | 7,423 | 1.03 | 4.16 | -26,373 | 0.91 | 4.12 | -54,073 | 0.81 | 4.08 | -95,729 | 0.66 | 4.00 |
| Exclude Private TTC | 189,720 | 1.62 | 5.48 | 75,379 | 1.25 | 5.37 | 33,385 | 1.11 | 5.32 | -1,159 | 1.00 | 5.27 | -53,429 | 0.81 | 5.18 |

## 4.6.4 Producing intersection reports

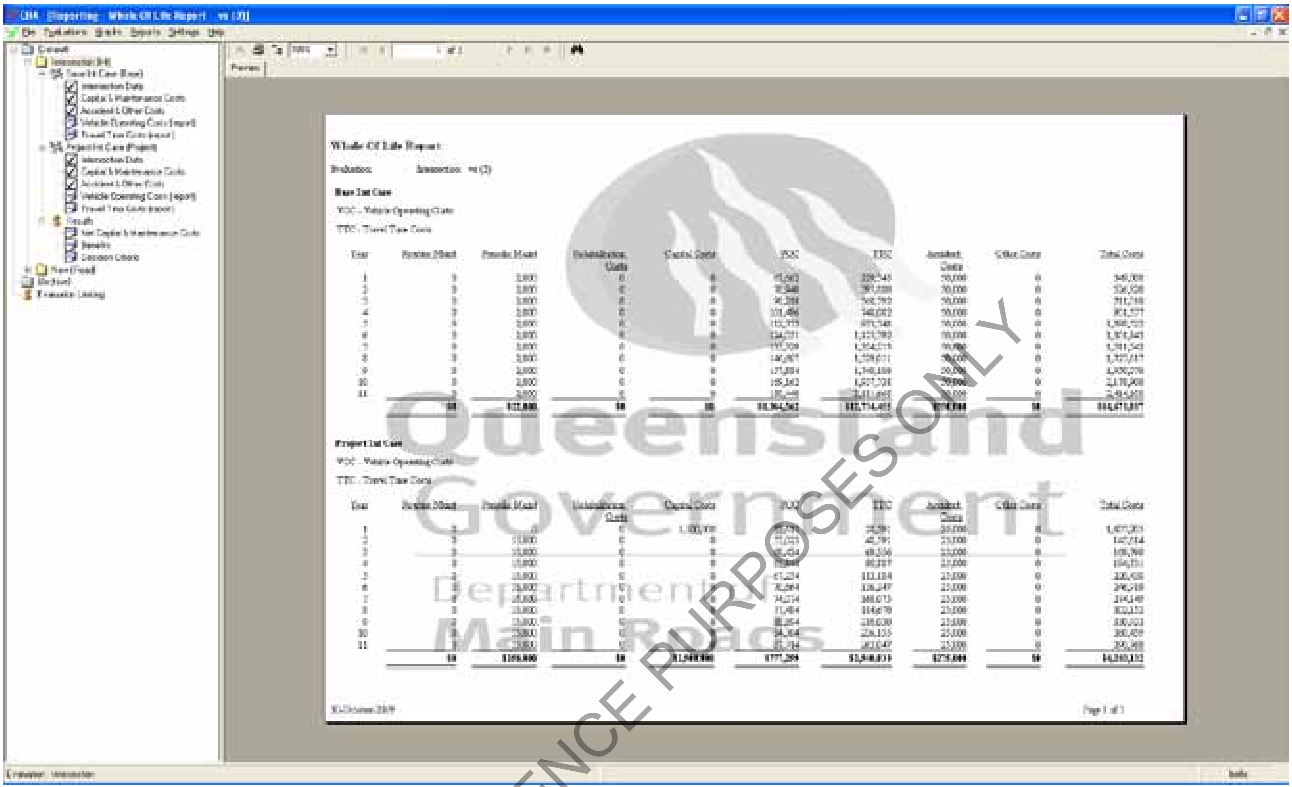
There are two types of intersection reports available within CBA6. These reports are the intersection summary sheet and the intersection whole-of-life report. The summary sheet includes user input components and decision criteria, and incorporates period details and SIDRA inputs for the modelled years, see Figure 58.

*Figure 58: Intersection summary sheet report*



The whole-of-life report provides a summary of the road agency and road user costs over the life of a project recorded on an annual basis, see Figure 59.

*Figure 59: Intersection whole-of-life report*

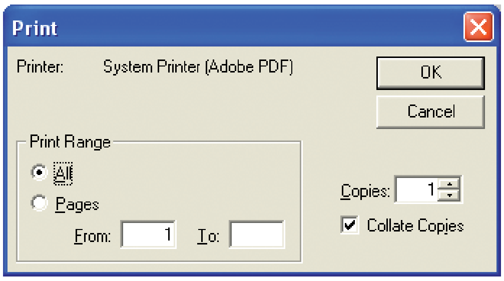


## 4.7 Printing reports

CBA6 uses the default printer when printing any report, see Figure 60. It is important that a system user has the correct default printer selected before the report is printed.

To electronically store evaluation results, print to PDF.

*Figure 60: CBA6 print*



## 4.8 Graphs

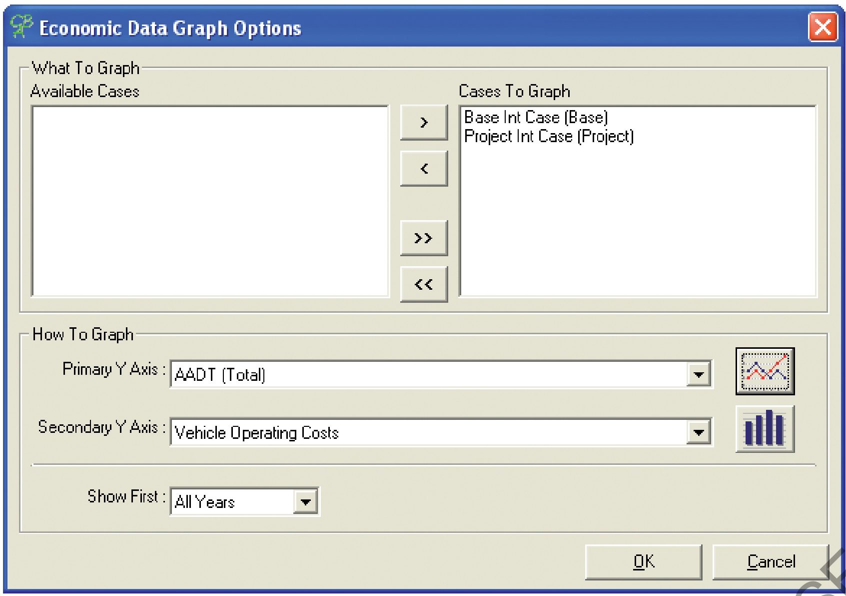
CBA6 allows the system user to graph selected variables per case against time. This function provides a valuable resource for system users to access visual representations of the inner workings of the tool while also providing a source of analysis for use in CBA reports.

The system user has the option of graphing the following variables:

- AADT (per vehicle type)
- AADT (total)
- operating speed (per vehicle type)
- volume in passenger car equivalents (per vehicle type)
- volume in passenger car equivalents (total)
- volume capacity ratios
- roughness count
- TTC
- VOC
- accident costs
- other costs
- total costs.

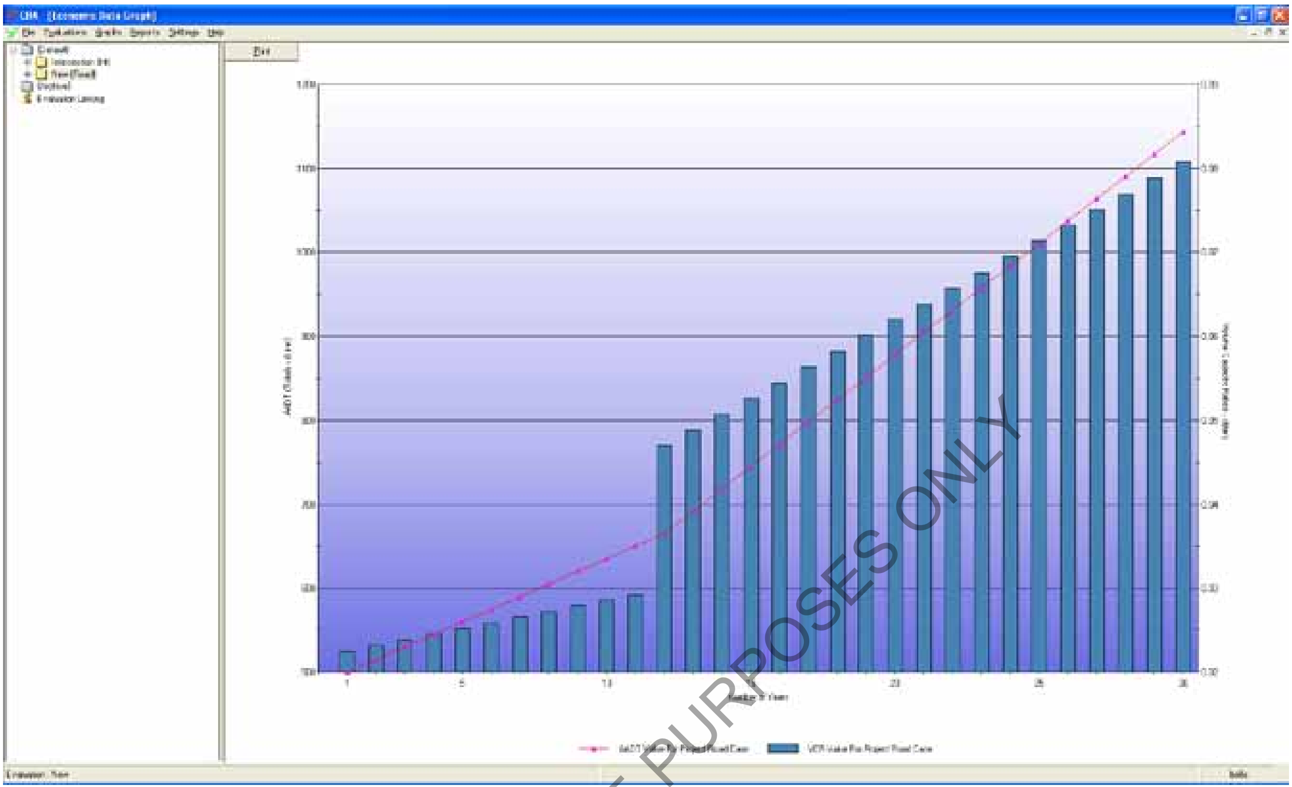
To create a graph the system user highlights a specific evaluation and selects the graph menu option, see Figure 14. The economic data graph option screen is shown in Figure 60. The system user can graph an individual case or both the base and project cases, using the arrow keys to select which case to graph. The system user can also specify the variables to be graphed on the Y axis. The primary Y axis option creates a line graph while the secondary Y axis options create a bar graph. The primary and secondary Y axis variables can be run simultaneously. The years to be graphed can also be specified in CBA6.

*Figure 61: Economic data graph options screen*




From Figure 61, AADT in the project case has been graphed against the volume capacity ratio for the road. This graph shows that there is a positive relationship between traffic growth and congestion. System users can create a number of graphs to compare variables between the base and project cases. For example, graph the volume capacity ratio in the base case against the project case to compare congestion levels.

*Figure 62: Graph (AADT and VCR)*



Once a graph is produced in CBA6, the system user has three options: print, copy or save the graph. To copy the graph, click the print button. The printing options will give the system user the opportunity to select whether the graph is printed, saved as a file, or copied to the clipboard.

## 4.9 Understanding the results

When completing a road project evaluation, there are certain results that occasionally appear erroneous. For example, in the decision criteria, there may be disbenefits, negative costs and negative first year rates of return. This section aims to highlight the majority of these issues and explain what they mean in the context of CBA6.

Note: The system user is directed to the *Technical Guide* for information on the calculations made by CBA6.

### 4.9.1 Disbenefits

Most benefits are a result of the savings in road user costs between the base and project cases. If the project case costs exceed those of the base case, this is likely to be reflected in CBA6 as a negative benefit, or disbenefit.

Note: Disbenefits are displayed in red in the CBA6 results screen.

For example, provision of an improved road surface may increase the speed of the fleet, leading to increased consumption of fuel, oil and tyres. This increase in VOC is transferred to the road user who incurs this extra cost. In CBA6, this would result in a disbenefit to the road user. VOC are typically the most common disbenefit. These disbenefits are not usually incorrect or misleading. Where these disbenefits exist, project results should be carefully scrutinised for errors in the inputs. Examples where outputs may warrant cross check of the inputs could include:

- When CBA6 generates travel time disbenefits even though operating speed increases in the project case. For example, in the case of a bypass, the project will result in faster operating speeds but the appearance of disbenefits as AADT is higher.
- When CBA6 generates accident disbenefits although the width of the road has increased, resulting in a safer road. For example, this could occur where the section length is longer in the project case.
- When VOC increase in the project case despite an improvement in the road surface.



### 4.9.2 Negative costs

Negative costs are fundamentally the opposite of disbenefits. Negative costs refer to the savings in operating and maintenance costs, including any residual value, and will be displayed in red in the 'decision criteria' screen under the heading of 'other costs'. Like disbenefits, negative costs are not necessarily incorrect or misleading. As previously mentioned, negative costs are the result of savings in maintenance costs over the life of a project, and can be due to better pavement construction.

### 4.9.3 Conflicting results from decision criteria

Conflicting results are unusual, but can occur within the decision criteria. It is possible to get BCR below 1 but positive NPV, or negative FYRR and BCR above 1. For example:

- If an alternative maintenance strategy is proposed to the current strategy, a BCR below 1 may result if the alternative maintenance strategy costs less than the current strategy.
- A project may result in a negative FYRR if there are disbenefits in the first year of operation.

If the decision criteria indicators are not clear, decisions should be based on NPV alone.

## 4.10 Response to unexpected results

Table 2 provides a useful output matrix for the system user to apply when confronted with unexpected results. System users can ensure the accuracy of the results by checking the inputs against the outputs. For example if a project provides accident disbenefits, the system user should check the road description (MRS, section length and AADT inputs). In this case, an incorrect MRS may have been used for the project case. This would mean the results in CBA6 are due to a human error. However if the project case has a longer section length than the base case it would be reasonable for accident disbenefits to occur. If system users observe unexpected or conflicting results, this table may assist in cross checking the outputs with the appropriate inputs. For further assistance, system users should direct all queries to the CBA Team.

Ultimately all results in CBA6 can be manually calculated and cross checked using the formulas presented in the *Technical Guide*.

*Table 2: CBA6 output matrix*



| **CBA6 input** | **CBA6 output** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Vehicle operating costs** | | | | | **Travel time costs** | **Accidents** |
| | **Fuel** | **Oil** | **Tyres** | **Depreciation** | **Repairs and maintenance** | | |
| Road description (MRS) | L | L | L | L | M | H | H |
| Section length | M (+) | M (+) | M (+) | M (+) | M (+) | M (+) | M (+) |
| Speed limit | M (+/-) | M (+/-) | M (+/-) | M (+/-) | M (+/-) | H (-) | - |
| Initial roughness | L (+) | L (+) | L (+) | L (+) | H (+) | L (+) | - |
| Pavement type | L | - | L | - | L | L | - |
| Surface type | L | - | L | M | M | M | - |
| Vertical alignment | L | - | L | - | - | L | - |
| Horizontal alignment | L | - | H | - | - | M | - |
| AADT | H (+) | H (+) | H (+) | H (+) | H (+) | H (+) | H (+) |
| Traffic breakdown | H | H | H | H | H | H | - |

The degree of impact on each output per input is based on a score of high (h), medium (m) or low (l). Each impact is also measured in terms of a positive (+) and negative (-) relationship where appropriate. For example, an increase in the speed limit will decrease TTC (when all other inputs are held constant).

Note: The speed input can have a positive or negative relationship with some of the VOC outputs due to the nature of the speed/consumption relationship. For further detail, see Section 11 of the *Technical Guide*.

## 4.11 Presenting CBA6 results

Once the system user has completed an evaluation, there are several presentation options. Results can be presented in the form of standard and detailed road case reports (see Section 4.6.1) which can be used as attachments to funding proposals. Alternatively system users can use the CBA6 reports (decision criteria, see Figure 53) or the 'copy to clipboard' function to create a variety of graphs to illustrate discussion points.

Note: Interpretation of CBA results can often be quite challenging. The advice of qualified specialists should be sought when interpreting results and making conclusions of the CBA.

# 5 Case studies

The case studies provide an instructional guide for undertaking a road evaluation using CBA6. Projects can vary in complexity and CBA6 has a number of different modules that are used to evaluate a variety of road projects. CBA6 has been designed to encompass the types of capital and maintenance projects usually undertaken by TMR. Each case study provides an opportunity for system users to quickly become familiar with operating the tool.

Case studies have been included in this section for the following types of projects:

- maintenance strategies
- road widening
- shoulder sealing
- overtaking lanes
- flood immunity and road closures
- intersections
- duplication
- town bypasses
- unsealed roads
- generated traffic
- freight
- multiple project options
- incremental analysis
- linking evaluation files.

Note: Detailed printed reports for each case study are presented in Appendix A (CBA6.1 printouts).

The explanation of the case studies are accompanied by detailed instructions on entering project data into CBA6 together with guidance on project results.

## 5.1 Maintenance

This case study provides guidance to undertake a maintenance strategy evaluation. A maintenance evaluation will primarily compare the roughness deterioration profile between the base and project cases and the ensuing change in maintenance costs. It is sometimes required, when bringing forward some maintenance work, to delay other work. CBA6 can be used to calculate the net economic benefits of mutually exclusive maintenance programs.

TMR's asset management guidelines (2002) prescribe three categories of maintenance:

- routine maintenance
- programmed maintenance – road resurfacing and/or bulk routine maintenance
- rehabilitation.

In CBA6 programmed maintenance is referred to as 'periodic maintenance'.

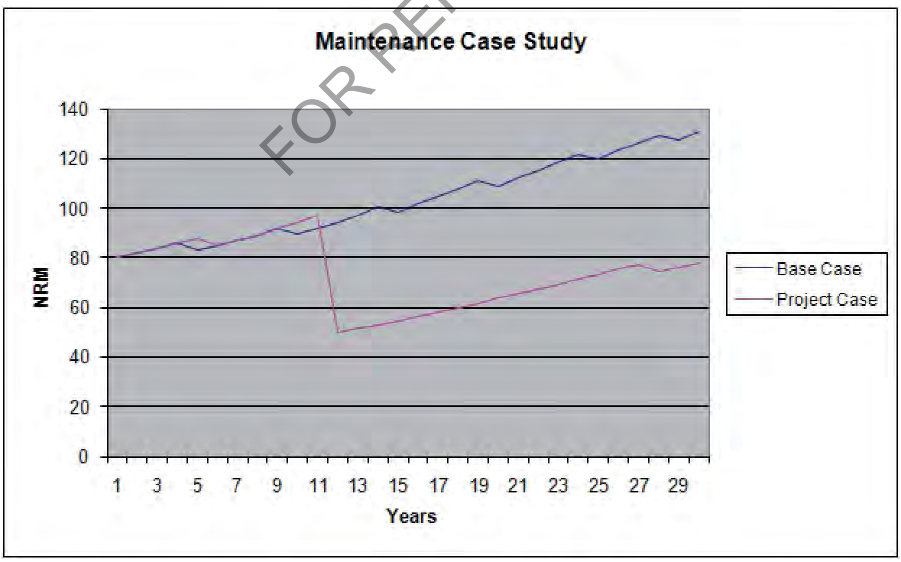
### 5.1.1 Maintenance case study

This case study involves the evaluation of a narrow two-lane road with pavement in fair condition. The road has low traffic volumes but there is a large proportion of heavy commercial vehicles that make up the traffic fleet. The characteristics of the road may not justify the capital costs due to low traffic volumes, but TMR wants to test an alternative maintenance strategy that will better cater for the heavy vehicles using the road.

The current maintenance strategy for the road consists of annual routine maintenance and periodic maintenance in Years 5, 10, 15, 20, 25 and 29. The periodic maintenance works will improve the road surface by 5 NRM.

The objective of this CBA is to determine the economic viability of pursuing the new maintenance program in place of the current program. All the required input data for this maintenance case study can be found in Appendix A.

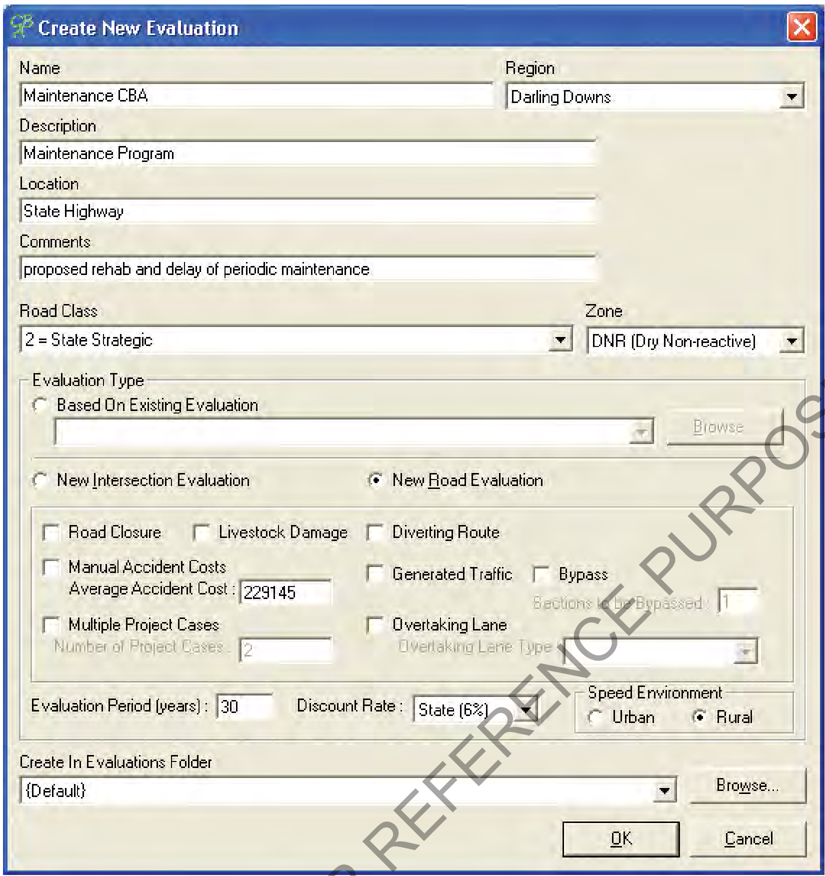
*Figure 63: Maintenance case study NRM*



## 5.1.2 Create new evaluation screen

Figure 64 shows the maintenance case study evaluation details screen. The key attributes of this screen are the selection of the discount rate, the evaluation period, the zone and the speed environment. The remaining details in the 'create evaluation' screen are superfluous and can be entered according to the system user's own preference.

*Figure 64: Maintenance create new evaluation*






## 5.1.3 Road details screen

The data entered into the 'road details' screen for the base case and project case are the same. Enter an MRS of 8, a section length of 2 km, an initial roughness of 80 NRM, a safe speed of 80 km/h, a pavement type of flexible, a surface type of sprayed seal, a straight horizontal alignment and a vertical alignment of rolling and undulating. For a maintenance only evaluation the road details for the base and project cases should remain the same.

## 5.1.4 Road traffic data screen

The road traffic data is the same for the base case and the project case. The AADT is 2500 in Year 1; the growth rate is 2.0% and linear. Traffic breakdown is 73% cars – private, 5% cars – commercial, 5% non-articulated, 0% buses, 5% articulated, 8% B-doubles, 3% road train type 1 and 1% road train type 2.

## 5.1.5 Capital and maintenance costs

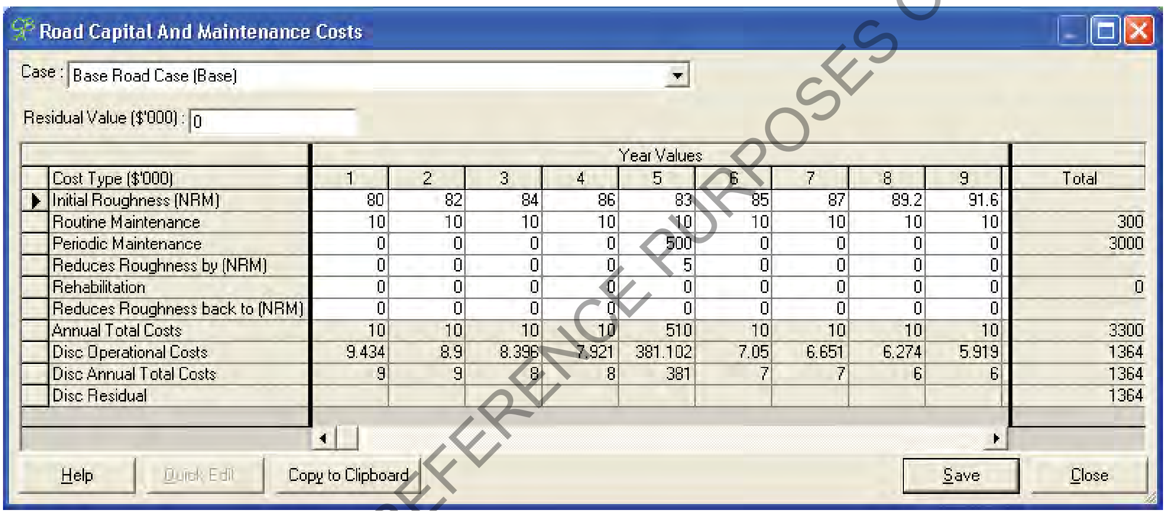
The most important inputs for a maintenance evaluation are found in the 'capital and maintenance costs' screen. Assumptions and data for the maintenance strategy will differ between the base and project cases.

### 5.1.5.1 Base case

Base case maintenance costs are shown in Figure 65.

Routine maintenance – enter $10 000 each year. Routine maintenance is work carried out each year that does not change the condition of the road NRM, such as grass cutting and road kill clean up. Use the 'quick edit' button to populate the routine maintenance fields for the entire evaluation period. The 'quick edit' buttons are explained in detail in Section 3.6.7. Note: If the base case and project case routine maintenance costs are the same, they do not need to be entered in CBA6. Periodic maintenance – enter $500 000 in Years 5, 10, 15, 20, 25 and 29 in the 'periodic maintenance' row. Enter a reduction in roughness by 5 NRM in the 'reduces roughness by (NRM)' row to correspond with the periodic maintenance costs. Periodic maintenance will provide a temporary improvement in the road's surface but roughness will deteriorate at a faster rate than if rehabilitation had taken place. Rehabilitation – $0, no reconstruction in the base case. The current maintenance strategy only provides periodic maintenance. Once all the maintenance data has been entered in CBA6, click 'save' and begin the same procedure for the project case. In the project case, the assumptions on the timing of periodic maintenance will change and rehabilitation will now be included in CBA6.

*Figure 65: Maintenance case study base case*




| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year Values | | | | | | | | | |
| Initial Roughness (NRM) | 80 | 82 | 84 | 86 | 83 | 85 | 87 | 89.2 | 91.6 | |
| Routine Maintenance | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 300 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 500 | 0 | 0 | 0 | 0 | 3000 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Annual Total Costs | 10 | 10 | 10 | 10 | 510 | 10 | 10 | 10 | 10 | 3300 |
| Disc Operational Costs | 9.434 | 8.9 | 8.396 | 7.921 | 381.102 | 7.05 | 6.651 | 6.274 | 5.919 | 1364 |
| Disc Annual Total Costs | 9 | 9 | 8 | 8 | 381 | 7 | 7 | 6 | 6 | 1364 |
| Disc Residual | | | | | | | | | | 1364 |



### 5.1.5.2 Project case

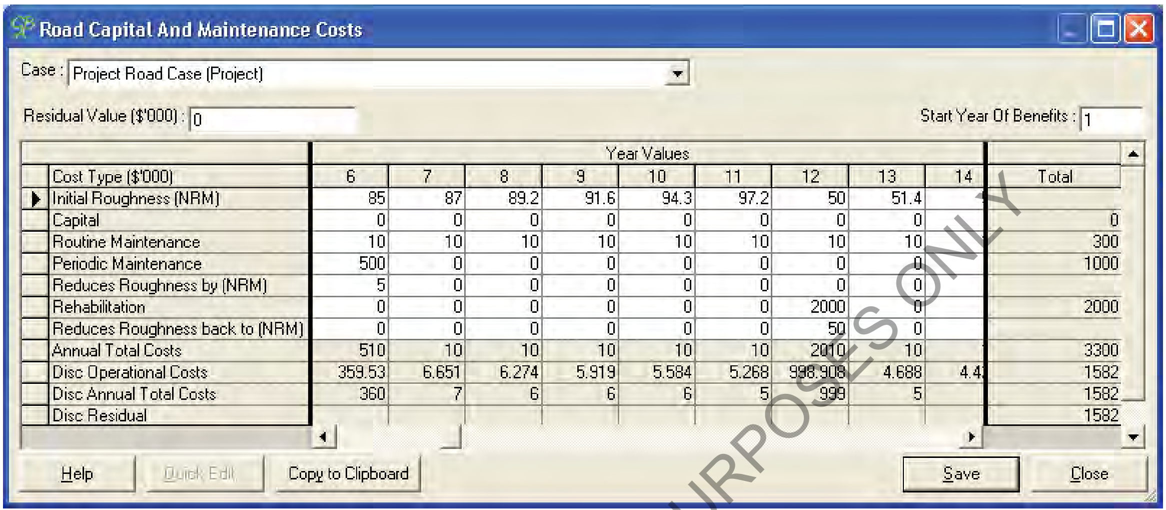
Project case maintenance costs are shown in Figure 65.

- Capital – $0, no capital costs for a maintenance strategy.
- Routine maintenance – in this example, routine maintenance does not change for the project case, so use $10 000 for each year. Note: If the base case and project case routine maintenance costs are the same they do not need to be entered in CBA6 as the net result will be zero.
- Periodic maintenance – $500 000 in Years 6 and 28 with corresponding roughness reduction of 5 NRM.
- Rehabilitation – enter $2 million in Year 12 in the 'rehabilitation' row. As in Figure 64 enter a new roughness of 50 NRM in the 'reduces roughness to (NRM)' row to correspond with the rehabilitation costs. Rehabilitation will provide a more permanent improvement to road roughness than periodic maintenance. After rehabilitation, roughness will deteriorate at a slower rate than if periodic maintenance had just been applied.
- Start year of benefits – this is only available for the project case. This value defaults to 1, but changes to the year of the last entered capital cost plus 1. A maintenance strategy can be tested from Year 1.

- Residual value – this evaluation does not have a residual value, as capital costs have not been incurred in this project. For information regarding residual value refer to Section 3.6.5.

Once all the maintenance data has been entered into CBA6 click ‘save’. Click ‘copy to clipboard’ to create a graph of the maintenance and roughness deterioration profile in a spreadsheet. This is useful to provide a simple visual comparison of the base and project cases.

*Figure 66: Maintenance case study project case*




| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| Initial Roughness (NRM) | 85 | 87 | 89.2 | 91.6 | 94.3 | 97.2 | 50 | 51.4 | | |
| Capital | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Routine Maintenance | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | 300 |
| Periodic Maintenance | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1000 |
| Reduces Roughness by (NRM) | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 2000 | 0 | | 2000 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | | |
| Annual Total Costs | 510 | 10 | 10 | 10 | 10 | 10 | 2010 | 10 | | 3300 |
| Disc Operational Costs | 359.53 | 6.651 | 6.274 | 5.919 | 5.584 | 5.268 | 998.908 | 4.688 | 4.4 | 1582 |
| Disc Annual Total Costs | 360 | 7 | 6 | 6 | 6 | 5 | 999 | 5 | | 1582 |
| Disc Residual | | | | | | | | | | 1582 |

## 5.1.6 Accident and other costs

It has been assumed in CBA6, that pure maintenance strategies do not influence accident costs.

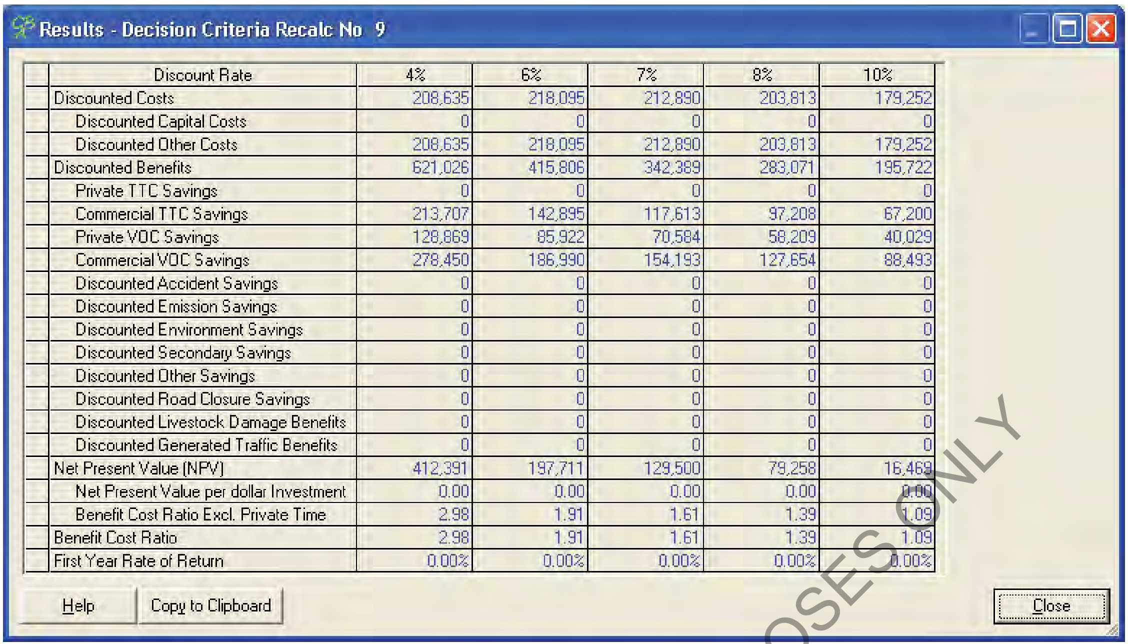
## 5.1.7 Results and decision criteria

The ‘results’ screen in Figure 66 provides the system user with information as to which maintenance strategy provides greater economic value.

The project case maintenance strategy requires higher maintenance costs, in the order of $218 095, than the base case maintenance strategy, at a discount rate of 6%. No capital was applied to this evaluation. The increase in maintenance costs is justified, as the benefits for existing road users are greater than the increase in maintenance costs. The majority of the project benefits are comprised of VOC savings for commercial vehicles. The results imply that the project satisfies the objective of catering better for heavy vehicles using the road. The NPV for the proposed maintenance strategy is $197 711 at the discount rate of 6%. The BCR for our new maintenance strategy is 1.91 at the discount rate of 6%, which indicates a positive economic return on the costs. The BCR produced for maintenance strategies should not be used in comparison with capital projects, see Section 3.5.3.2.

The alternative maintenance strategy in this case study is a better option than the existing strategy. CBA6 can compare a number of mutually exclusive options using the ‘multiple project cases’, see Section 5.11. This module provides a guide to undertaking multiple options analysis. This will be useful in developing the optimum maintenance strategy for the road network.

*Figure 67: Maintenance case results*




| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 208,635 | 218,095 | 212,890 | 203,813 | 179,252 |
| Discounted Capital Costs | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Costs | 208,635 | 218,095 | 212,890 | 203,813 | 179,252 |
| Discounted Benefits | 621,026 | 415,806 | 342,389 | 283,071 | 195,722 |
| Private TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Commercial TTC Savings | 213,707 | 142,895 | 117,613 | 97,208 | 67,200 |
| Private VOC Savings | 128,869 | 85,922 | 70,584 | 58,209 | 40,029 |
| Commercial VOC Savings | 278,450 | 186,990 | 154,193 | 127,654 | 88,493 |
| Discounted Accident Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 412,391 | 197,711 | 129,500 | 79,258 | 16,469 |
| Net Present Value per dollar Investment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Benefit Cost Ratio Excl. Private Time | 2.98 | 1.91 | 1.61 | 1.39 | 1.09 |
| Benefit Cost Ratio | 2.98 | 1.91 | 1.61 | 1.39 | 1.09 |
| First Year Rate of Return | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

## 5.2 Road widening

A road widening project involves increasing the seal width of the road. Road widening projects are designed to alleviate minor congestion issues and provide a safer operating environment for road users. For the purposes of conducting evaluations using CBA6, road widening projects have been divided into two categories.

- Section 5.2.1 – road widening without shoulder sealing
- Section 5.2.2 – road widening with shoulder sealing

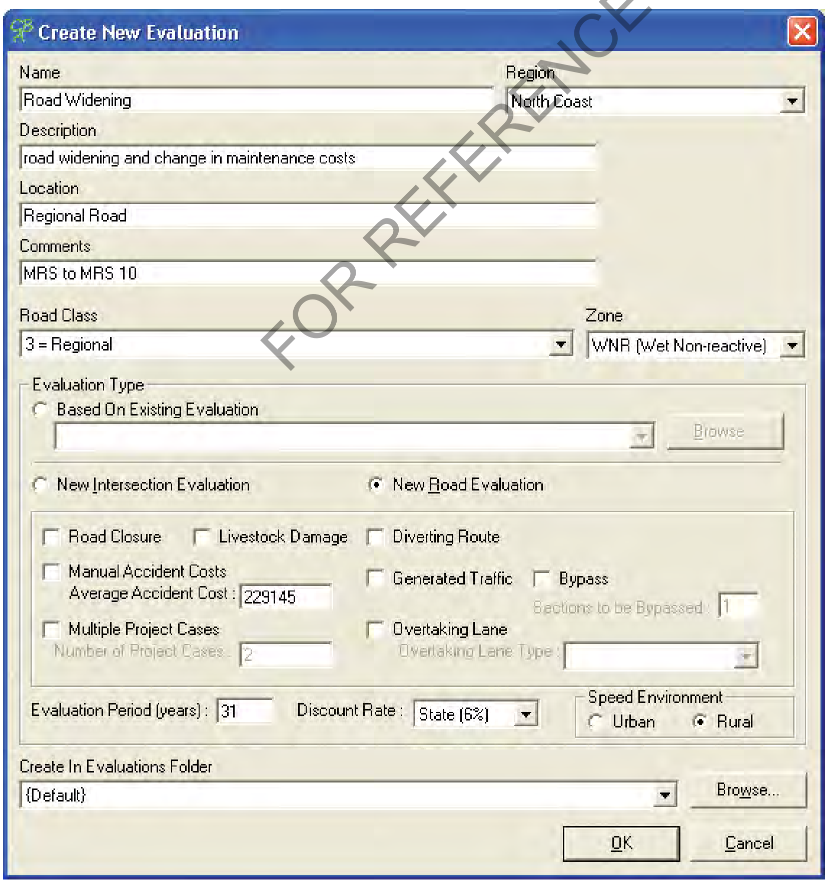
### 5.2.1 Road widening without shoulder sealing

This example involves the evaluation of a regional road with a poor safety record. A road widening is proposed to mitigate the higher than average accident rate. The proposed road widening will increase the seal width from a model road state MRS 7 (two-lane seal 5.3 m– 5.8 m) to MRS 10 (two-lane seal 7.1 m – 7.6 m), both of which do not provide sealed shoulders. The proposed road widening is expected to cost $2.5 million and take one year to complete.

#### 5.2.1.1 Create new evaluation screen

The 'create new evaluation' screen for this case study is shown in Figure 68. The evaluation period is set to 31 years. There will be one year of construction and a useful life of 30 years for the asset. In this example it may be appropriate to provide comment on the widening work being proposed in the 'description' field.

*Figure 68: Road widening case study*



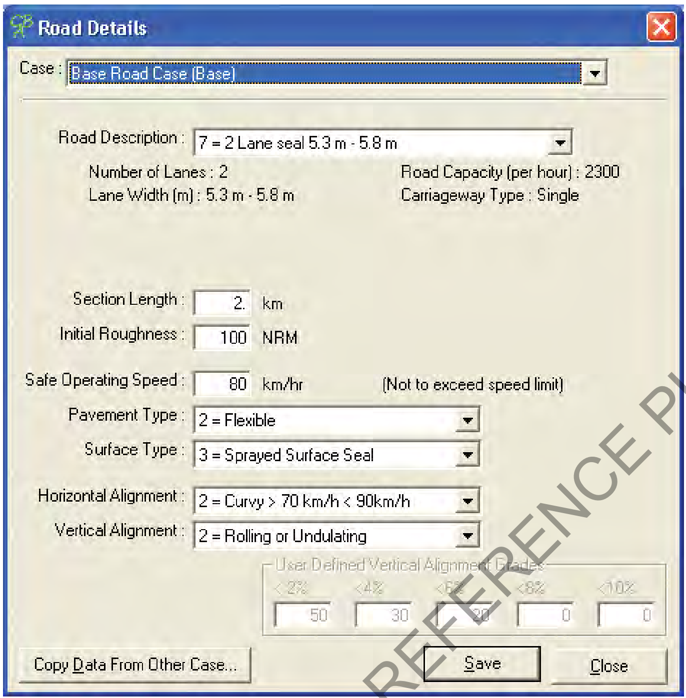
#### 5.2.1.2 Road details

The 'road details' screen highlights the important difference between the base and project cases. In a simple road widening project the most important inputs to CBA6 will be in the description of model road state.

5.2.1.2.1. Base case

The base case road details are shown in Figure 69. The base case 'road description' is an MRS of 7. The current roughness of the road is 100 NRM. The pavement and surface type have been defaulted to match the MRS of 7. Once the 'road details' screen for the base case is complete, click 'save'.

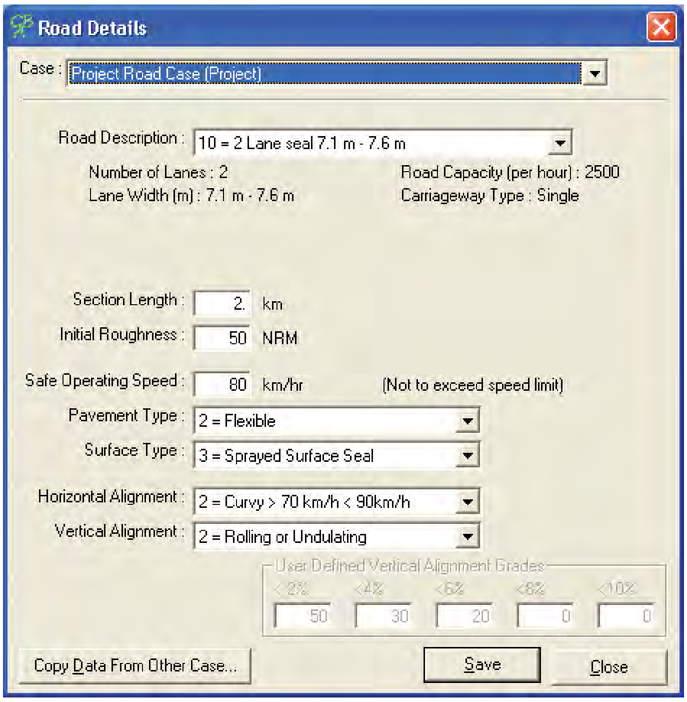
*Figure 69: Road widening base case*




5.2.1.2.2. Project case

The only change to the 'road details' screen for the project case in this simple widening will be the MRS and initial roughness, see Figure 70. To quickly populate the project case road details screen press the 'copy data from other case' button and use the base case road details. Once all the base case details have been copied over, change the MRS using the drop-down menu. The MRS in the project case should be 10 (two-lane seal 7.1 m – 7.6 m). The initial roughness in the project case is 50 NRM.

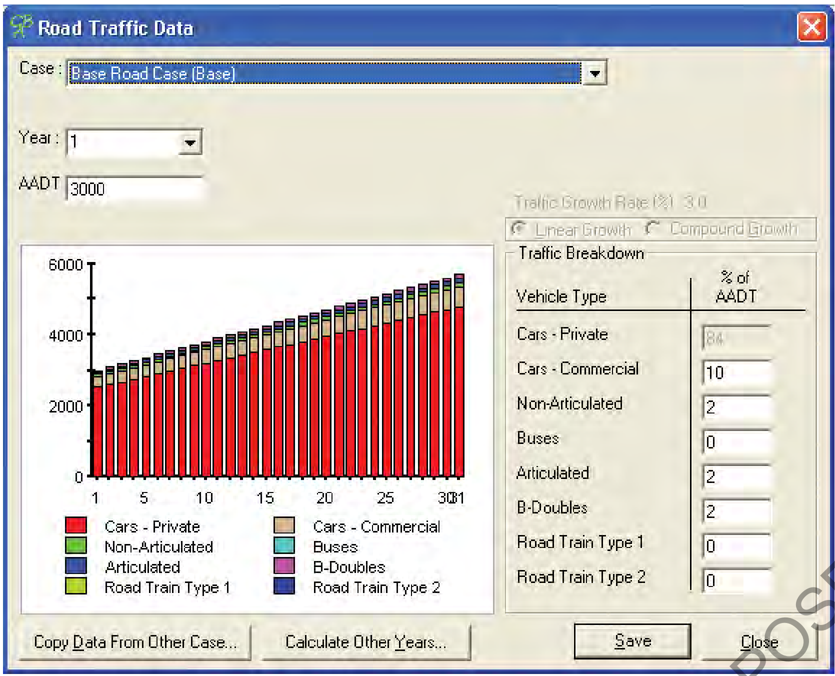
*Figure 70: Road widening project case*




### 5.2.1.3 Road traffic data

In this example, the AADT is 3000 vehicles per day, see Figure 71. Traffic data for the base and project cases will be the same. Once the base case traffic data has been saved, use the 'copy data from other case' button to quickly transfer the same data for the project case.

Figure 71: Road widening traffic data




### 5.2.1.4 Capital and maintenance costs

In this example, the project case has $2.5 million in capital costs. In this example it is necessary to change the maintenance profile for the project case.

5.2.1.4.1. Base case

Routine maintenance – $10 000 each year. Routine maintenance is work carried out each year that does not change the condition of the road NRM, such as grass cutting and road kill clean up. Use the 'quick edit' to populate the routine maintenance fields for the entire evaluation period, see Section 3.6.7. Periodic maintenance – $500 000 in Years 7, 21 and 28 with corresponding roughness reduction of 5 NRM. Periodic maintenance (programmed maintenance) will provide a temporary improvement in the road's surface. Rehabilitation – $1 million in Year 14 that reduces roughness back to 80 NRM. The 'copy to clipboard' button may be used to copy the capital and maintenance cost data and paste into a suitable external program such as Excel. Once all the maintenance data has been applied in CBA6, click the 'save' button and begin the same procedure for the project case.

5.2.1.4.2. Project case

- Capital – $2.5 million entered in Year 1. CBA6 uses cost data in '000 – input 2500 in CBA6 to represent $2.5 million, see Figure 71.
- Routine maintenance – assume routine maintenance is the same as the base case, therefore input $10 000 each year.
- Periodic maintenance – the maintenance profile between the base and project cases now changes. Only three maintenance interventions are now required. Enter $500 000 in Years 10, 17, and 24 with corresponding roughness reduction of 5 NRM.
- Rehabilitation – $0, no reconstruction in the project case.

- Start year of benefits – this field is only available for the project case and will default to Year 1. As the benefits of the project will flow post construction, this default value needs to be changed to the year of the last entered capital cost plus one. For this case study the project will be assessed from Year 2.

- Residual value – there is no residual value of the asset after the 31-year evaluation period.

- The 'copy to clipborad' button may be used to copy the capital and maintenance cost data and paste into a suitable external program such as Excel.

*Figure 72: Road widening project costs*

**Road Capital And Maintenance Costs**

Case : Project Road Case (Project)

Residual Value ($'000) : 0 Start Year Of Benefits : 2

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 50 | 51.4 | 52.9 | 54.4 | 56 | 57.6 | 59.2 | 60 | |
| Capital | 2500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 2500 |
| Routine Maintenance | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 300 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1500 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 2500 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 4300 |
| Disc Operational Costs | 0 | 8.9 | 8.396 | 7.921 | 7.473 | 7.05 | 6.651 | 6.274 | 5.9 | 718 |
| Disc Annual Total Costs | 2358 | 9 | 8 | 8 | 7 | 7 | 7 | 6 | | 3076 |
| Disc Residual | | | | | | | | | | 3076 |

Help | Quick Edit | Copy to Clipboard | Save | Close

### 5.2.1.5 Accident and other costs

Safety is a major reason behind the planning and construction of road widening projects. This example involves the evaluation of a project which produces a significant reduction in accidents (see Section 6 of the *Technical Guide* for the relationship between MRS and accident rates). Accident costs decrease in the first year of the evaluation from $354 000 in the base case to only $190 000 in the project case, see Figures 73 and 74. If the accident cost estimates are not representative of the section of road analysed, the system user can manually calculate the accident costs. To manually calculate accident costs, the 'manual accident cost' box found in the 'create new evaluation' screen needs to be clicked.

*Figure 73: Road widening accident costs – base case*

**Road Accident And Other Costs**

Case : Base Road Case (Base)

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
| Accident | 354 | 364 | 375 | 385 | 396 | 407 | 417 | 428 | 439 | 15,896 |
| Emission | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Environment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Secondary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual Total Costs | 354 | 364 | 375 | 385 | 396 | 407 | 417 | 428 | 439 | 15,896 |
| Disc Annual Total Costs | 334 | 324 | 315 | 305 | 296 | 287 | 278 | 268 | 260 | 6,489 |

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*Figure 74: Road widening accident costs – project case*

Road Accident And Other Costs

Case : Project Road Case (Project)

| Cost Type ($'000) | Year Values 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
|---|---|---|---|---|---|---|---|---|---|---|
| Accident | 190 | 196 | 201 | 207 | 213 | 219 | 224 | 230 | 236 | 8,544 |
| Emission | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Environment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Secondary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual Total Costs | 190 | 196 | 201 | 207 | 213 | 219 | 224 | 230 | 236 | 8,544 |
| Disc Annual Total Costs | 179 | 174 | 169 | 164 | 159 | 154 | 149 | 144 | 140 | 3,488 |

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### 5.2.1.6 Results and decision criteria

The estimated capital cost for this project is $2.5 million. As a result of capital works, TMR has been able to delay some programmed maintenance. The increase in spending is justified as benefits exceed the costs. Discounted benefits for existing road users are valued at over $3.3 million.

The majority of project benefits are derived from savings in accident costs totalling $2.8 million, see Figure 75. The results imply that the project satisfies the objective of reducing the frequency of accidents. At a discount rate of 6%, the NPV of the proposed maintenance strategy is over $1.4 million and the BCR is 1.72.



*Figure 75: Road widening decision criteria*

Results - Decision Criteria Recalc No 3

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 1,840,171 | 1,917,703 | 1,942,988 | 1,961,645 | 1,983,946 |
| Discounted Capital Costs | 2,403,846 | 2,358,491 | 2,336,449 | 2,314,815 | 2,272,727 |
| Discounted Other Costs | -563,675 | -440,787 | -393,460 | -353,169 | -288,781 |
| Discounted Benefits | 4,312,983 | 3,291,466 | 2,908,203 | 2,587,616 | 2,088,383 |
| Private TTC Savings | 8,652 | 6,801 | 6,041 | 5,371 | 4,261 |
| Commercial TTC Savings | 78,523 | 62,962 | 56,782 | 51,425 | 42,652 |
| Private VOC Savings | 325,956 | 256,523 | 230,324 | 208,268 | 173,473 |
| Commercial VOC Savings | 150,153 | 118,547 | 106,565 | 96,451 | 80,439 |
| Discounted Accident Savings | 3,749,699 | 2,846,632 | 2,508,490 | 2,226,101 | 1,787,557 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 2,472,812 | 1,373,762 | 965,215 | 625,971 | 104,437 |
| Net Present Value per dollar Investment | 1.03 | 0.58 | 0.41 | 0.27 | 0.05 |
| Benefit Cost Ratio Excl. Private Time | 2.34 | 1.71 | 1.49 | 1.32 | 1.05 |
| Benefit Cost Ratio | 2.34 | 1.72 | 1.50 | 1.32 | 1.05 |
| First Year Rate of Return | 7.31% | 7.17% | 7.10% | 7.04% | 6.91% |

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## 5.2.2 Road widening with shoulder sealing

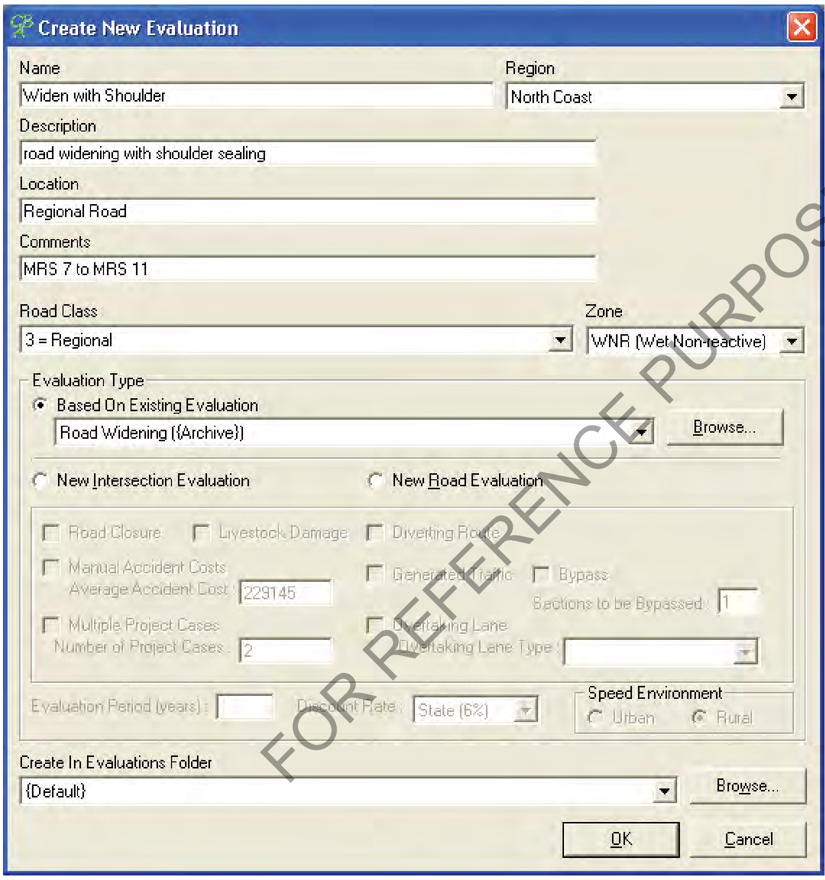
This case study will provide instruction on using CBA6 to conduct an evaluation of initiatives that involve both widening the road and providing a sealed shoulder.

### 5.2.2.1 Create new evaluation

The ‘create new evaluation screen’ is shown in Figure 76.

Note: ‘Based on existing evaluation’ option has been selected.

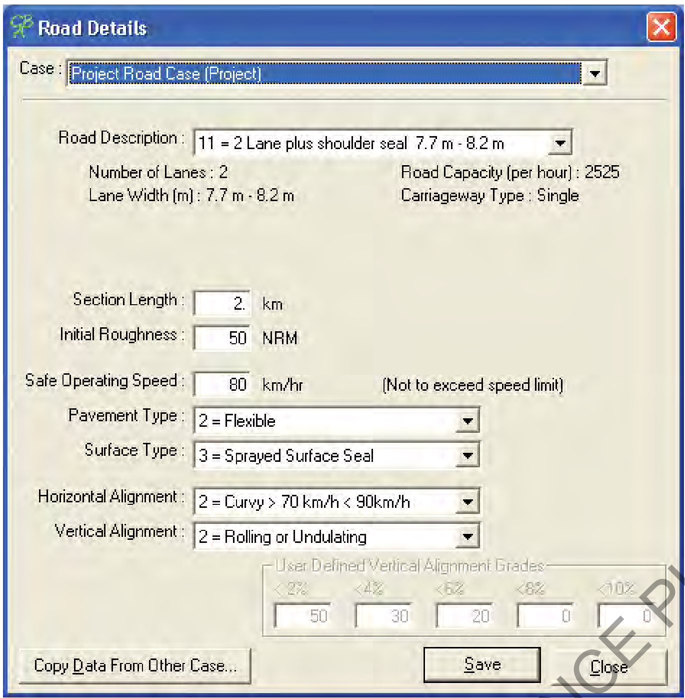
*Figure 76: Road widening with shoulder sealing*



### 5.2.2.2 Road details

The base case MRS is 7 (two-lane seal 5.3 m – 5.8 m without sealed shoulders). The project will widen the road to MRS 11 with sealed shoulders (two-lane seal 7.7 m – 8.2 m), see Figure 77.

*Figure 77: Project case with sealed shoulders*



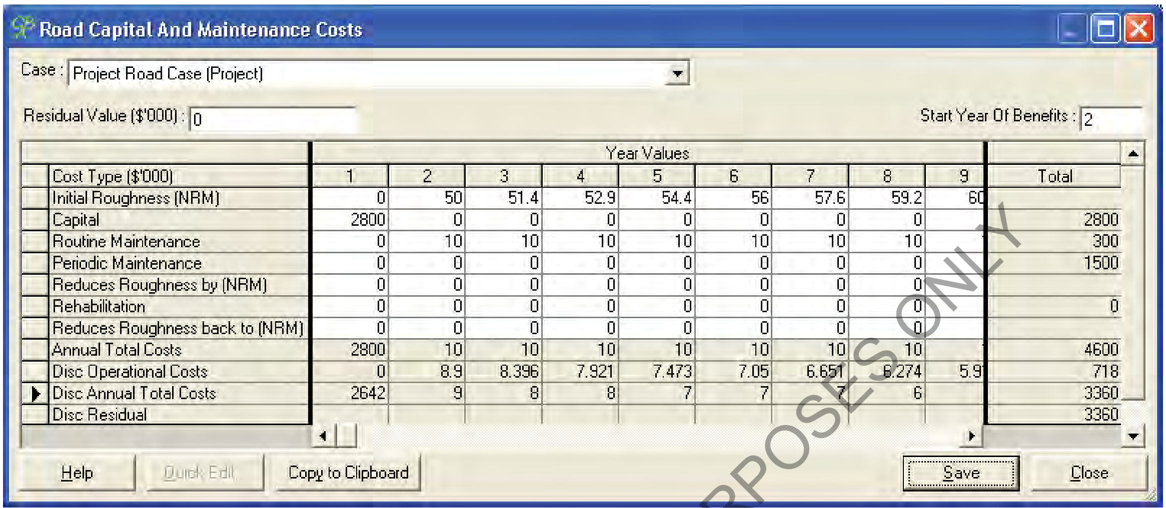

### 5.2.2.3 Road traffic data

Traffic volumes will remain unchanged from the previous case study which included AADT of 300 vehicles per day.

### 5.2.2.4 Capital and maintenance costs

The provision of sealed shoulders is expected to incur an additional $500 000 in costs. Capital costs for this project will be $3 million, see Figure 78. For simplicity, maintenance and ongoing costs have remained consistent with the previous case study. However, in some instances, the provision of sealed shoulders may actually increase ongoing costs.

*Figure 78: Widen and shoulder seal costs*




| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 50 | 51.4 | 52.9 | 54.4 | 56 | 57.6 | 59.2 | 60 | |
| Capital | 2800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 2800 |
| Routine Maintenance | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | 300 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1500 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 2800 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | 4600 |
| Disc Operational Costs | 0 | 8.9 | 8.396 | 7.921 | 7.473 | 7.05 | 6.651 | 6.274 | 5.9 | 718 |
| Disc Annual Total Costs | 2642 | 9 | 8 | 8 | 7 | 7 | 7 | 6 | | 3360 |
| Disc Residual | | | | | | | | | | 3360 |



### 5.2.2.5 Accident and other costs

Accident rates for roads with sealed shoulders are usually lower than for roads without sealed shoulders. In this case study, it is assumed that accident cost savings will comprise a greater proportion of benefits than the previous case study.

### 5.2.2.6 Results and decision criteria

The results of this evaluation are shown in Figure 79. Total benefits for this project are $3.7 million at the 6% discount rate. In the previous case study, total benefits for the project were only $3.6 million. However the provision of sealed shoulders results in the BCR being lower than the BCR for the previous case study, and the project NPV at $1.56 million is higher than the previous case study that returned an NPV of $1.37 million. This result suggests that the additional funds to provide a sealed shoulder are economically justified in comparison to the previous case study. See Section 5.11 for further discussion on option analysis.

*Figure 79: Road widen and shoulder seal decision criteria*

Results - Decision Criteria Recalc No 3

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 2,128,632 | 2,200,722 | 2,223,362 | 2,239,423 | 2,256,673 |
| Discounted Capital Costs | 2,692,308 | 2,641,509 | 2,616,822 | 2,592,593 | 2,545,455 |
| Discounted Other Costs | -563,675 | -440,787 | -393,460 | -353,169 | -288,781 |
| Discounted Benefits | 4,926,657 | 3,757,222 | 3,318,583 | 2,951,755 | 2,380,722 |
| Private TTC Savings | 8,652 | 6,801 | 6,041 | 5,371 | 4,261 |
| Commercial TTC Savings | 78,523 | 62,962 | 56,782 | 51,425 | 42,652 |
| Private VOC Savings | 330,213 | 259,662 | 233,052 | 210,655 | 175,342 |
| Commercial VOC Savings | 151,511 | 119,549 | 107,436 | 97,213 | 81,036 |
| Discounted Accident Savings | 4,357,758 | 3,308,248 | 2,915,272 | 2,587,091 | 2,077,432 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 2,798,025 | 1,556,500 | 1,095,221 | 712,332 | 124,049 |
| Net Present Value per dollar Investment | 1.04 | 0.59 | 0.42 | 0.27 | 0.05 |
| Benefit Cost Ratio Excl. Private Time | 2.31 | 1.70 | 1.49 | 1.32 | 1.05 |
| Benefit Cost Ratio | 2.31 | 1.71 | 1.49 | 1.32 | 1.05 |
| First Year Rate of Return | 7.47% | 7.33% | 7.26% | 7.19% | 7.06% |

Help | Copy to Clipboard | Close

## 5.3 Realignment

Road alignment can impact on vehicle speed and also trafffic volume. Realignment projects are designed to improve unnecessary bends and make the road safer to traverse, and can be applied to the approaches of existing bridge structures and also to roads with poor design standards. In some cases realignment projects shorten the distance road users have to travel. Realignment projects that improve the horizontal alignment of the road could provide substantial TTC savings and accident cost savings.

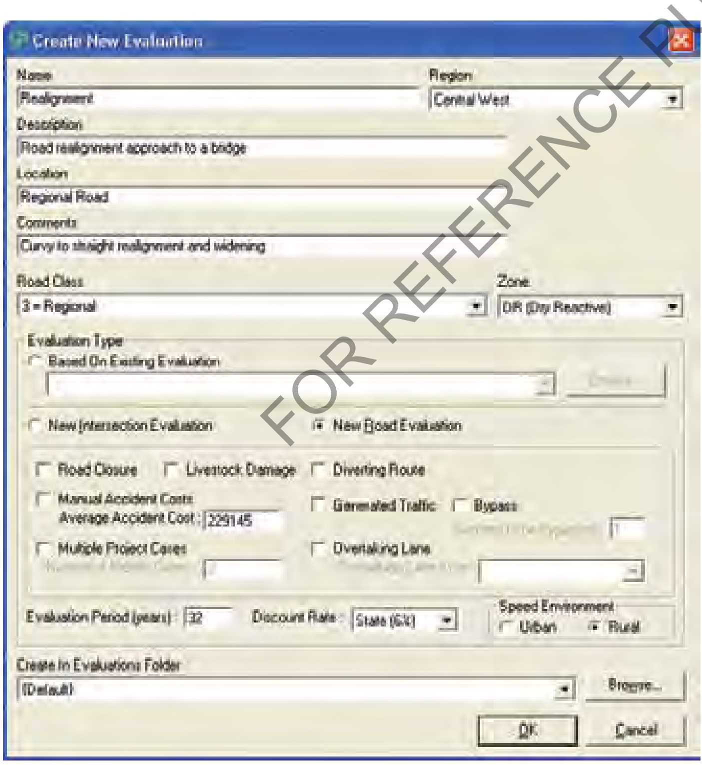
### 5.3.1 Realignment case study

A regional road is curvy and only provides safe operating speeds of up to 80 kilometres per hour. The aim of this project is to straighten the alignment to allow for an increase in the posted speed limit. The new posted speed will be 100 kilometres per hour. Construction of this project will occur over two years and will reduce the road length from 2.5 kilometres to 2.3 kilometres.

### 5.3.2 Create new evaluation

To create a new evaluation, enter a road class of regional, a zone of dry reactive, an evaluation period of 32 years and a discount rate of 6% in the 'create new evaluation' screen. The boxes for advanced projects should not be ticked, see Figure 80.

*Figure 80: Realignment case study*





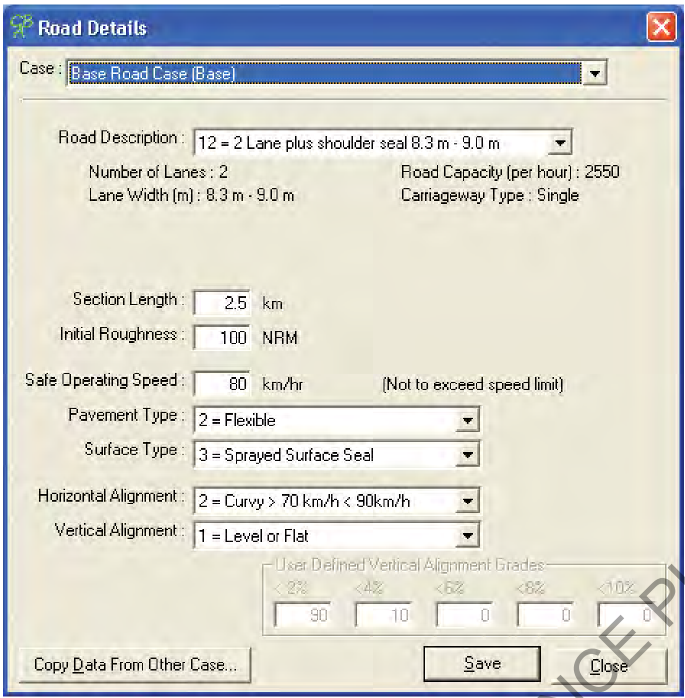

### 5.3.3 Road details

The 'road details' screens highlight the important difference between the base and project cases. In this example the horizontal alignment of the base case is specified as curvy while in the project case the new road design caters for speeds over 90 km/h. The project case horizontal alignment will be straight.

#### 5.3.3.1 Base case

The base case road details are shown in Figure 81. The current horizontal alignment in the base case is curvy (please refer to Section 4.3 of the *Technical Guide* for tyre wear curvature parameters for curvy and very curvy roads).

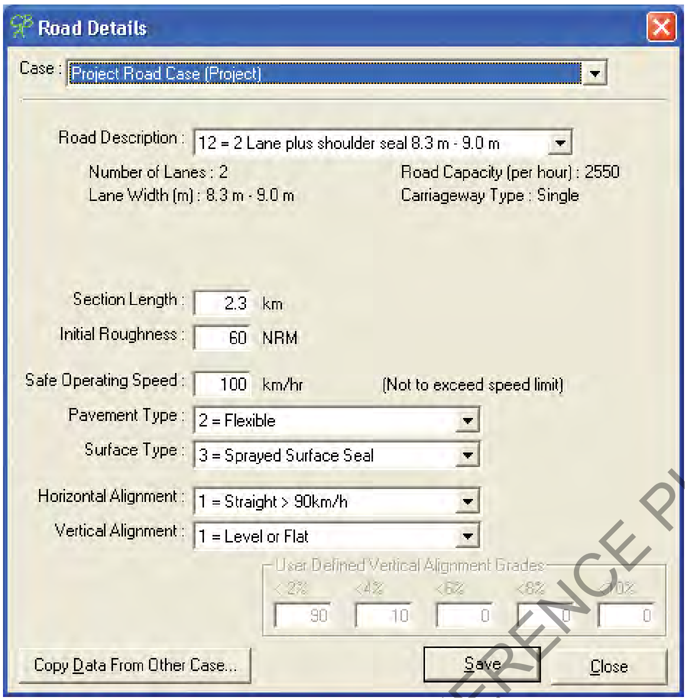
*Figure 81: Realignment base case*



#### 5.3.3.2 Project case

For the project case use the 'copy data from other case' button to transfer the data from main case. The following changes need to be made to the project case: Section length – as a result of the realignment the road has been shortened. The new section length is 2.3 km. The input with the largest influence on the benefits for this case study is the horizontal alignment. The project case will improve the road from curvy to straight. Figure 82 shows the road details for the realigned project case.

*Figure 82: Realignment project case*






### 5.3.4 Road traffic data

The road traffic data is the same for the base case and the project case. The AADT is 5000 in Year 1; the growth rate is 4% and compound. Traffic breakdown is 85% private cars, 5% commercial cars, 4% non-articulated, 2% buses, 2% articulated, 2% B-doubles, 0% road train type 1 and 0% road train type 2.

### 5.3.5 Capital and maintenance costs

The proposed project will have a construction timeframe of two years. Construction will occur in Year 2 with detailed design and minor works to be undertaken in Year 1. The maintenance strategy will also differ between the base and project cases.

#### 5.3.5.1 Base case

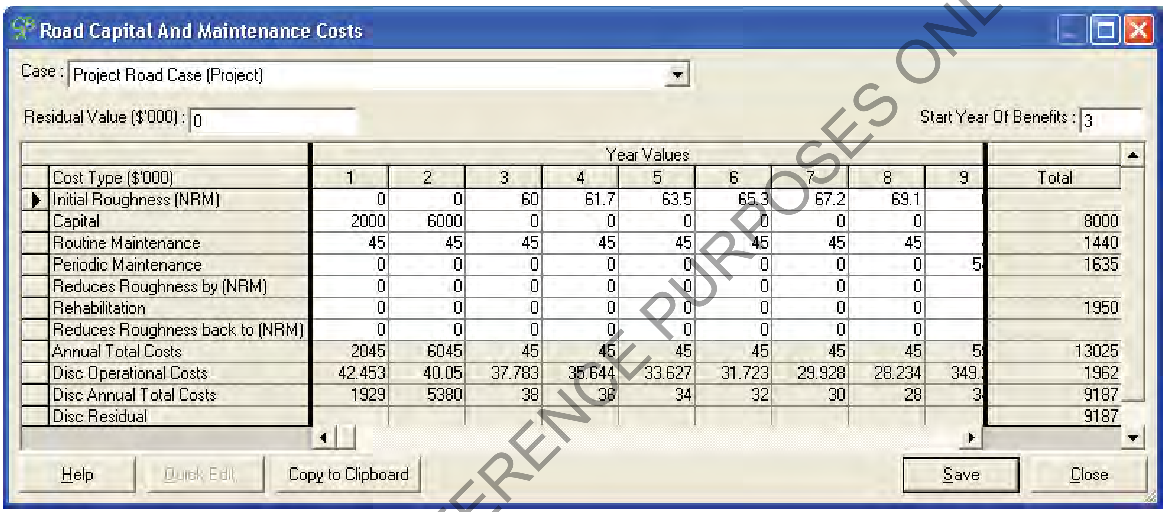
Routine maintenance – enter $50 000 each year. Use the 'quick edit' button to populate the routine maintenance fields for the entire evaluation period. Periodic maintenance – enter $550 000 in Years 7, 21 and 28 in the 'periodic maintenance' row. Enter a reduction in roughness by 5 NRM in adjoining years. Rehabilitation – the current maintenance strategy for the road involves reconstruction costs of $2 million in Year 14. The roughness of the road will be reduced back to 50 NRM. Once all the maintenance data has been entered into CBA6 click 'save' and begin the same procedure for the project case.

### 5.3.5.2 Project case

For the project case enter the following:

Capital – the total cost for the project is $8 million. In Year 1 the costs will be $2 million with the remainder spent in Year 2. Routine maintenance – assume routine maintenance will be lower in the project case given there is less road to maintain. Routine maintenance will be $45 000 per annum. Periodic maintenance – $545 000 in Years 9, 23 and 30 with corresponding roughness reduction of 5 NRM. Rehabilitation – enter $1.95 million in Year 16 of the 'rehabilitation' row. Enter a new roughness of 50 NRM in the 'reduces roughness to (NRM)' row to correspond with the rehabilitation costs. Start year of benefits – the start year of benefits will be in Year 3. Residual value – this evaluation does not have a residual value. Once all the maintenance data has been entered in CBA6 click 'save'. Use the 'copy to clipboard' button to graph the maintenance and roughness deterioration profile in a spreadsheet. This is useful when comparing the base and project cases. Figure 83 shows the capital and maintenance costs for the realignment project case.

*Figure 83: Realignment costs*


Road Capital And Maintenance Costs

Case : Project Road Case (Project)

Residual Value ($'000) : 0 | Start Year Of Benefits : 3

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 0 | 60 | 61.7 | 63.5 | 65.3 | 67.2 | 69.1 | | |
| Capital | 2000 | 6000 | 0 | 0 | 0 | 0 | 0 | 0 | | 8000 |
| Routine Maintenance | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | | 1440 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1635 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1950 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 2045 | 6045 | 45 | 45 | 45 | 45 | 45 | 45 | 5 | 13025 |
| Disc Operational Costs | 42.453 | 40.05 | 37.783 | 35.644 | 33.627 | 31.723 | 29.928 | 28.234 | 349. | 1962 |
| Disc Annual Total Costs | 1929 | 5380 | 38 | 36 | 34 | 32 | 30 | 28 | 3 | 9187 |
| Disc Residual | | | | | | | | | | 9187 |

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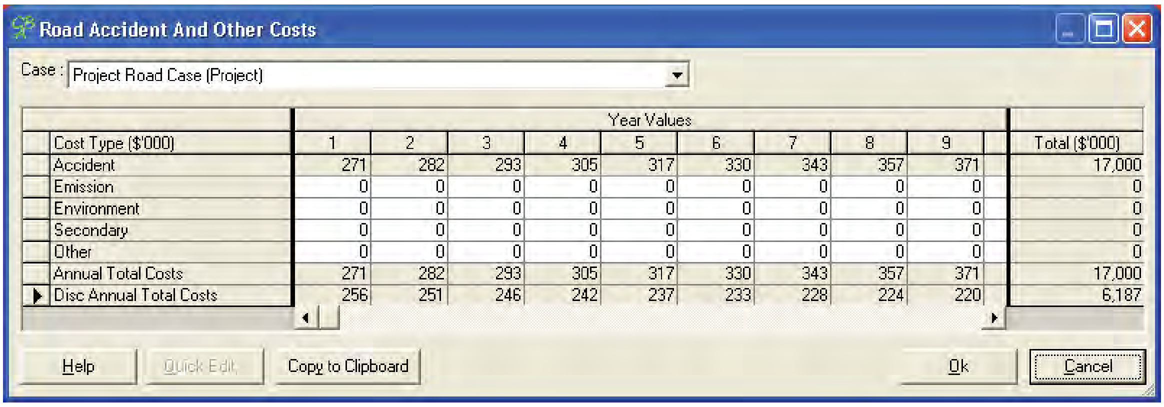
## 5.3.6 Accident and other costs

After the maintenance section of the evaluation is complete, the 'accident and other costs' box will be ticked automatically. The reduction in road length has provided savings in accident costs. Accident costs in the first year of the base case are estimated at $295 000 while the project case accident costs are only $271 000, see Figure 84.

*Figure 84: Realignment accident costs*


Road Accident And Other Costs

Case : Project Road Case (Project)

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
| Accident | 271 | 282 | 293 | 305 | 317 | 330 | 343 | 357 | 371 | 17,000 |
| Emission | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Environment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Secondary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual Total Costs | 271 | 282 | 293 | 305 | 317 | 330 | 343 | 357 | 371 | 17,000 |
| Disc Annual Total Costs | 256 | 251 | 246 | 242 | 237 | 233 | 228 | 224 | 220 | 6,187 |

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### 5.3.7 Results and decision criteria

In this example, the intention of the proposed project is to realign a poorly designed section of road. The new road will provide a safer, higher speed environment for road users. The project has a discounted cost of $6.9 million at the 6 % discount rate, see Figure 85. There are some minor savings in maintenance costs due to the delay in periodic maintenance costs. The majority of project benefits comprise savings in VOC for road users. As expected the realignment provides a new route that reduces fuel consumption and improves vehicle performance. The NPV for the project is over $12.6 million at the discount rate of 6%. The BCR for this realignment project is 2.82 at a discount rate of 6% suggesting that this initiative is economically viable.

*Figure 85: Realignment CBA results*

Results - Decision Criteria Recalc No 6

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 7,196,556 | 6,964,350 | 6,856,396 | 6,752,659 | 6,555,475 |
| Discounted Capital Costs | 7,470,414 | 7,226,771 | 7,109,791 | 6,995,885 | 6,776,860 |
| Discounted Other Costs | -273,859 | -262,421 | -253,396 | -243,225 | -221,384 |
| Discounted Benefits | 26,901,235 | 19,662,026 | 17,013,618 | 14,833,890 | 11,517,742 |
| Private TTC Savings | 5,755,645 | 4,293,204 | 3,750,416 | 3,299,524 | 2,604,374 |
| Commercial TTC Savings | 3,048,564 | 2,259,988 | 1,968,218 | 1,726,359 | 1,354,675 |
| Private VOC Savings | 11,668,930 | 8,438,145 | 7,264,435 | 6,302,847 | 4,849,660 |
| Commercial VOC Savings | 5,748,015 | 4,176,745 | 3,604,456 | 3,134,773 | 2,423,080 |
| Discounted Accident Savings | 680,080 | 493,944 | 426,093 | 370,387 | 285,952 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 19,704,679 | 12,697,676 | 10,157,222 | 8,081,230 | 4,962,267 |
| Net Present Value per dollar Investment | 2.64 | 1.76 | 1.43 | 1.16 | 0.73 |
| Benefit Cost Ratio Excl. Private Time | 2.94 | 2.21 | 1.93 | 1.71 | 1.36 |
| Benefit Cost Ratio | 3.74 | 2.82 | 2.48 | 2.20 | 1.76 |
| First Year Rate of Return | 12.11% | 11.83% | 11.69% | 11.55% | 11.29% |

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## 5.4 Overtaking lane

Overtaking lanes are usually built where the terrain and geometry of a road causes slow vehicles to impede the general flow of traffic. Overtaking lanes can range in length from several hundred metres to several kilometres. Figure 86 shows a side-by-side overtaking lane.

*Figure 86: Overtaking lane*



The evaluation of overtaking lane projects differs from other projects as special methods apply to the calculation of benefits.

1. Capacity is improved along the length of the overtaking lane. Increased capacity at a given AADT allows higher speeds (reduced travel time) and a lower accident risk. The construction of the overtaking lane reduces the accident rate at this site by 25%.

2. The provision of a passing lane has a 'downstream' effect on traffic. Overtaking lanes cause a dispersion of the traffic platoons that accumulate behind slow vehicles. Depending on the distance between overtaking lanes and their length, they have the effect of increasing the capacity of the road section immediately following the end of the passing lanes. Because the slow vehicles are now at the end of the platoon, other vehicles can travel more quickly along this downstream section. These vehicles experience user cost reductions along the downstream section, and the risk of accidents is further reduced as the need for overtaking is reduced.

3. The upstream road section or the road section leading up to the overtaking lane will experience a reduction in the accident rate of 2.5%. The assumption is that road users will be aware of the overtaking lane ahead and will delay overtaking.

CBA6 contains default factors for the estimation of downstream benefits:

- length of downstream area: 5 km
- capacity increase in downstream area: 20%
- accident reduction in downstream area: 2.5%
- length of upstream area: 3 km
- accident reduction in the upstream area: 2.5%.

System users are able to change the default capacity increase in the downstream area if there is sufficient site-specific data to support this change, see Section 2.6.3.

For more information on the calculation of overtaking lane benefits see Section 2.4.5 of the *Theoretical Guide* and Section 8.4 of the *Technical Guide*.

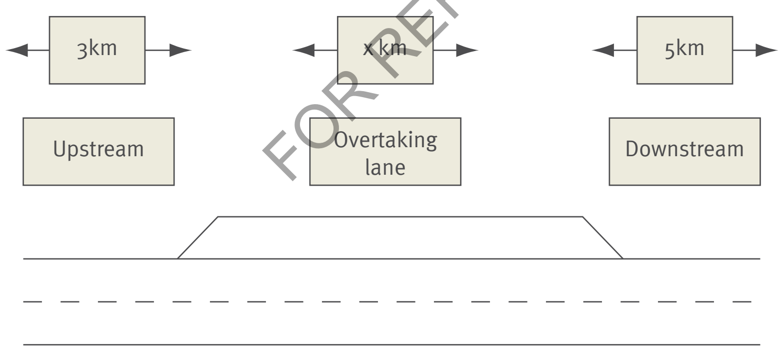
CBA6 has three overtaking modules: single, head-to-head and side-by-side. The remainder of Section 5.4 will provide case studies for each type of overtaking lane.

## 5.4.1 Single overtaking lane

A single overtaking lane currently provides for overtaking in one direction only. The single overtaking lane directs slow moving traffic to the left-hand lane, while faster vehicles overtake via the right-hand lane. For a single overtaking lane, there is only one upstream and downstream area.

Note: Sections 5.4.2 and 5.4.3 give examples of two adjoining overtaking lanes which provide overtaking opportunities in both directions.

*Figure 87: Single overtaking lane*






### 5.4.1.1 Single overtaking lane case study

A TMR example is used as a basis for this case study. TMR's Northern Region has proposed a 2 km overtaking lane be built on the Bruce Highway between Emmett Creek and Mackenzie Creek. The project's main objective is to improve travel times and safety on this section of the Bruce Highway.

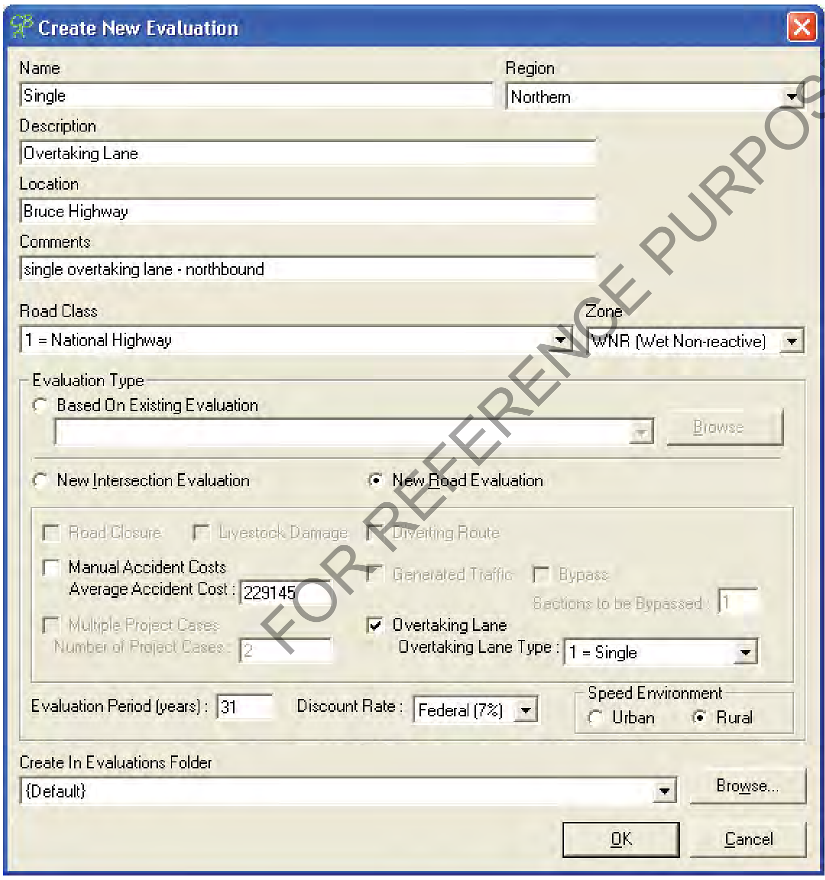
The base case is defined as the existing 2 km section consisting of a two-lane undivided seal of MRS 12. Traffic levels on this part of the highway remain reasonably stable at around 4545 AADT and grow at around 2% per annum. The base case includes routine maintenance costs on the existing two-lane highway for the life of the project evaluation period, and some periodic maintenance in Year 7 with subsequent spending every five years.

The project case will involve the construction of a single overtaking lane in the northbound direction of the highway. The timing of maintenance activity in the project case will be the same as the base case, but maintenance costs will be around 50% higher.

#### 5.4.1.2 Create new evaluation

Create a new evaluation as shown in Section 3.1 and previous case studies. For an overtaking lane project, tick the ‘overtaking lane’ box from the list of advanced modules. Select option 1 (1=single) from the overtaking lane drop-down menu, see Figure 88.

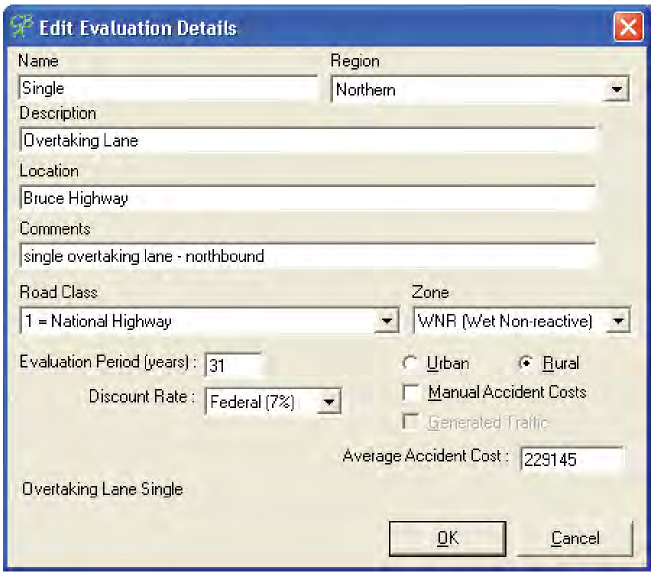
*Figure 88: Create new single overtaking lane evaluation*






Note: The ‘edit evalaution’ screen for a single overtaking lane is shown in Figure 89. The overtaking lane type is shown in the bottom left-hand corner.

*Figure 89: Single overtaking lane edit evaluation screen*

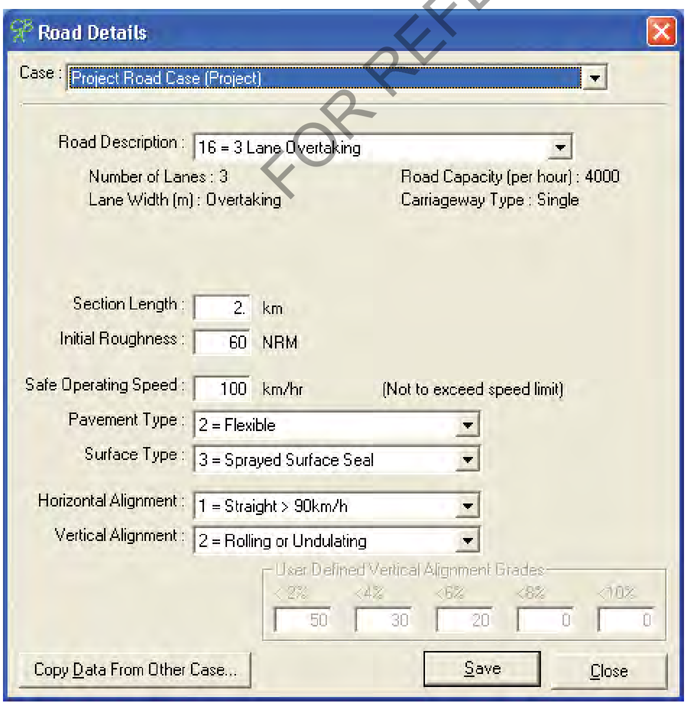



### 5.4.1.3 Road details

The 'road details' screen for an overtaking lane is similar to previous case studies. For the base case the section length is 2 km, initial roughness 80 NRM, speed 100 km/h, pavement type is flexible and there is a sprayed surface seal. In the base case the horizontal alignment is straight and there is a rolling vertical alignment. The project case details are shown in Figure 90.

Note: The only available option for the project case road description is MRS 16: 3 lane overtaking.

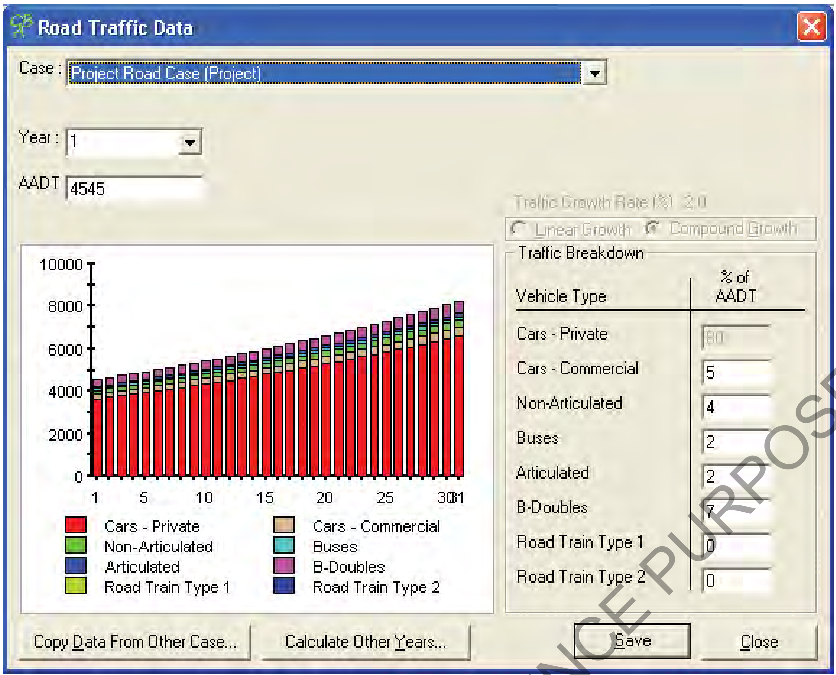
*Figure 90: Single overtaking lane project*



#### 5.4.1.4 Road traffic data

The road traffic data is the same for the base case and the project case, see Figure 91. The AADT is 4545 in Year 1; the growth rate is 2% compound per annum. Traffic breakdown is 80% private cars, 5% commercial cars, 4% non-articulated, 2% buses, 2% articulated, 7% B-doubles, 0% road train type 1 and 0% road train type 2.

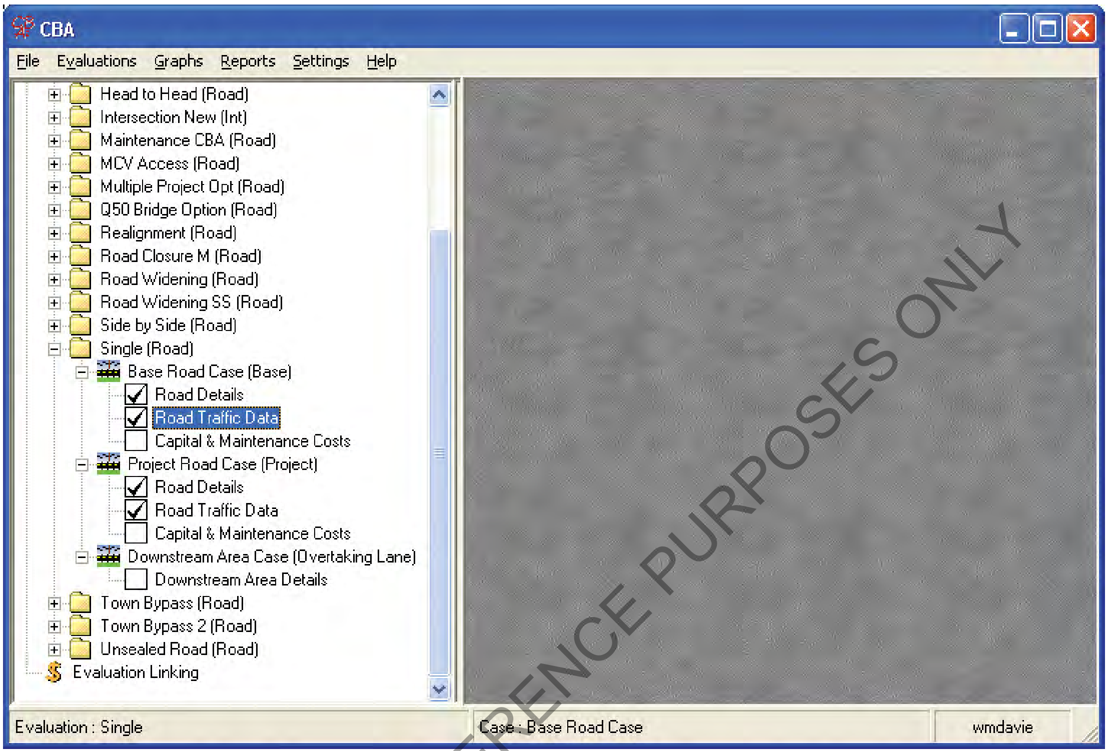
*Figure 91: Single overtaking lane traffic data*



### 5.4.1.5 Downstream area

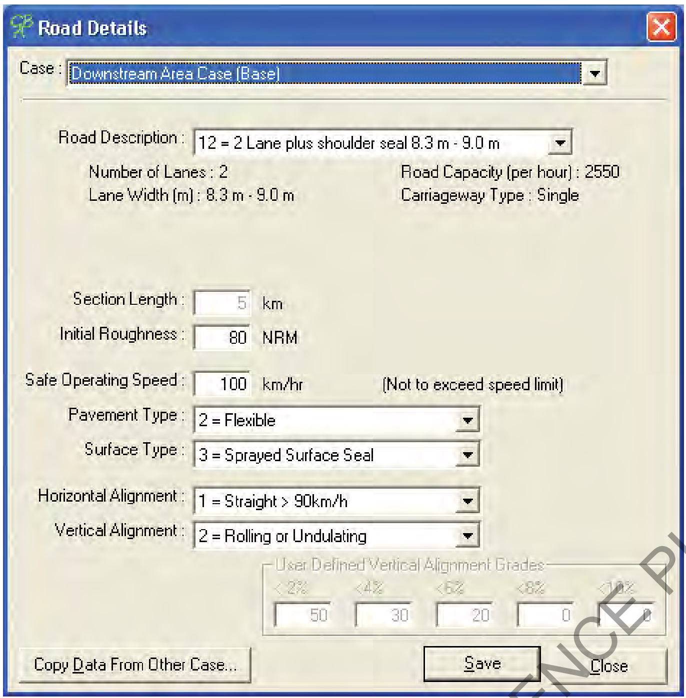
After the road traffic data has been entered for the base and project cases, a new drop-down option will appear for the 'downstream area case', see Figure 91. The downstream area in CBA6 refers to the area immediately after the overtaking lane, see Figure 92.

*Figure 92: Single overtaking lane downstream area workspace*



The downstream area case defines the road details for the highway immediately after the overtaking lane ends. System users will note that the section length has been defaulted to 5 km, see Figure 93. In this example the downstream area is assumed to have the same properties as the base case, however the downstream area has increased capacity of 20% over the base case road configuration. See Section 8.4.1 of the *Technical Guide* for further details on capacity increase. Use the 'copy data from other case' button to transfer the base case road details to the downstream area.

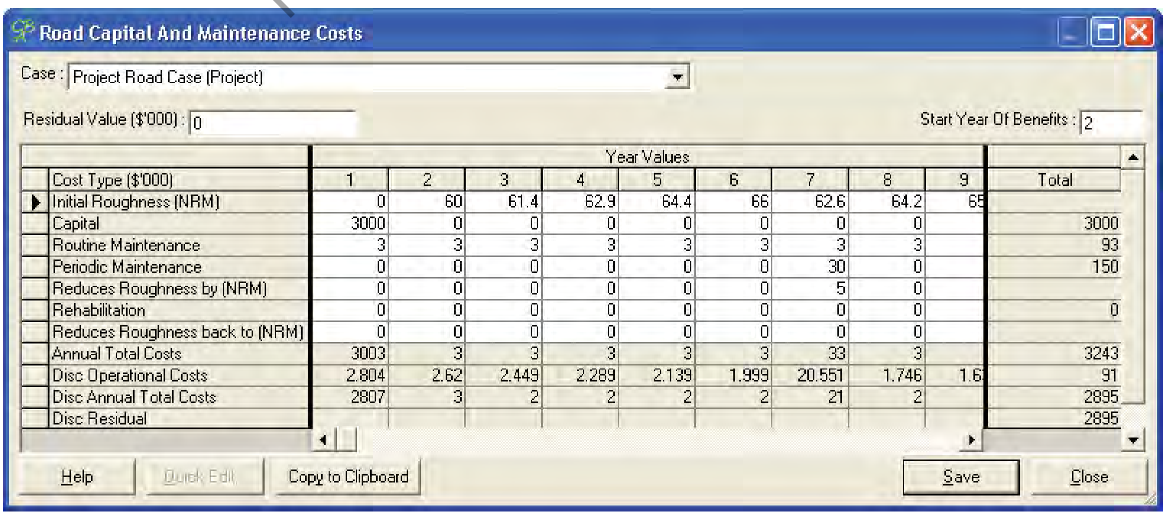
*Figure 93: Downstream area for single overtaking lane*




### 5.4.1.6 Capital and maintenance costs

Costs for the base and project cases can be found in Appendix A. As shown in Figure 94, the capital costs are $3 million in Year 1.

*Figure 94: Single overtaking lane costs*



Road Capital And Maintenance Costs

Case : Project Road Case (Project)

Residual Value ($'000) : 0

Start Year Of Benefits : 2

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 60 | 61.4 | 62.9 | 64.4 | 66 | 62.6 | 64.2 | 65 | |
| Capital | 3000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 3000 |
| Routine Maintenance | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | 93 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | | 150 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 3003 | 3 | 3 | 3 | 3 | 3 | 33 | 3 | | 3243 |
| Disc Operational Costs | 2.804 | 2.62 | 2.449 | 2.289 | 2.139 | 1.999 | 20.551 | 1.746 | 1.6 | 91 |
| Disc Annual Total Costs | 2807 | 3 | 2 | 2 | 2 | 2 | 21 | 2 | | 2895 |
| Disc Residual | | | | | | | | | | 2895 |

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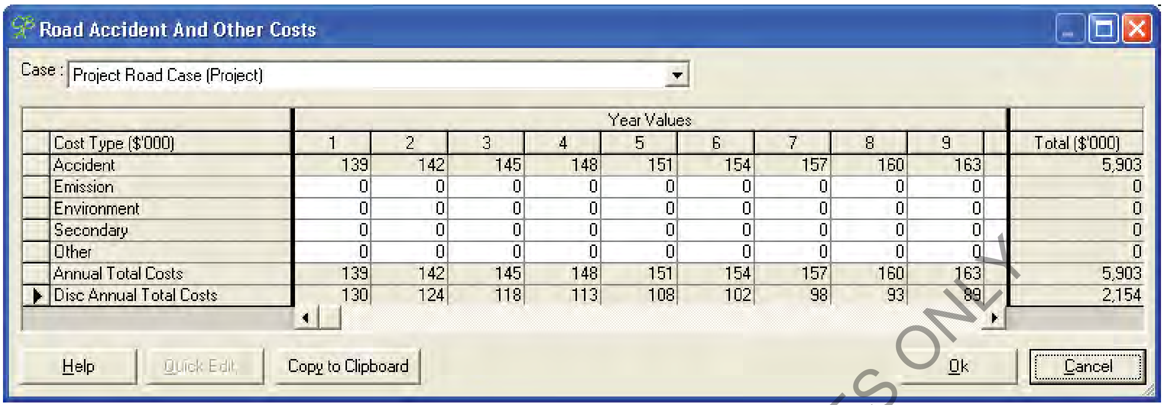
### 5.4.1.7 Accident and other costs

The provision of overtaking lanes provides a number of safety benefits. CBA6 assumes that there will be a 25% reduction in the frequency of accidents on the overtaking lane section.

*Figure 95: Single overtaking lane accident costs*




| Cost Type ($'000) | Year Values 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
|---|---|---|---|---|---|---|---|---|---|---|
| Accident | 139 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 5,903 |
| Emission | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Environment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Secondary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual Total Costs | 139 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 5,903 |
| Disc Annual Total Costs | 130 | 124 | 118 | 113 | 108 | 102 | 98 | 93 | 89 | 2,154 |

### 5.4.1.8 Results and decision criteria

The project has a total discounted cost of $2.8 million at the 7% discount rate. There are some minor increases in maintenance costs to cater for the overtaking lane. The majority of project benefits are savings in TTC and accident costs. As expected, the overtaking lane saved motorists over $1.3 million in TTC and $500 000 in accident costs. This satisfies our objective to provide a safer road for vehicles to pass slower traffic. System users should note that private VOC benefits are negative at some discount rates. This is due to the increase in operating speed that is achieved from the increased capacity of the overtaking lane which subsequently increases fuel consumption. The impact of roughness on VOC benefits in later years is further reduced with higher discount rates. See Section 4.1 of the *Technical Guide* for further information on fuel consumption.

The NPV for this project is over $600 000 at the discount rate of 7%. The BCR for the single overtaking lane is 1.21 at the discount rate of 7%.

*Figure 96: Single overtaking lane results*

Results - Decision Criteria Recalc No 2

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 2,928,870 | 2,864,300 | 2,833,970 | 2,804,728 | 2,749,039 |
| Discounted Capital Costs | 2,884,615 | 2,830,189 | 2,803,738 | 2,777,778 | 2,727,273 |
| Discounted Other Costs | 44,255 | 34,112 | 30,232 | 26,950 | 21,767 |
| Discounted Benefits | 5,476,662 | 3,983,516 | 3,439,232 | 2,992,614 | 2,316,658 |
| Private TTC Savings | 2,184,866 | 1,598,959 | 1,384,692 | 1,208,493 | 940,951 |
| Commercial TTC Savings | 678,733 | 467,240 | 392,290 | 331,960 | 243,281 |
| Private VOC Savings | 91,830 | 34,356 | 15,555 | 1,329 | -17,435 |
| Commercial VOC Savings | 897,200 | 647,611 | 556,933 | 482,691 | 370,706 |
| Discounted Accident Savings | 1,624,033 | 1,235,351 | 1,089,763 | 968,141 | 779,154 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 2,547,791 | 1,119,216 | 605,262 | 187,886 | -432,381 |
| Net Present Value per dollar Investment | 0.88 | 0.40 | 0.22 | 0.07 | -0.16 |
| Benefit Cost Ratio Excl. Private Time | 1.12 | 0.83 | 0.72 | 0.64 | 0.50 |
| Benefit Cost Ratio | 1.87 | 1.39 | 1.21 | 1.07 | 0.84 |
| First Year Rate of Return | 5.50% | 5.39% | 5.34% | 5.29% | 5.20% |

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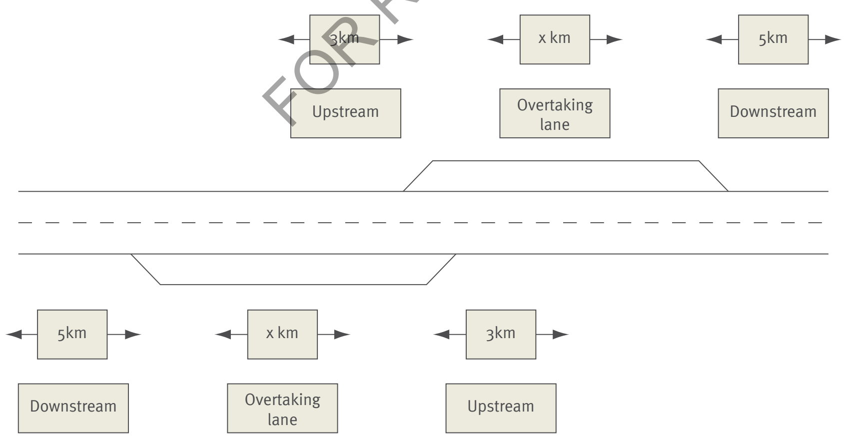
## 5.4.2 Head-to-head overtaking lane

A head-to-head overtaking lane configuration provides a passing lane in each direction. The passing lanes will be located so that they are not adjacent to each other. While the single overtaking lane caters for traffic in one direction, the head-to-head overtaking lane will provide passing opportunities on both sides of the road, see Figure 97.

*Figure 97: head-to-head overtaking lane scaled*



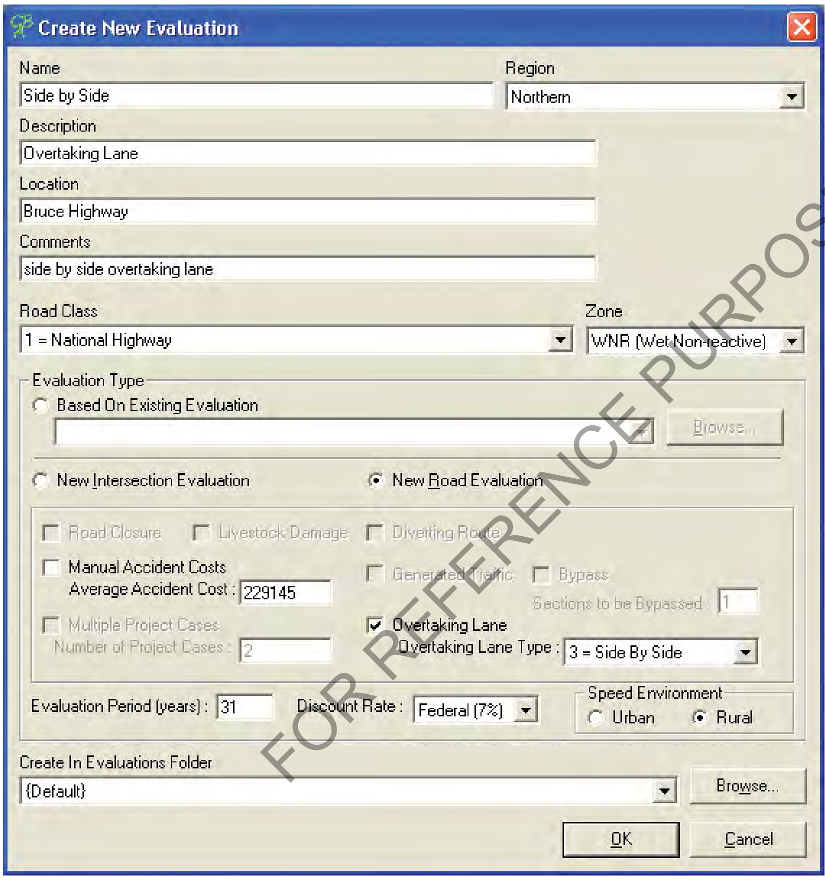
#### 5.4.2.1 Head-to-head overtaking lane case study

This case study will build on the case study from Section 5.4.1.1. Assume that the region is proposing two separate overtaking lanes, one in each direction, on the Bruce Highway between Emmett Creek and Mackenzie Creek. The proposed upgrade of the site incorporates a total area of 4 km. All other data will remain the same (see Appendix A for further data inputs).

5.4.2.1.1. Create new evaluation

For an overtaking lane project, tick the 'overtaking lane' box from the list of advanced modules. From the overtaking lane drop-down menu select option 2 head-to-head, see Figure 98.

*Figure 98: Head-to-head evaluation*






Note: The 'edit evaluation' screen for the head-to-head overtaking lane is shown in Figure 99. The overtaking lane type is shown in the bottom left hand corner.

*Figure 99: Head-to-head overtaking lane edit evaluation screen*

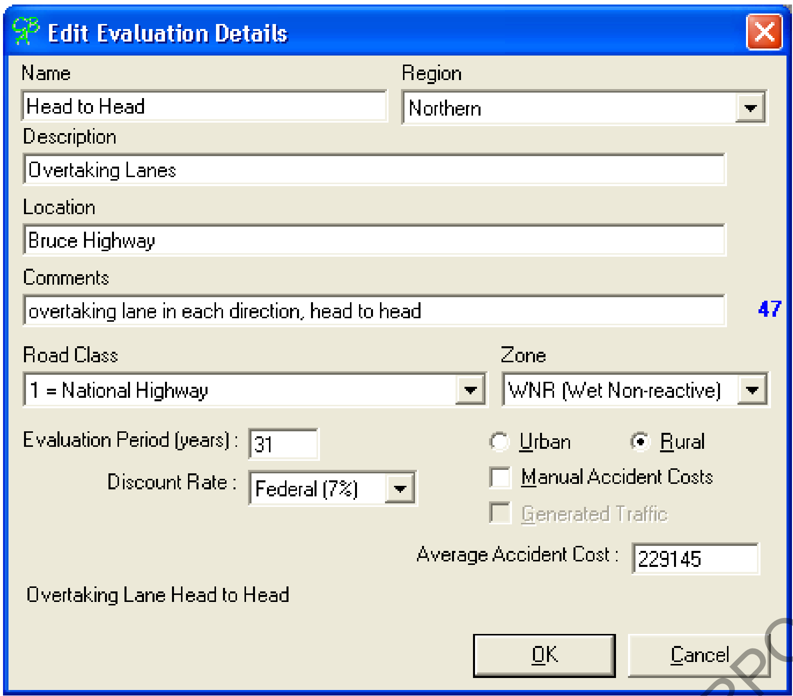
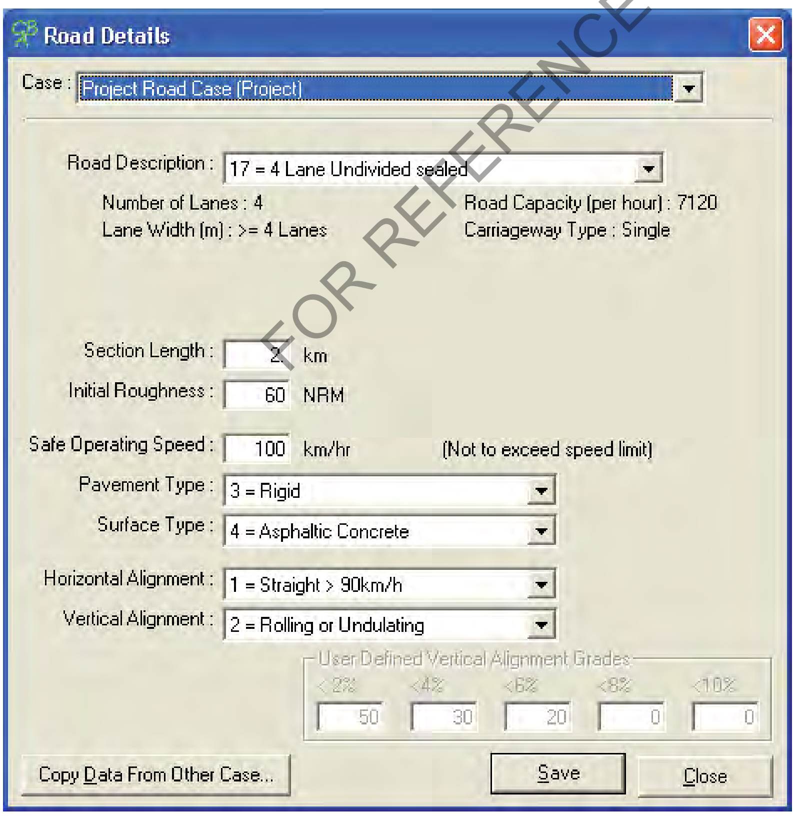


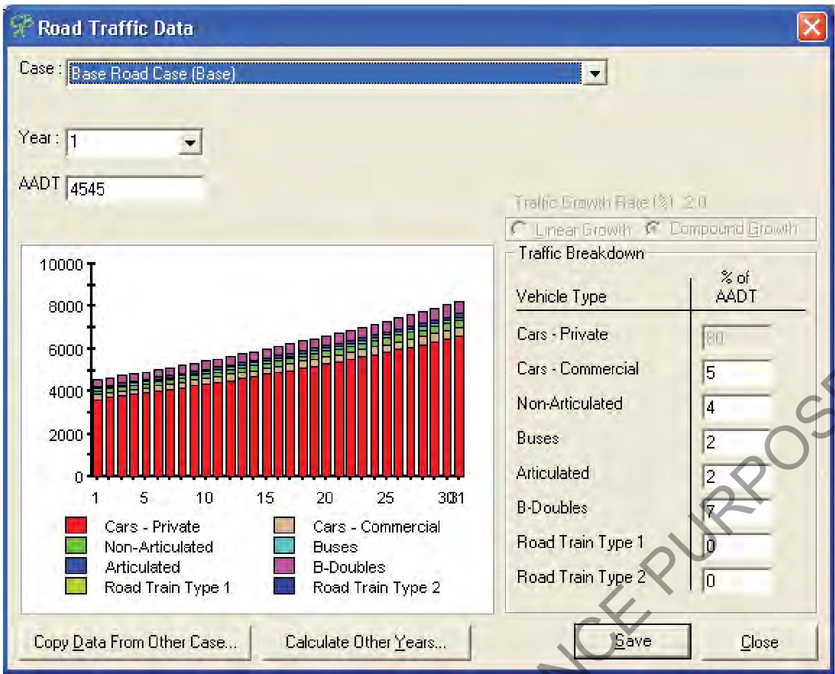

*Figure 100: Head-to-head road details*



### 5.4.2.2 Road details

The 'road details' screen for a head-to-head overtaking lane remains similar to previous case studies. The section length needs to be altered to 4 km, see Figure 100. The project case MRS will be 16, as pavement improvement works will be undertaken together with the construction of the overtaking lanes. Initial roughness in the project case will be 60 NRM.

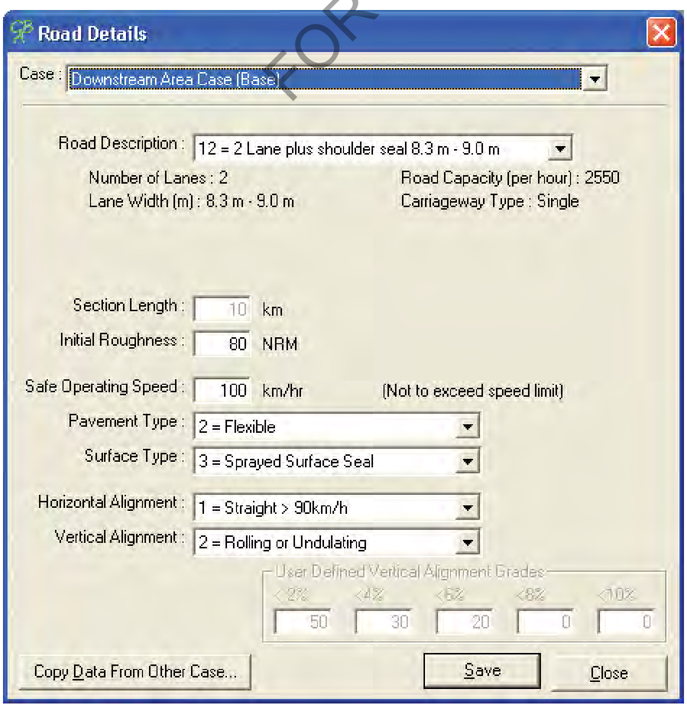
*Figure 101: Head to head traffic data*




### 5.4.2.3 Road traffic data

Road traffic data inputs are the same for the base case and the project case. The AADT is 4545 in Year 1; the growth rate is 2% and compound, see Figure 101.

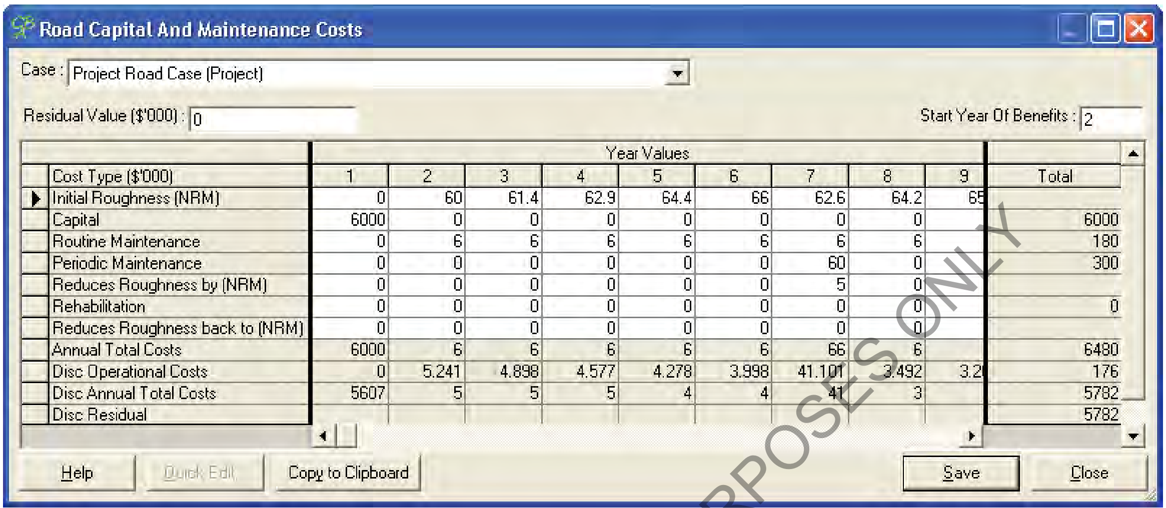
*Figure 102: Head-to-head downstream area*



### 5.4.2.4 Downstream area

The downstream area case defines the road details for the highway immediately after the overtaking lane ends. The section length has now been defaulted to 10 km as there are effectively two downstream areas (immediately following the northbound overtaking lane and immediately following the southbound overtaking lane), see Figure 102.

*Figure 103: Head-to-head overtaking lane costs*



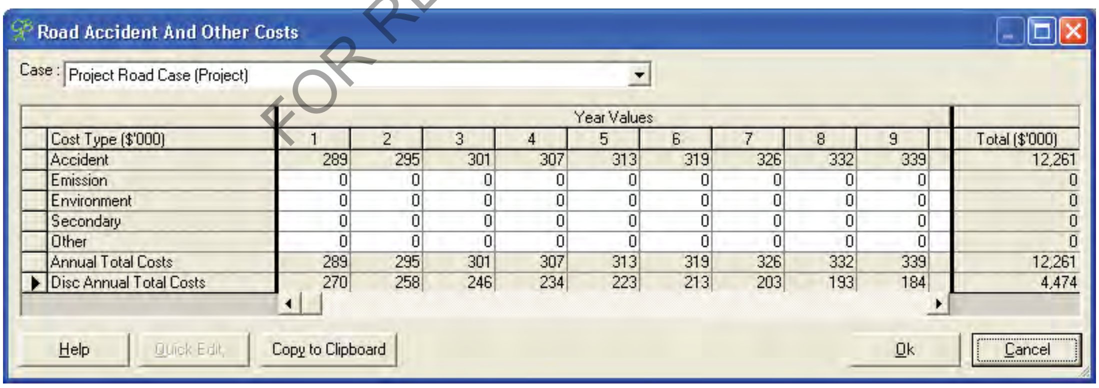

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 60 | 61.4 | 62.9 | 64.4 | 66 | 62.6 | 64.2 | 65 | |
| Capital | 6000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 6000 |
| Routine Maintenance | 0 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | | 180 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | | 300 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 6000 | 6 | 6 | 6 | 6 | 6 | 66 | 6 | | 6480 |
| Disc Operational Costs | 0 | 5.241 | 4.898 | 4.577 | 4.278 | 3.998 | 41.101 | 3.492 | 3.2 | 176 |
| Disc Annual Total Costs | 5607 | 5 | 5 | 5 | 4 | 4 | 41 | 3 | | 5782 |
| Disc Residual | | | | | | | | | | 5782 |



### 5.4.2.5 Capital and maintenance costs

Cost data for the base and project cases can be found in Appendix A. Project capital costs are now $6 million in Year 1 to allow for the construction of an additional overtaking lane in the southbound direction, see Figure 103.

*Figure 104: Head-to-head accident costs*




| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
| Accident | 289 | 295 | 301 | 307 | 313 | 319 | 326 | 332 | 339 | 12,261 |
| Emission | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Environment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Secondary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual Total Costs | 289 | 295 | 301 | 307 | 313 | 319 | 326 | 332 | 339 | 12,261 |
| Disc Annual Total Costs | 270 | 258 | 246 | 234 | 223 | 213 | 203 | 193 | 184 | 4,474 |

### 5.4.2.6 Accident and other costs

The head-to-head overtaking lane provides a significant reduction in accident frequency compared to the base case. Accident costs for the head-to-head overtaking lane are shown in Figure 103. See Section 8.4.2.2 of the *Technical Guide* for detailed information on head-to-head overtaking lane accident cost savings. It is useful to compare the accident cost savings of the head-to-head overtaking lane to the single overtaking lane shown in the previous case study (compare discounted accident cost savings of Figure 94 to Figure 104).

*Figure 105: Head-to-head overtaking lane results*

Results - Decision Criteria Recalc No 5

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 5,851,972 | 5,722,940 | 5,662,332 | 5,603,900 | 5,492,624 |
| Discounted Capital Costs | 5,769,231 | 5,660,377 | 5,607,477 | 5,555,556 | 5,454,545 |
| Discounted Other Costs | 82,741 | 62,563 | 54,856 | 48,344 | 38,079 |
| Discounted Benefits | 10,721,320 | 7,790,555 | 6,722,784 | 5,846,923 | 4,522,009 |
| Private TTC Savings | 4,369,731 | 3,197,917 | 2,769,383 | 2,416,986 | 1,881,902 |
| Commercial TTC Savings | 1,357,466 | 934,480 | 784,579 | 663,919 | 486,563 |
| Private VOC Savings | 183,661 | 68,712 | 31,110 | 2,658 | -34,869 |
| Commercial VOC Savings | 1,794,400 | 1,295,222 | 1,113,866 | 965,383 | 741,413 |
| Discounted Accident Savings | 3,016,061 | 2,294,223 | 2,023,846 | 1,797,977 | 1,447,001 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 4,869,348 | 2,067,614 | 1,060,452 | 243,023 | -970,615 |
| Net Present Value per dollar Investment | 0.84 | 0.37 | 0.19 | 0.04 | -0.18 |
| Benefit Cost Ratio Excl. Private Time | 1.09 | 0.80 | 0.70 | 0.61 | 0.48 |
| Benefit Cost Ratio | 1.83 | 1.36 | 1.19 | 1.04 | 0.82 |
| First Year Rate of Return | 5.32% | 5.22% | 5.17% | 5.12% | 5.03% |

Help | Copy to Clipboard | Close



### 5.4.2.7 Results and decision criteria

In this example the proposed head-to-head overtaking lane should provide a safe passing opportunity for road users travelling in both directions on the Bruce Highway. Results for the head-to-head overtaking lane are shown in Figure 105.

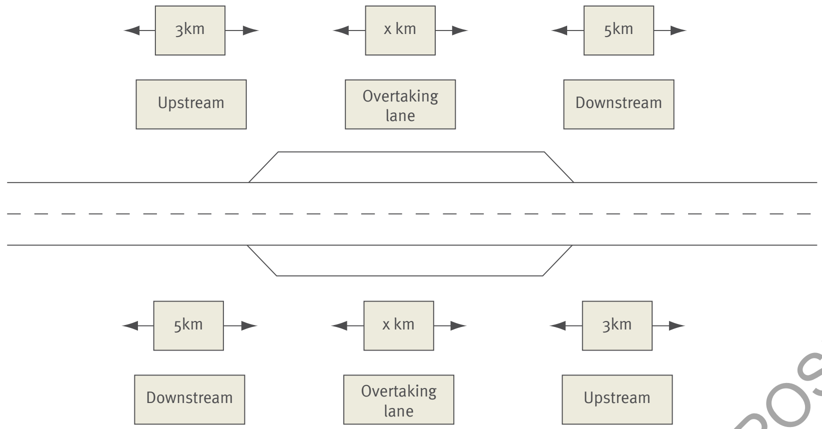
The project has a total discounted cost of $5.6 million at the 7% discount rate. There are some minor increases in maintenance costs to cater for two overtaking lanes. The majority of project benefits are achieved through TTC savings and accident cost savings. As expected, the two overtaking lanes saved motorists over $3.4 million in TTC and $2 million in accident costs. This satisfies our objective to provide a safer road for vehicles to pass slower traffic on the Bruce Highway.

The NPV for the project is over $1 million at a discount rate of 7%. This is a significant increase over the NPV achieved for the preceding single overtaking lane example. If the cost per overtaking lane is kept constant (i.e. $3 million), the head-to-head overtaking lane should have a higher NPV than a single overtaking lane due to the increase in overtaking opportunities in both directions accompanied by the increase in downstream benefits. If the incremental increase in cost for an additional overtaking lane is above that of a single overtaking lane, the additional overtaking lane may not be viable.

## 5.4.3 Side-by-side overtaking lane

An alternative overtaking lane design to those presented in the previous two case studies is the side-by-side overtaking lane. A side-by-side design provides a passing lane in each direction and locates the lanes adjacent to each other. A side-by-side overtaking lane is essentially a duplication of the two existing lanes. Although a side-by-side overtaking lane and a duplication are similar, there are key design differences for the purpose of conducting an evaluation using CBA6.

*Figure 106: Side-by-side overtaking lane*



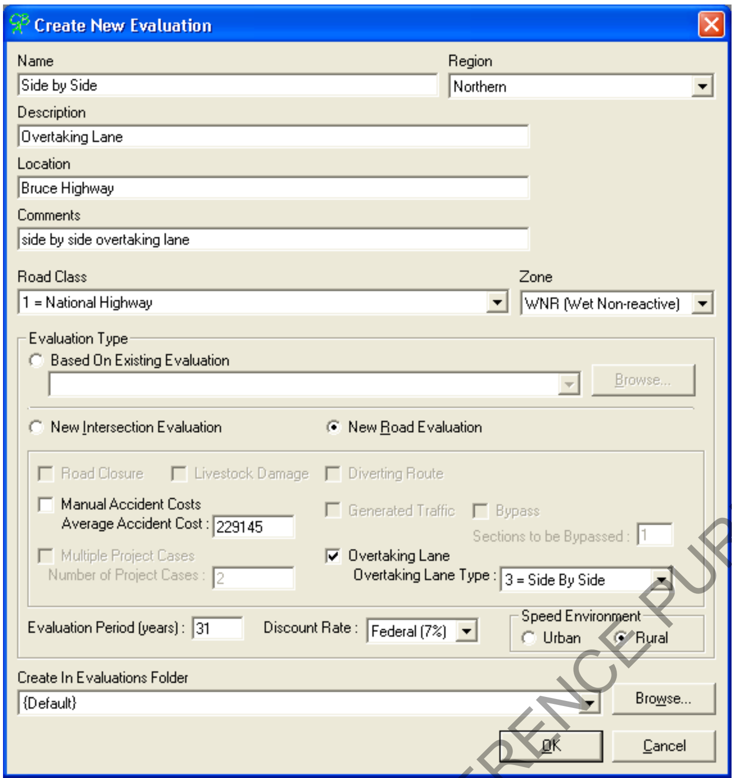

### 5.4.3.1 Side-by-side overtaking lane case study

This case study proposes a side-by-side overtaking lane as an alternative to the single overtaking lane from Section 5.4.1.1 or the head-to-head overtaking lane from Section 5.4.2.1. The project involves constructing a 2 km side-by-side overtaking lane on the Bruce Highway between Emmett Creek and Mackenzie Creek.

### 5.4.3.2 Create new evaluation

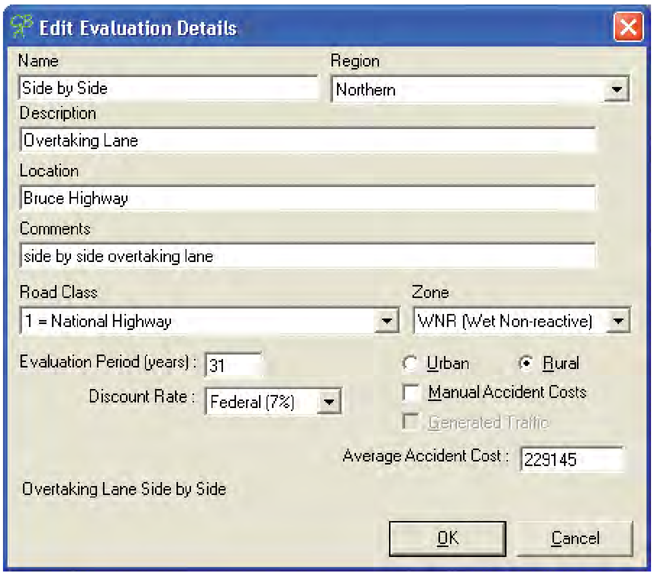
Create a new evaluation as per previous case studies. For an overtaking lane project tick the ‘overtaking lane’ box from the list of advanced modules. From the overtaking lane drop-down menu select option 3 side-by-side, see Figure 107.

*Figure 107: Side-by-side overtaking lane evaluation*




Note: The ‘edit evalaution’ screen for the side-by-side overtaking lane is shown in Figure 108. The overtaking lane type is shown in the bottom left hand corner.

Figure 108: Side-by-side overtaking lane edit evaluation screen

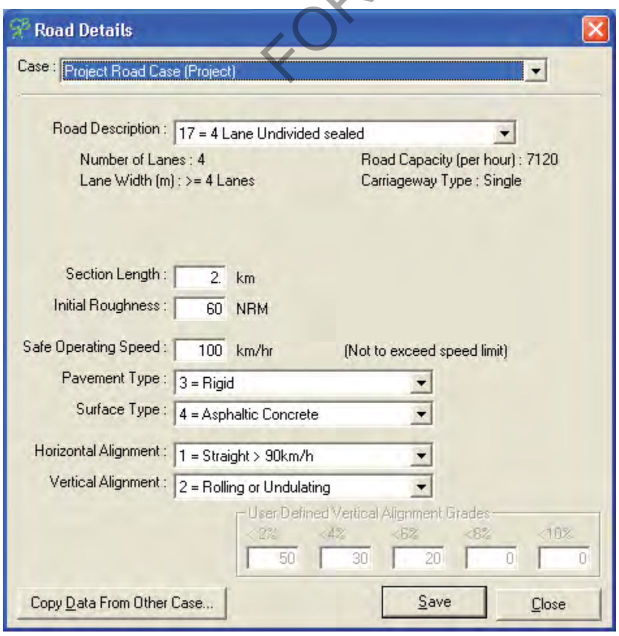



### 5.4.3.3 Road details

The road details screen for a side-by-side overtaking lane is similar to the previous case studies. However, the only available option for the project case road description is MRS 17, four-lane undivided seal, see Figure 109. The default pavement type and surface type for MRS 17 have been adopted. The system user should change these inputs whenever appropriate.

Note: For the side-by-side evaluation, the section length is specified at 2 km whereas the section length for the head-to-head overtaking lane was 4 km.

Figure 109: Side-by-side overtaking lane road details



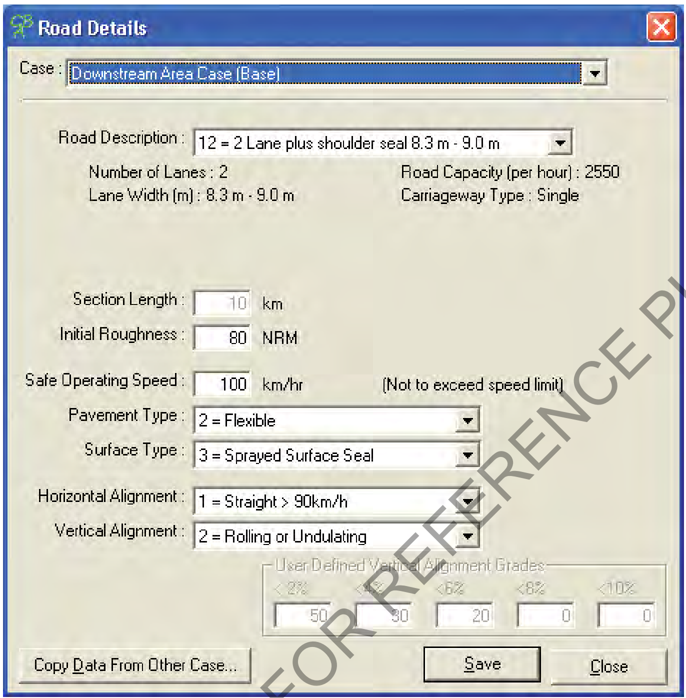
### 5.4.3.4 Road traffic data

The road traffic data inputs are the same for the base case and the project case. The AADT is 4545 in Year 1; the growth rate is 2% and compound. This is the same input data as the previous overtaking lane case studies, see Figure 101.

### 5.4.3.5 Downstream area

After the road traffic data has been entered for the base case and project case, a new drop-down option will appear for the 'downstream area case'. System users will note that the section length has now been defaulted to 10 km to account for two downstream areas. Use the 'copy data from other case' button to transfer the base case road details to the downstream area. Before doing this, system users should check input data. For simplicity, the downstream area in both directions is assumed to have the same road characteristics, see Figure 110.

*Figure 110: Head to head downstream area*






### 5.4.3.6 Capital and maintenance costs

Cost data for the base and project cases can be found in Appendix A. Project capital costs are now $5.5 million in Year 1 to take into account costs on the side-by-side overtaking lanes. As the two overtaking lanes will be co-located, it will be assumed that costs will be lower compared to the costs of a head-to-head project.

### 5.4.3.7 Accident and other costs

The side-by-side overtaking lane will provide a number of safety benefits. See Section 8.4.2.3 of the *Technical Guide* for further information on the reduction in accidents for side-by-side overtaking lanes.

### 5.4.3.8 Results and decision criteria

In this example a side-by-side overtaking lane is proposed as an alternative to a head-to-head overtaking lane. Figure 111 presents the CBA results of the side-by-side overtaking lane. The BCR for this overtaking lane option is 0.98 which implies that the side-by-side overtaking lanes are not viable.

*Figure 111: Side by side overtaking lane results*

Results - Decision Criteria Recalc No 6

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 5,371,202 | 5,251,242 | 5,195,043 | 5,140,937 | 5,038,079 |
| Discounted Capital Costs | 5,288,462 | 5,188,679 | 5,140,187 | 5,092,593 | 5,000,000 |
| Discounted Other Costs | 82,741 | 62,563 | 54,856 | 48,344 | 38,079 |
| Discounted Benefits | 8,036,747 | 5,888,963 | 5,102,570 | 4,455,397 | 3,471,669 |
| Private TTC Savings | 3,199,025 | 2,335,015 | 2,019,303 | 1,759,843 | 1,366,275 |
| Commercial TTC Savings | 1,108,677 | 794,275 | 680,577 | 587,785 | 448,490 |
| Private VOC Savings | 364,137 | 241,607 | 198,455 | 163,896 | 113,556 |
| Commercial VOC Savings | 1,276,866 | 929,758 | 803,110 | 699,120 | 541,578 |
| Discounted Accident Savings | 2,088,042 | 1,588,308 | 1,401,124 | 1,244,753 | 1,001,770 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 2,665,544 | 637,721 | -92,473 | -685,540 | -1,566,410 |
| Net Present Value per dollar Investment | 0.50 | 0.12 | -0.02 | -0.13 | -0.31 |
| Benefit Cost Ratio Excl. Private Time | 0.90 | 0.68 | 0.59 | 0.52 | 0.42 |
| Benefit Cost Ratio | 1.50 | 1.12 | 0.98 | 0.87 | 0.69 |
| First Year Rate of Return | 4.61% | 4.53% | 4.49% | 4.44% | 4.36% |

Help | Copy to Clipboard | Close

## 5.5 Road closure

The road closure module within CBA6 is relatively complex and requires the system user to collect a wide range of inputs before conducting a road project evaluation. System users will require detailed information on the project site and some understanding of traffic conditions in the immediate area of a project. CBA6 has two separate road closure modules: road closure (with diversion) and road closure. This manual uses the example of a flood immunity project to illustrate the module in CBA6. A road closure can be any type of closure.

### 5.5.1 Road closure (with diversion)

CBA6 can be used to evaluate flood improvement projects. Flood immunity projects require a detailed understanding of both the road network and road user behaviour. Road user responses to flooding can be quite variable depending on the frequency, severity and extent of flooding. Flood warning times and the availability of alternative routes will also affect the decisions made by road users. The following three options exist for road users affected by flooded roads:

- Wait – remain at the flood site for waters to subside.
- Divert – use an alternative route around the flood affected area.
- Do not travel – choose not to travel at all.

For all road closure projects CBA6 requires information and data on the average annual time of closure (AATOC) and the average duration of closure (ADC) for the base and project cases.

Before undertaking a flood immunity improvement project the system user should have sufficient knowledge of the following:

- flood area – frequency of flooding from historical evidence, at least 10 years
- travel demand – road users response to a closed road, number of vehicles that will wait, divert or choose not to travel
- diversion route – the road network and suitable alternative routes for road users
- network inundation – other affected roads.

Note: While this section highlights roads closed due to flooding, the same information and theory applies to other causes of road closures. These could include rock falls or land slippages.

#### 5.5.1.1 Flood immunity improvement case study

This case study involves a bridge that is consistently inundated.

Table 3 shows the flood history for the project site. Based on information from the last 20 years there have been five flooding events where the ADC was 56 hours. The subsequent AATOC for the road over the last 20 years is 14 hours.

*Table 3: Base case flooding history*

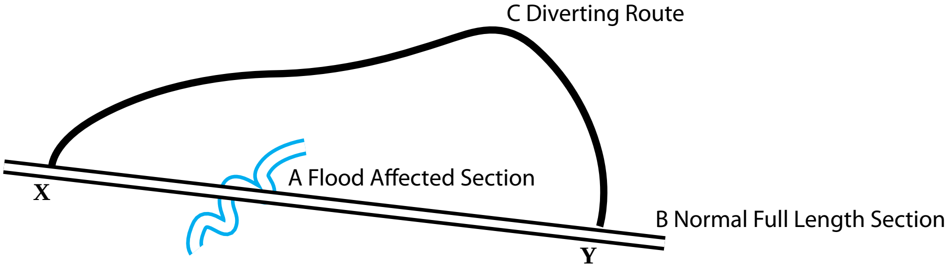
| **Base case flooding** | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Number of floods | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Total time closed (hours) | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | 0 | 0 | 48 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 80 | 0 |
| | | | | | | | | | | | | | | | | | | | AATOC | 14 |
| | | | | | | | | | | | | | | | | | | | ADC | 56 |

From Figure 111, road users that choose to divert during road closures must travel an additional 40 km along Section C compared with the normal length of the road from Section X to Section Y.

TMR now proposes a Q100 standard bridge be built on the project site. Section A from Figure 112 is the 1 km flood affected section to be upgraded. All other input data for this case study is shown in Appendix A.

The appropriate sequence of data entry into CBA6 for road closure evaluations has been outlined in Section 5.5.1.2.

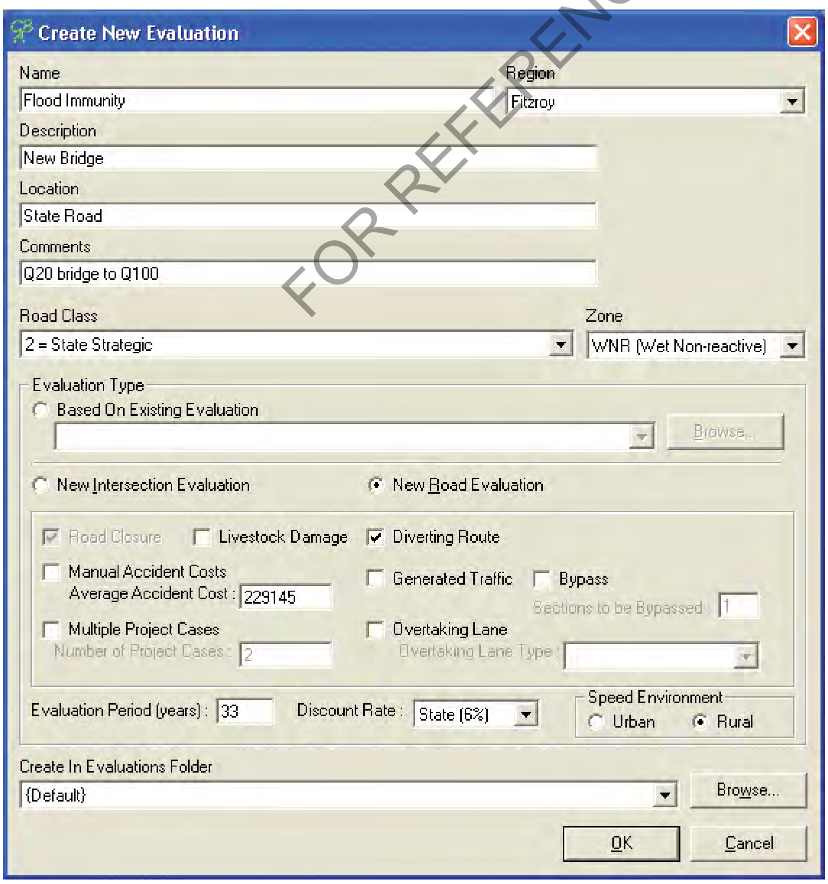
*Figure 112: Flood and diversion route*




### 5.5.1.2 Create new evaluation

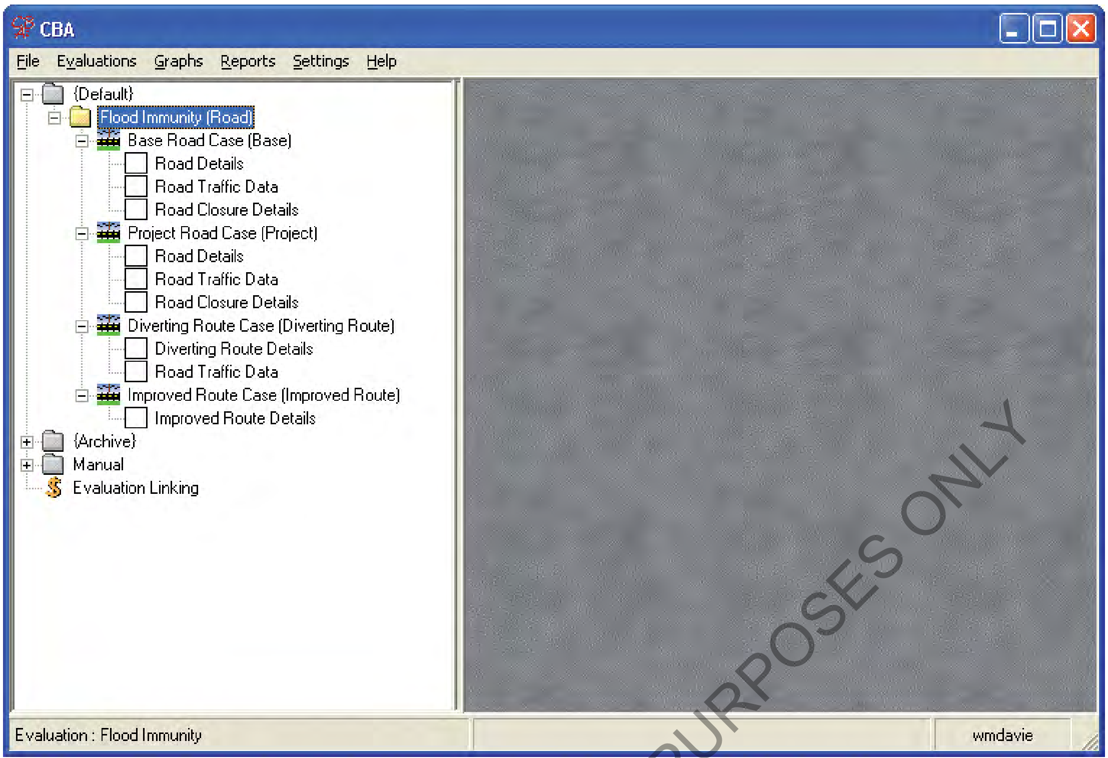
To create a flood immunity improvement project using CBA6, the system user must ensure the 'road closure' and 'diverting route' boxes are ticked, see Figure 113. Selecting the 'diverting route' box will automatically tick the 'road closure' option.

*Figure 113: Flood immunity new evaluation screen*



After the flood immunity improvement project has been initially created in CBA6, there are a number of new input fields the system user is required to complete. From Figure 114, the new inputs include road closure details, diverting route case and the improved route case (input of data in CBA6 should follow the sequence of sections below).

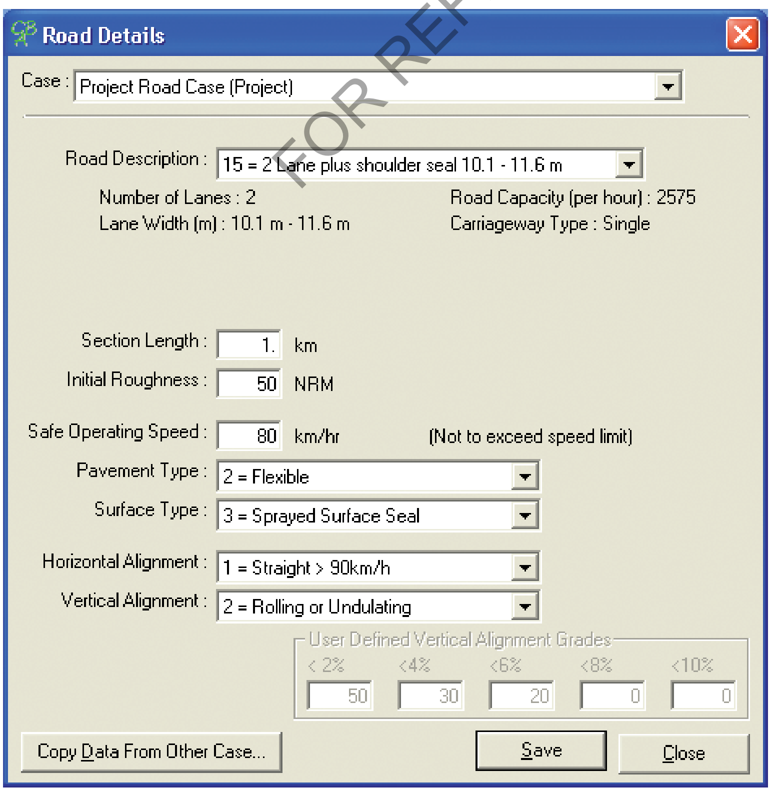
*Figure 114: Flood immunity workspace*




### 5.5.1.3 Road details

The current 1 km section in the base case has an MRS of 10. The project case will provide a new bridge that is wider and has a better alignment. From Figure 115, the new bridge in the project case provides an MRS of 15 and a straight horizontal alignment.

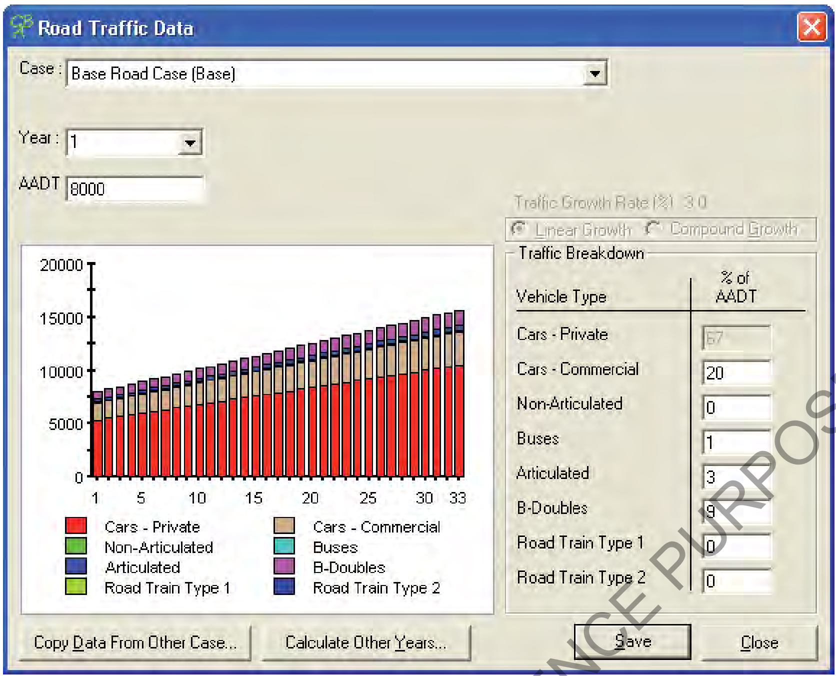
*Figure 115: Road details for new bridge*



### 5.5.1.4 Road traffic data

The road traffic data for the flood affected section of road is the same for the base case and the project case. The AADT is 8000 in Year 1 with a linear growth rate of 3% per annum, see Figure 116. System users should note that CBA6 uses the same traffic configuration for both the project case and the diversion case.

*Figure 116: Road traffic data flood affected section*



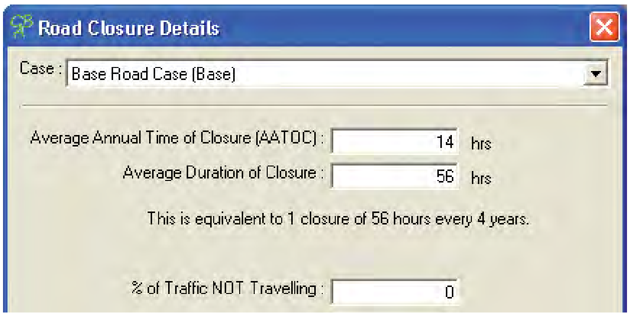

### 5.5.1.5 Road closure details

The 'road closure details' screen displays the main inputs for a flood immunity improvement project. Here the system user is required to develop a pattern of road user behaviour when the road is flooded.

The flooding history of the road indicated an AATOC of 14 hours over the last 20 years. The duration of a flooding event at the site lasted 56 hours on average. In Figure 117 the behaviour of motorists is classified according to traffic not travelling, traffic waiting and those users that divert via an alternative route during a flooding event. Given that an average flooding event at a project site lasts for 56 hours, it is logical to assume that many road users will not wait at the project site, therefore only 10% of the traffic will choose to wait at the flood site. This proportion of the fleet represents local traffic. The remaining 90% of the traffic will choose to divert the additional 40 km.

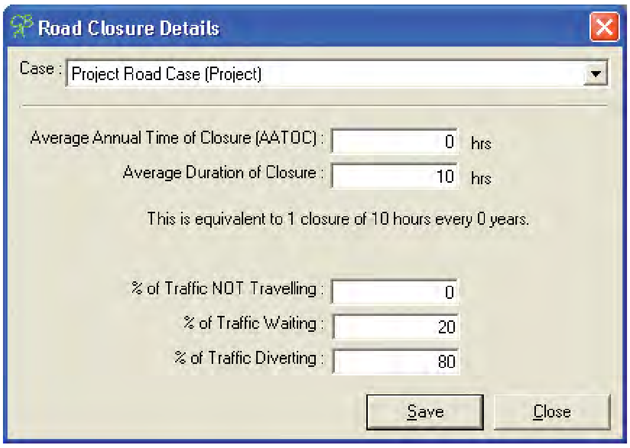
Note: Traffic that chooses not to travel during the closure period will not incur any road user costs. Where the proportion of traffic that chooses not to travel is high, the system user should seek specialist advice to calculate these economic costs. In this example the percentage of vehicles travelling is zero. For simplicity the cost of not travelling has therefore been excluded from the analysis.

*Figure 117: Base case road closures*



The bridge to be built in the project case is designed to a Q100 standard. Based on historical flood levels, the average duration of closure for this bridge would be 10 hours. Traffic behaviour is assumed to change, as the time of closure is lower than in the base case. Details for the project case road closure is shown below in Figure 118. It has been assumed that 20% of road users will wait for flood levels to subside due to the lower average duration of closure.

*Figure 118: Project case road closure details*



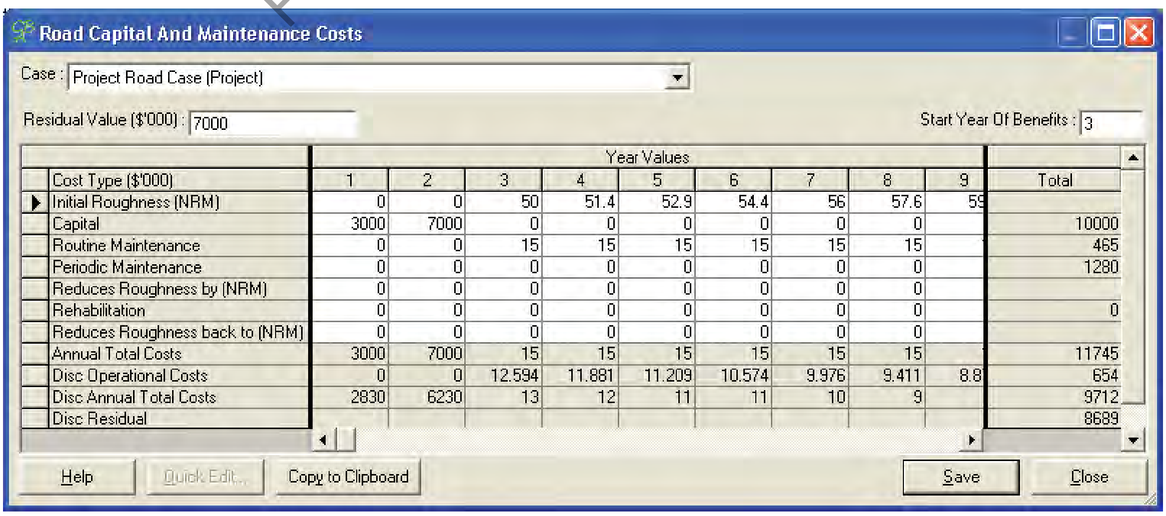

Note: The AATOC for a Q100 bridge with an average duration of closure would be 0.1 hours (10 hours divided by 100 years). In CBA6 the AATOC and ADC can only be measured in hours, therefore in this example the AATOC has been rounded down to zero.



### 5.5.1.6 Capital and maintenance costs

The estimated capital costs for the project is $10 million. The expected breakdown of costs for the project is $3 million in Year 1 and $7 million in spending for Year 2. The project will open to road users in Year 3 and CBA6 will calculate benefits from this time, see Figure 119. The bridge is expected to have a useful life of 100 years, therefore a residual value has been developed to value the useful life of the bridge after the 30-year evaluation period has ended. See Section 9.7 of the *Technical Guide* for formulas to calculate the residual value.

*Figure 119: New bridge costs*



Road Capital And Maintenance Costs

Case : Project Road Case (Project)

Residual Value ($'000) : 7000 Start Year Of Benefits : 3

| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 0 | 0 | 50 | 51.4 | 52.9 | 54.4 | 56 | 57.6 | 59 | |
| Capital | 3000 | 7000 | 0 | 0 | 0 | 0 | 0 | 0 | | 10000 |
| Routine Maintenance | 0 | 0 | 15 | 15 | 15 | 15 | 15 | 15 | | 465 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1280 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 3000 | 7000 | 15 | 15 | 15 | 15 | 15 | 15 | | 11745 |
| Disc Operational Costs | 0 | 0 | 12.594 | 11.881 | 11.209 | 10.574 | 9.976 | 9.411 | 8.8 | 654 |
| Disc Annual Total Costs | 2830 | 6230 | 13 | 12 | 11 | 11 | 10 | 9 | | 9712 |
| Disc Residual | | | | | | | | | | 8689 |

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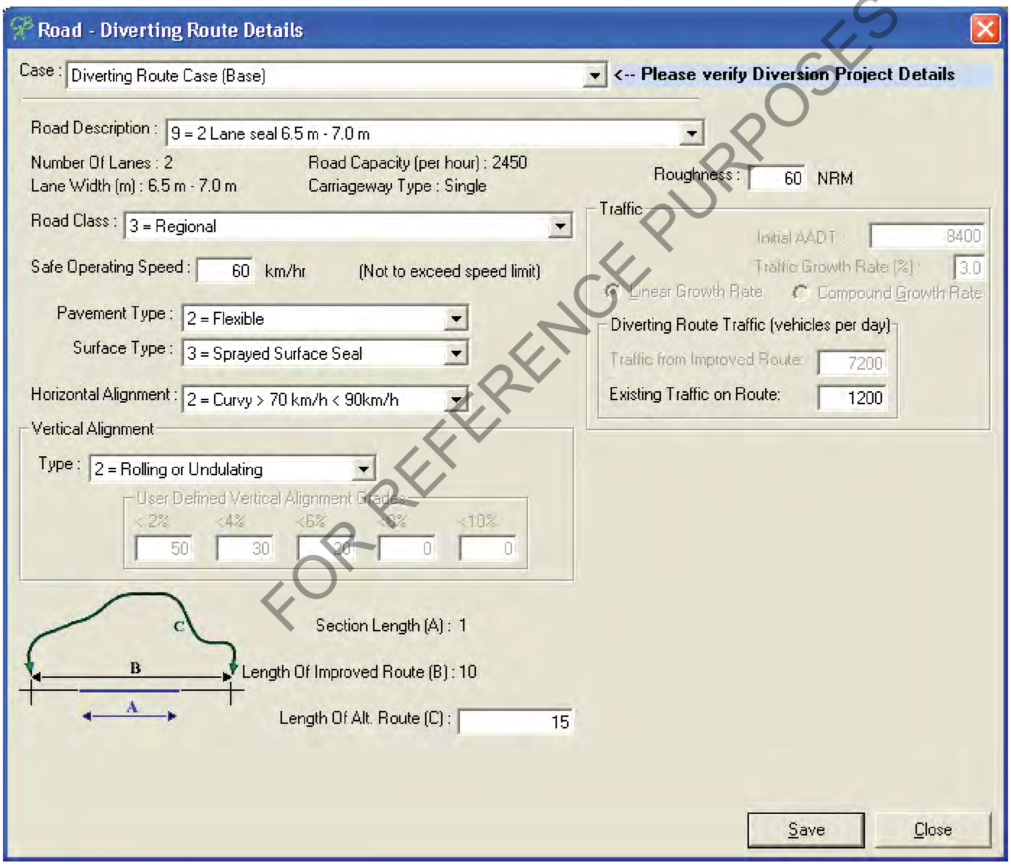
### 5.5.1.7 Accident and other costs

Accident costs will be automatically calculated by CBA6. The project provides savings in accident costs due to the change in MRS. During periods of road closure, increased traffic volumes will result in increased accidents on the diversion route, as diverting traffic will mix with existing road users. See Appendix C for a more detailed breakdown of benefits. Existing traffic volumes are used in CBA6 to determine the extent of congestion on the diverting route but no benefits or costs are attributed to them in the evaluation. See Section 8.1 of the *Technical Guide* for further explanations.

### 5.5.1.8 Diverting route road details

In this example the only available diversion route is a regional road. The traffic on the diversion route is referred to as existing traffic. In this example there are 1200 road users per day on the alternative route. The length of the alternative diversion route is 15 km, see Figure 120.

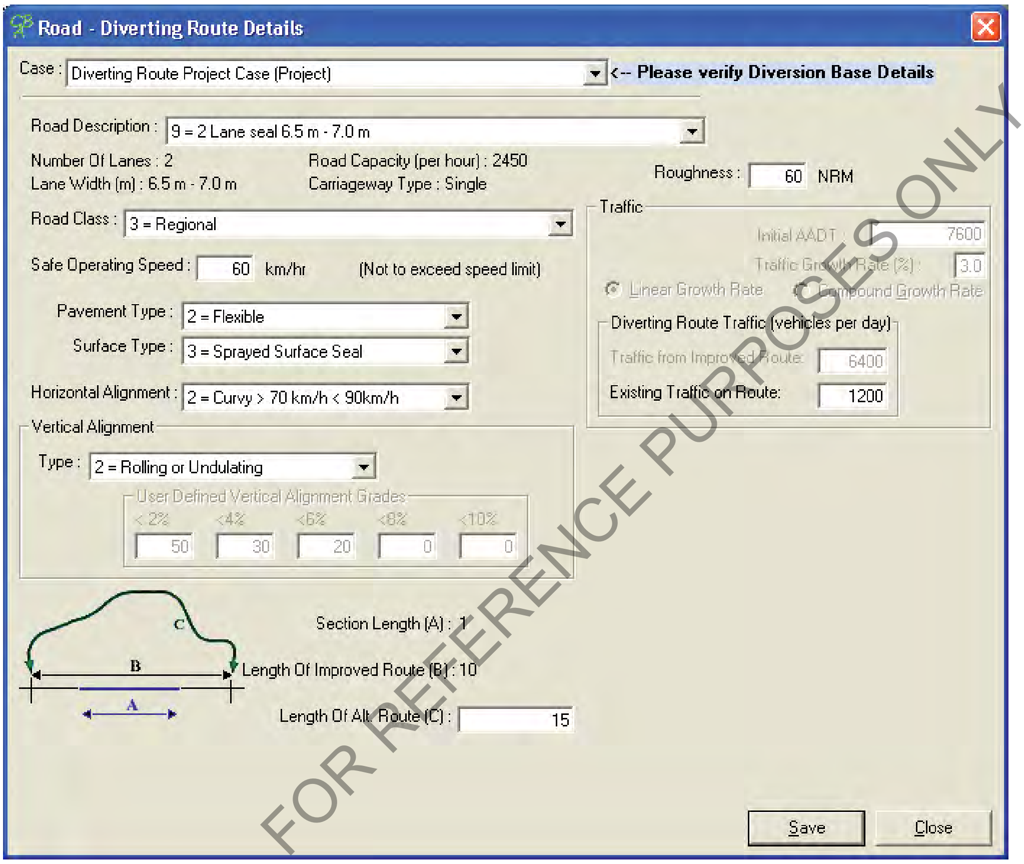
*Figure 120: Base case diversion route details*



System users can edit the project case diversion route details using the 'case' drop-down menu. In this example the project case diversion route has the same characteristics as the base case, see Figure 121.

The 'project case details' screen can be accessed to confirm the project case details, but any changes to the project case will also change the base case. The only variable that will change is the traffic data. Only 6400 road users will choose to divert in the project case compared with 7200 in the base case. This reflects the change in driver behaviour between the base and project cases. The new bridge in the project case has a shorter closure period. This means more road users will wait for the flood waters to subside and fewer road users will be inclined to travel the extra distance on the diversion route.

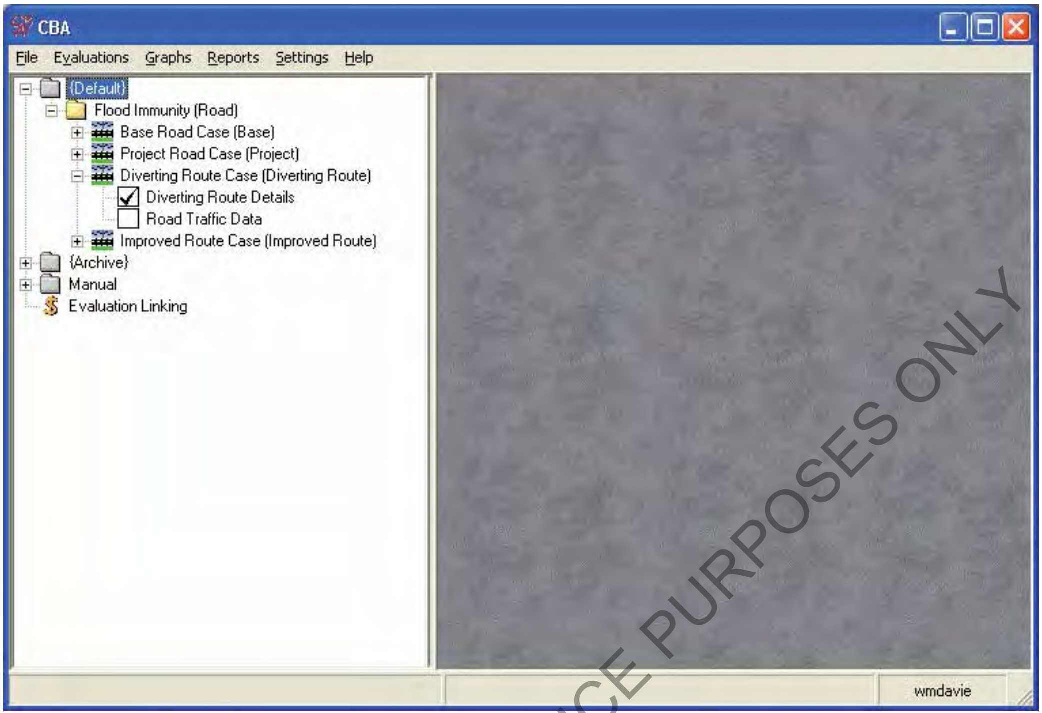
*Figure 121: Project case diversion route details*



### 5.5.1.9 Diverting route traffic data

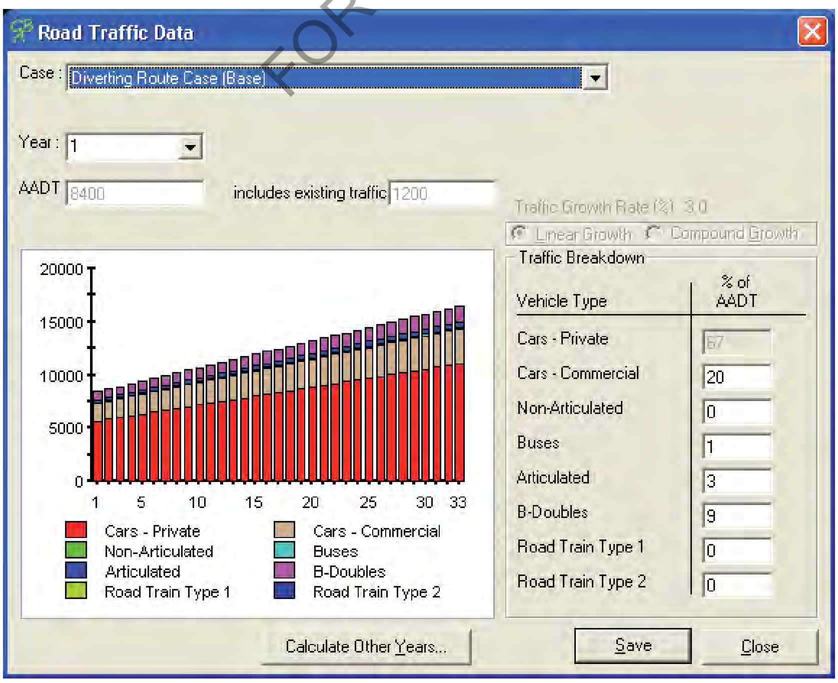
The road traffic data for the diversion route is the next required input, see Figure 122.

*Figure 122: Diverting route workspace*



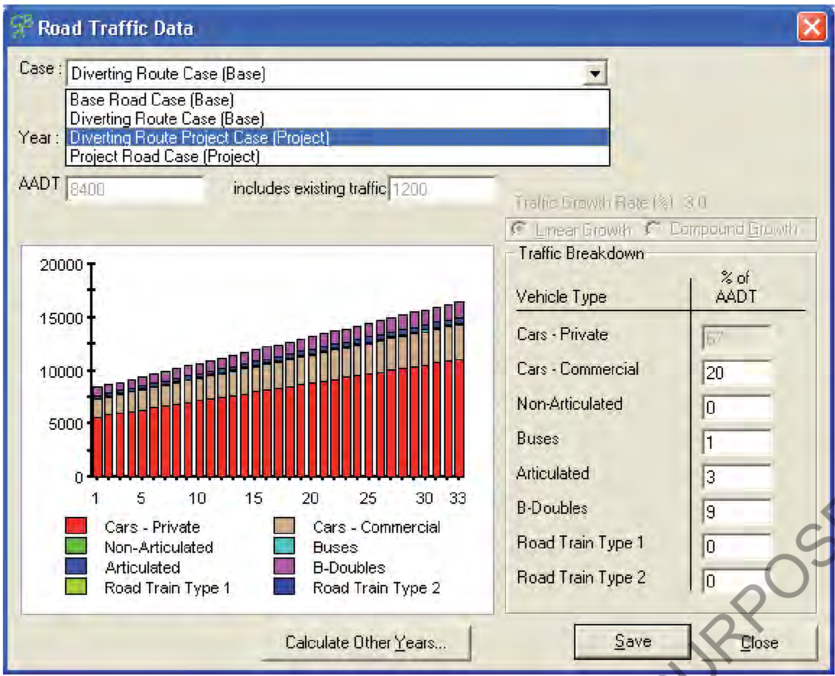

The only available option for system users is to adjust the traffic breakdown for the diversion route, as the initial AADT will be calculated automatically from CBA6 using data previously input by the system user. System users will note that the AADT includes the existing traffic on the diversion route, see Figure 123. In this case study, traffic breakdown of existing traffic is the same as diverting traffic.

*Figure 123: Base case diverting route traffic*



System users must also complete the diverting route project case road traffic data, see Figure 124.

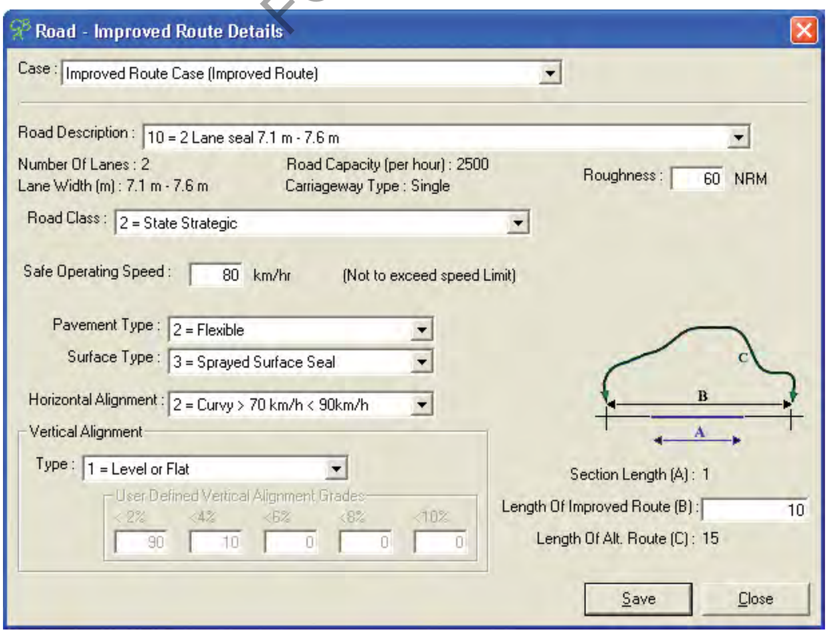
*Figure 124: Project case diverting route*




### 5.5.1.10 Improved route details

The improved route is the normal section of road that is used when the road is open to traffic (Section B in Figure 110). The system user is required to define the length of the improved route from the beginning to the end of the diversion route. The improved route will therefore remain the same between the base and project cases. In Figure 125, the improved route is shown as 10 km (includes the 1 km for Section A).

*Figure 125: Improved route details*



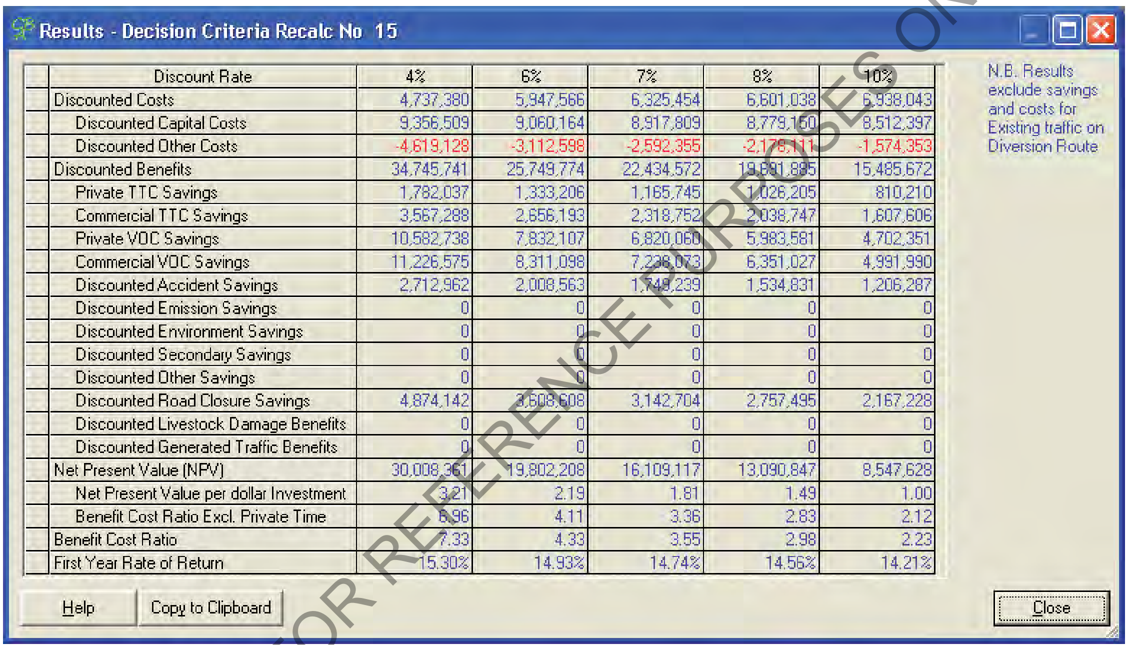
#### 5.5.1.11 Results and decision criteria

In this example, the proposed project involves construction of a new bridge with Q100 flood immunity. The project has a total discounted capital cost of $9 million at the 6% discount rate. There are some savings in costs due to the inclusion of the residual value.

The majority of project benefits comprise TTC savings for road users. In the base case road users suffered delays waiting for flood waters to subside and increased journey times via the diversion route. This new bridge provides a better flood immunity for the site. The 'discounted road closure savings' row shows the delay costs for road users waiting for flood levels to subside. There is a saving of $3.6 million in waiting costs.

The NPV for the project is over $19.8 million at the discount rate of 6%. An NPV above zero is an indicator that the project will improve economic welfare. The BCR for the new bridge is 4.33 at the discount rate of 6% which suggests that the project is economically viable.

*Figure 126: Flood immunity improvement results*




| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 4,737,380 | 5,947,566 | 6,325,454 | 6,601,038 | 6,938,043 |
| Discounted Capital Costs | 9,356,509 | 9,060,164 | 8,917,809 | 8,779,150 | 8,512,397 |
| Discounted Other Costs | -4,619,128 | -3,112,598 | -2,592,355 | -2,178,111 | -1,574,353 |
| Discounted Benefits | 34,745,741 | 25,749,774 | 22,434,572 | 19,691,885 | 15,485,672 |
| Private TTC Savings | 1,782,037 | 1,333,206 | 1,165,745 | 1,026,205 | 810,210 |
| Commercial TTC Savings | 3,567,288 | 2,656,193 | 2,318,752 | 2,038,747 | 1,607,606 |
| Private VOC Savings | 10,582,738 | 7,832,107 | 6,820,060 | 5,983,581 | 4,702,351 |
| Commercial VOC Savings | 11,226,575 | 8,311,098 | 7,238,073 | 6,351,027 | 4,991,990 |
| Discounted Accident Savings | 2,712,962 | 2,008,563 | 1,749,239 | 1,534,831 | 1,206,287 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 4,874,142 | 3,608,608 | 3,142,704 | 2,757,495 | 2,167,228 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 30,008,361 | 19,802,208 | 16,109,117 | 13,090,847 | 8,547,628 |
| Net Present Value per dollar Investment | 3.21 | 2.19 | 1.81 | 1.49 | 1.00 |
| Benefit Cost Ratio Excl. Private Time | 6.96 | 4.11 | 3.36 | 2.83 | 2.12 |
| Benefit Cost Ratio | 7.33 | 4.33 | 3.55 | 2.98 | 2.23 |
| First Year Rate of Return | 15.30% | 14.93% | 14.74% | 14.56% | 14.21% |



Note: To test for any uncertainty in the input data, system users can re-run the evaluation under different assumptions such as changes to the time of closure details, traffic behaviour during road closures or existing traffic on the diversion route. Alternatively, the sensitivity results shown in the printed CBA6 report can be used as a reference point.

### 5.5.2 Road closure (without diversion)

The road closure module in CBA6 is used for projects that are associated with frequent road closures without suitable diversion routes. As is the case with the road closure with diversion module, the road closure module will require system users to possess a wide range of data inputs and also have some understanding of local traffic conditions.

The following two options exist for road users affected by flooded roads:

- Wait – remain at the flood site for waters to subside.
- Do not travel – choose not to travel at all.

Before undertaking a flood immunity improvement project, the system user must be in possession of project data including AATOC and ADC for the base and project cases.

### 5.5.2.1 Road closure case study

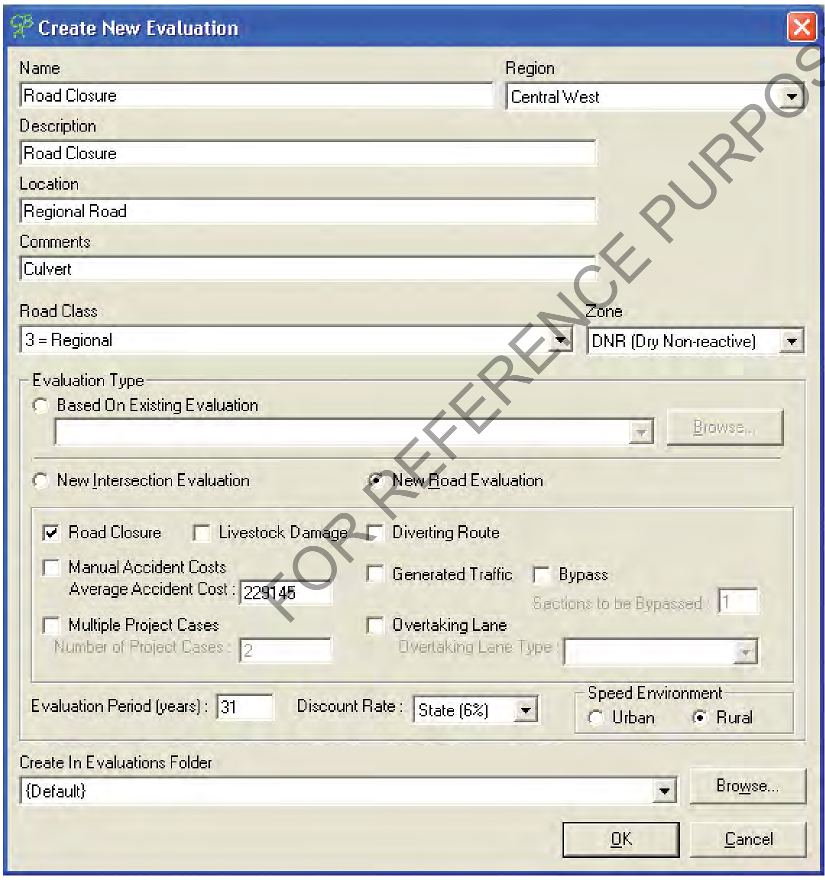
This case study involves a low lying road that floods during the wet season. This occurs every year with an average duration of closure of 12 hours. This road is an important freight link used by a number of heavy vehicles. As there is no suitable diversion route, it is assumed that all vehicles will wait at the flood affected site.

TMR will raise the height of the road through earth works and provide a culvert to eliminate future road closures.

### 5.5.2.2 Create new evaluation

To create a road closure project the system user must ensure the 'road closure' box is ticked, see Figure 127.

*Figure 127: Road details for culvert*

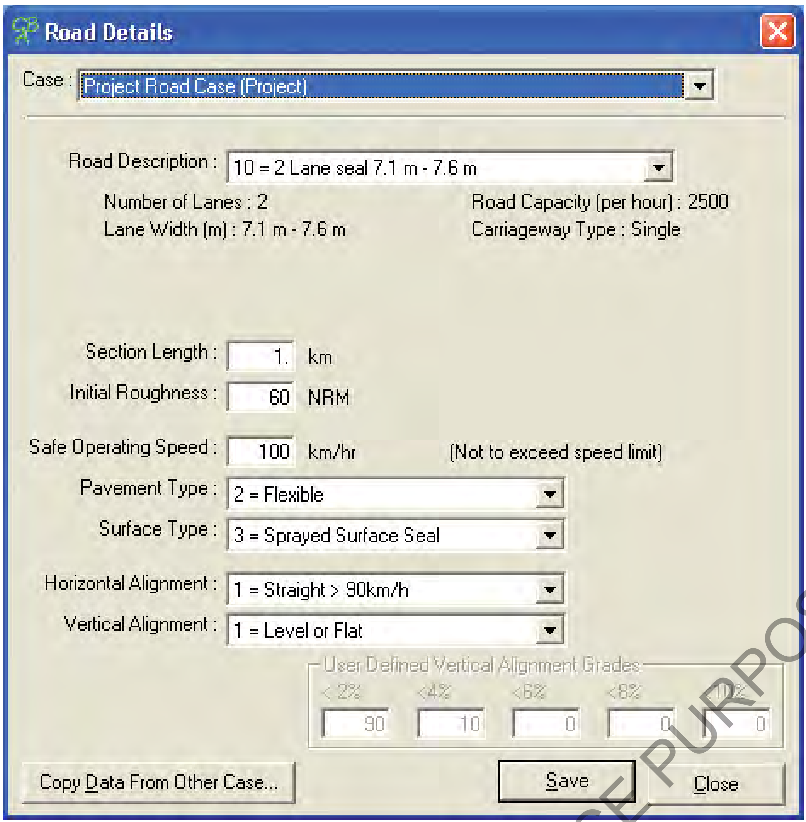





### 5.5.2.3 Road details

The 'road details' screen describes the section of road to be upgraded and improved in the project case. The current road has a roughness of 110 NRM while the project works will provide a new seal of 60 NRM, see Figure 128. All other input data will remain the same.

*Figure 128: Closure road details*

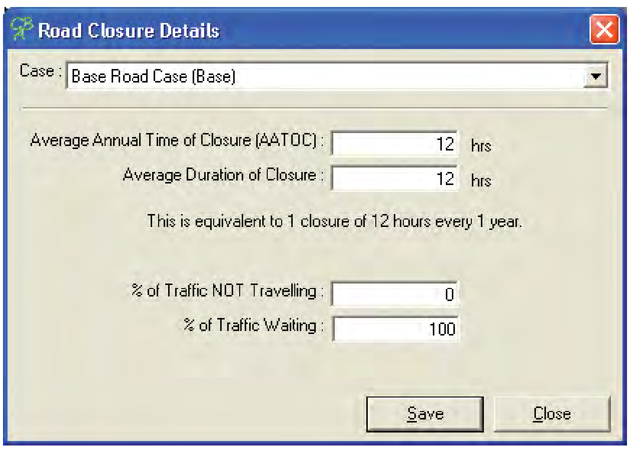





### 5.5.2.4 Road closure details

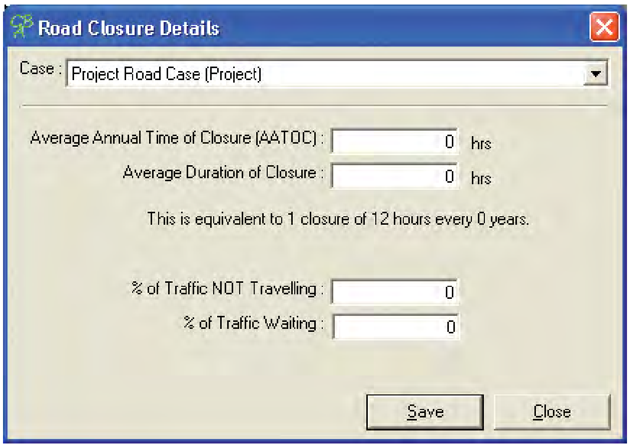
Historical records suggest that this road floods for 12 hours every year. In the base case the AATOC is 12 hours and the corresponding ADC is 12 hours, therefore the estimated frequency of road closures over the evaluation period is one closure of 12 hours every year, see Figure 129. Longer road closures are likely to result in less traffic waiting at the project site and more traffic choosing not to travel (see Section 5.5.1 for further information on the costs of not travelling). As there is no suitable alternative route in this case study, it is assumed that all vehicles will wait at the project site for the flood to subside. If an alternative route is available some vehicles will elect to use it.

*Figure 129: Base case road closures*



New culvert and earthworks will eliminate all future road closures caused by flooding. Road closure details for the project case are shown in Figure 130.

*Figure 130: Project case road closures*




### 5.5.2.5 Capital and maintenance costs

Construction will occur over a one-year time frame. The estimated cost for the project is $800 000 with the project being commissioned in Year 2. It is assumed that maintenance capital costs will remain the same in the base and project cases, therefore the net result will be zero.

### 5.5.2.6 Accident and other costs

Accident costs will be calculated automatically by CBA6. However as there is no change in MRS between the base and project cases there are no accident cost savings recorded.

### 5.5.2.7 Results and decision criteria

In this example, a culvert will be built to stop the frequent flooding that occurs along a regional road. The road closure savings for this project are over $1 million while the BCR is 1.69 at the 6% discount rate. The FYRR for the project of 8.77% shows that at current traffic volumes, immediate construction of the project is warranted.

*Figure 131: Road closure results*

Results - Decision Criteria Recalc No 3

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 769,231 | 754,717 | 747,664 | 740,741 | 727,273 |
| Discounted Capital Costs | 769,231 | 754,717 | 747,664 | 740,741 | 727,273 |
| Discounted Other Costs | 0 | 0 | 0 | 0 | 0 |
| Discounted Benefits | 1,676,538 | 1,272,791 | 1,121,611 | 995,355 | 799,281 |
| Private TTC Savings | 22 | 12 | 9 | 7 | 4 |
| Commercial TTC Savings | 130,076 | 98,795 | 87,077 | 77,287 | 62,078 |
| Private VOC Savings | 17,942 | 13,624 | 12,006 | 10,656 | 8,557 |
| Commercial VOC Savings | 146,759 | 111,395 | 98,156 | 87,102 | 69,938 |
| Discounted Accident Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 1,381,740 | 1,048,966 | 924,363 | 820,304 | 658,703 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 907,307 | 518,074 | 373,947 | 254,615 | 72,008 |
| Net Present Value per dollar Investment | 1.18 | 0.69 | 0.50 | 0.34 | 0.10 |
| Benefit Cost Ratio Excl. Private Time | 2.18 | 1.69 | 1.50 | 1.34 | 1.10 |
| Benefit Cost Ratio | 2.18 | 1.69 | 1.50 | 1.34 | 1.10 |
| First Year Rate of Return | 8.93% | 8.77% | 8.68% | 8.60% | 8.45% |

Help | Copy to Clipboard | Close

## 5.6 Intersection

Intersection evaluations can be undertaken in CBA6 using the intersection module. CBA6 has been designed to use output information from the SIDRA intersection performance tool. Before undertaking an economic evaluation in CBA6, the system user will require traffic modelling results from SIDRA. System users should seek support from the CBA Team when using alternative traffic models.

The CBA6 intersection module takes into account queuing behaviour and delays within the boundaries of the intersection and determines the impact on travel time and fuel costs. Changes in VOC other than fuel are not calculated by CBA6 or SIDRA.

The intersections module is best used for evaluating projects which are not expected to have significant network effects. A transport network model or microsimulation tool should be used if the intersection under evaluation is expected to have significant effects on traffic volumes or speeds of connecting links.

The CBA6 intersection module can be used for:

- intersection only projects such as replacing an unsignalised intersection with a roundabout or signals
- intersection projects which are expected to cause traffic diversions to or from alternate routes. The evaluation would be made up of composite runs of CBA6 using the intersection module and the normal road module of CBA6 for estimating benefits to existing and diverting traffic. The 'linking projects' function would be used to combine the individual components into a total project, see Section 5.13.

Note: CBA6 has been specifically designed to use outputs from SIDRA, although it may be possible to use outputs from other intersection modelling tools. System users should consult with the CBA Team before attempting to use outputs from other modelling tools.



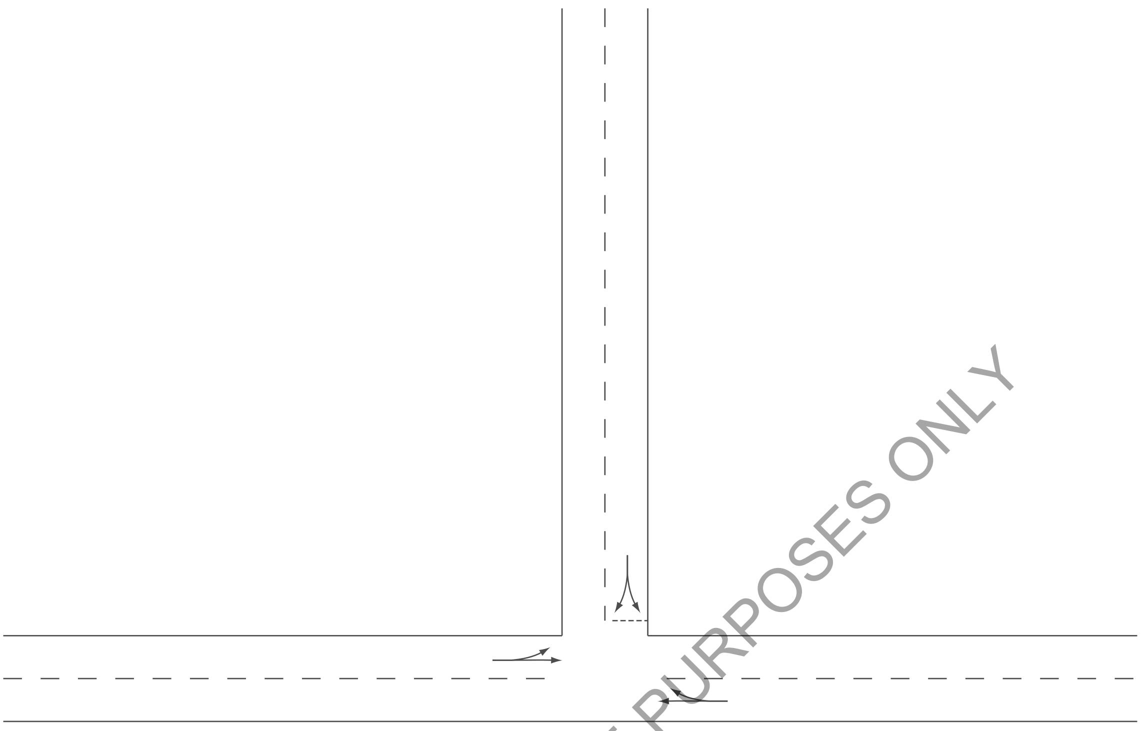
### 5.6.1 Intersection case study

This case study involves the signalisation of a simple intersection which connects a local road to an arterial road. Currently, a stop sign on the local road controls vehicular access to the arterial road. During afternoon peak periods there are significant delays to traffic merging onto the arterial road. The intersection is currently oversaturated. A signalised intersection will reduce these delays and increase safety at the site by controlling all vehicle movements. The project will take one year to construct and will have a useful life of 10 years. To determine the savings in delay times, a SIDRA analysis was undertaken on both the current intersection and the new signalised intersection. The results of the SIDRA analysis for the base case (stop sign) intersection are shown in Table 4. Figure 132 illustrates the structure of the T intersection.

*Table 4: SIDRA base case (unsignalised)*

| Year | Period | Duration (hours) | Vehicles per hour | Average delay (S/veh) | Fuel consumption (L/h (total) |
|---|---|---|---|---|---|
| Year 1 | Morning peak | 1 | 2,203 | 28.2 | 152.7 |
| | Afternoon peak | 1 | 2,361 | 36.3 | 161.8 |
| Year 11 | Morning peak | 1 | 2,646 | 181.1 | 335.3 |
| | Afternoon peak | 1 | 2,835 | 327 | 503.4 |

*Figure 132: Intersection layout*






The results of the SIDRA analysis for the project case (signalised) intersection are shown in Table 5.

*Table 5: SIDRA project case (signalised)*

| Year | Period | Duration (hours) | Vehicles per hour | Average delay (S/veh) | Fuel consumption (L/h (total) |
|---|---|---|---|---|---|
| Year 1 | Morning peak | 1 | 2,203 | 4.4 | 122.5 |
| | Afternoon peak | 1 | 2,361 | 3.7 | 126.7 |
| Year 11 | Morning peak | 1 | 2,646 | 56.9 | 235.5 |
| | Afternoon peak | 1 | 2,835 | 6.7 | 172.2 |

Note:

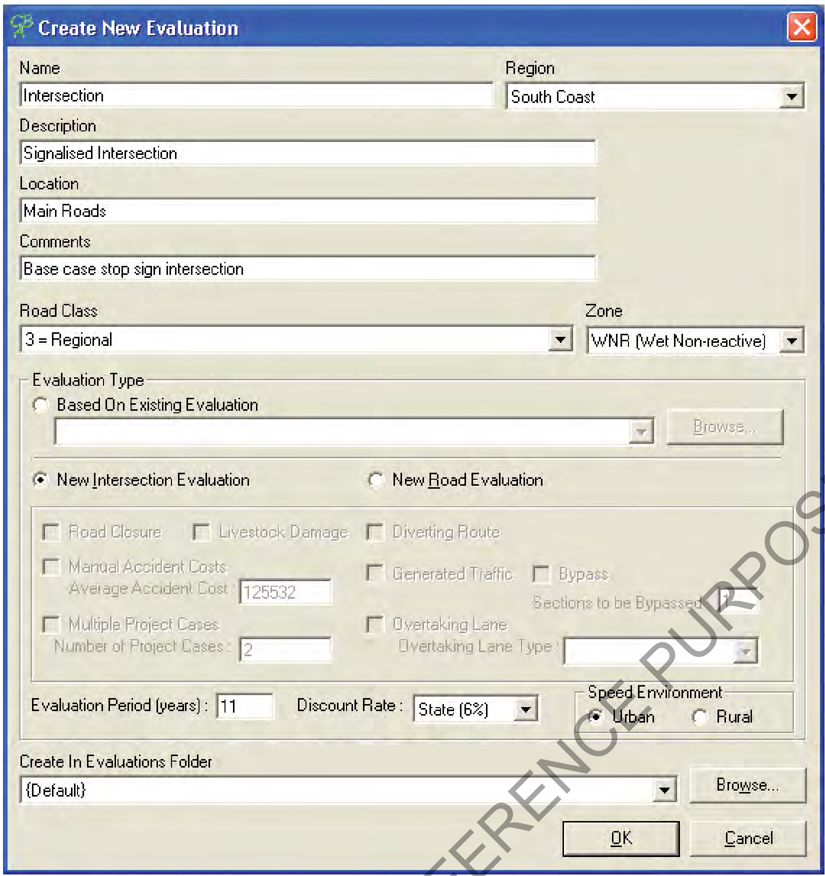
- The operation of the signals in combination with the large volume of traffic coming from the east in the morning reduces the effectiveness of the signals in the morning peak period relative to the afternoon peak period.
- Data for Years 1 to 11 will be interpolated by CBA6 using a simple liner technique, see Section 5.5.3.

## 5.6.2 Create new evaluation

To create a new intersection evaluation, ensure the 'new intersection evaluation' option is selected, see Figure 133. This will disable all other evaluation modules.

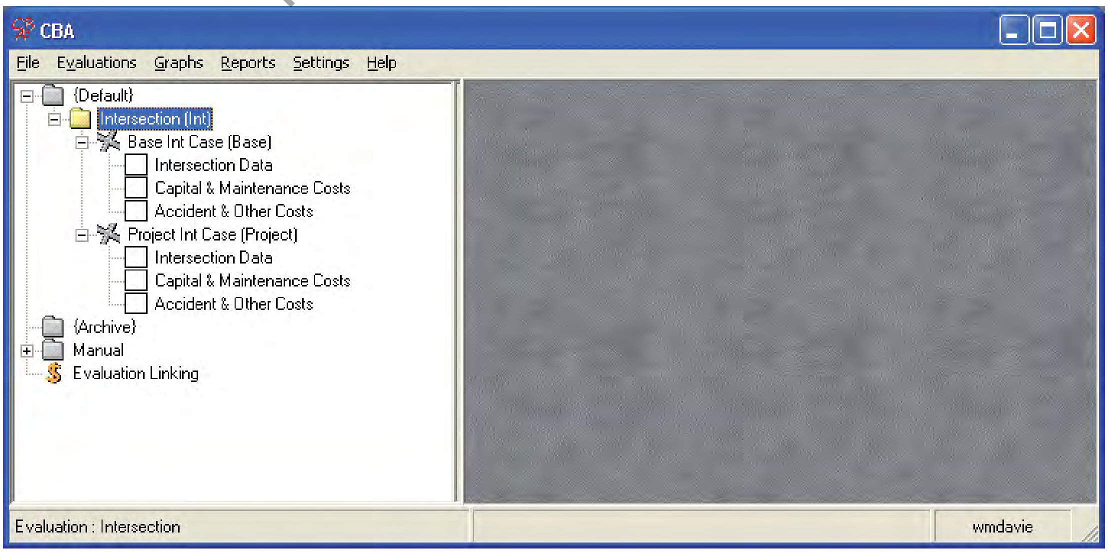
Note: The evaluation period is 11 years which includes one year for construction and 10 years of operation. The urban speed environment is selected as the project is located in the middle of a town.

*Figure 133: Intersection new evaluation*




The intersection module operates from a different node tree to road projects modules. From Figure 134, the new input field is 'intersection data'. The 'intersection data' screen is where the SIDRA data is required to be input.

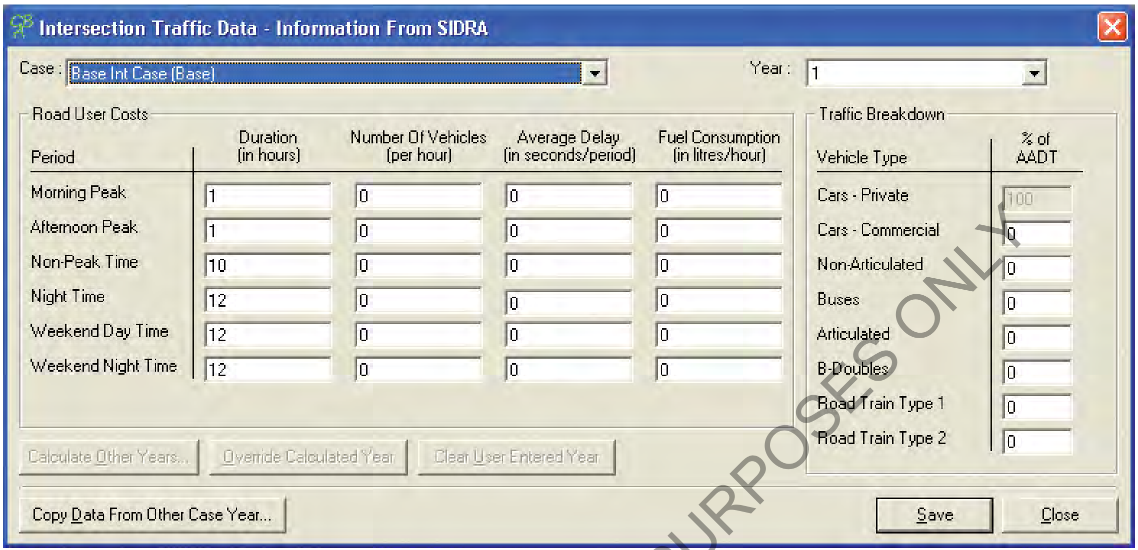
*Figure 134: Intersection workspace*



## 5.6.3 Intersection data

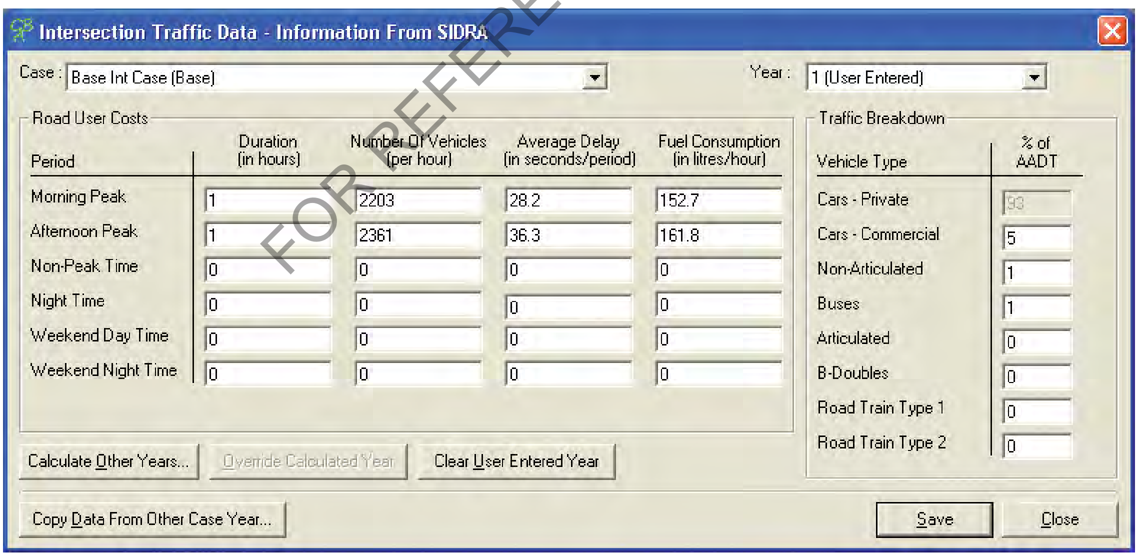
For this case study, the SIDRA analysis was only undertaken for the peak morning and afternoon periods of the day. The default time periods for an analysis in CBA6 include the peak periods, non-peak periods, night and weekends, see Figure 135.

*Figure 135: Intersection traffic data*




To input the base case data, fill in the required fields in Figure 136. After entering the data for Year 1, click ‘save’.

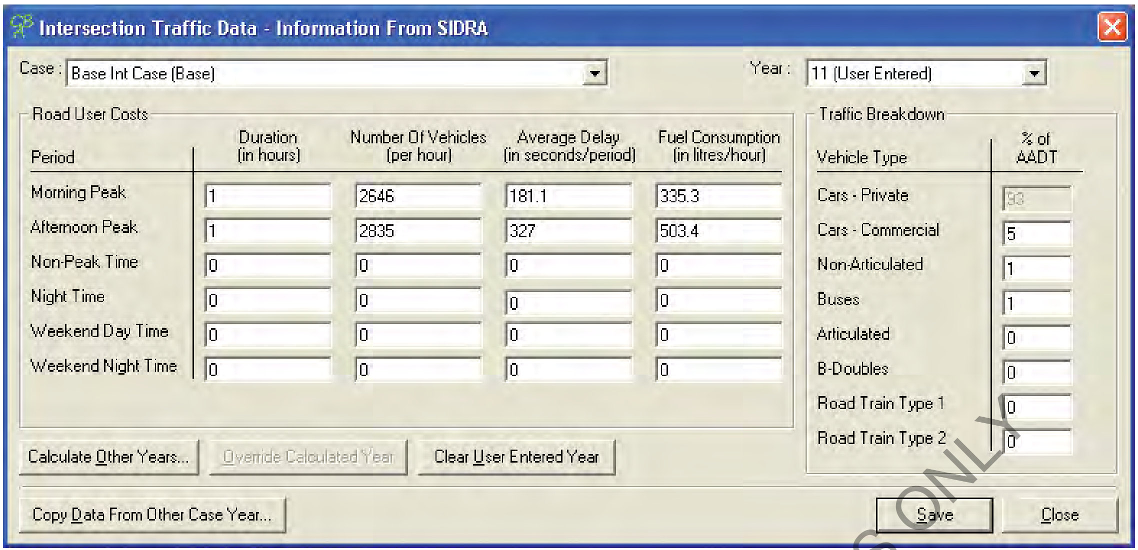
*Figure 136: Base case intersection data Year 1*




Note: Generally SIDRA analysis will only be undertaken for the peak periods. When this is the case, all other periods must be set to zero.

The next step requires the system user to enter the final year of SIDRA data in Year 11, see Figure 137.

*Figure 137: Base case intersection data Year 11*



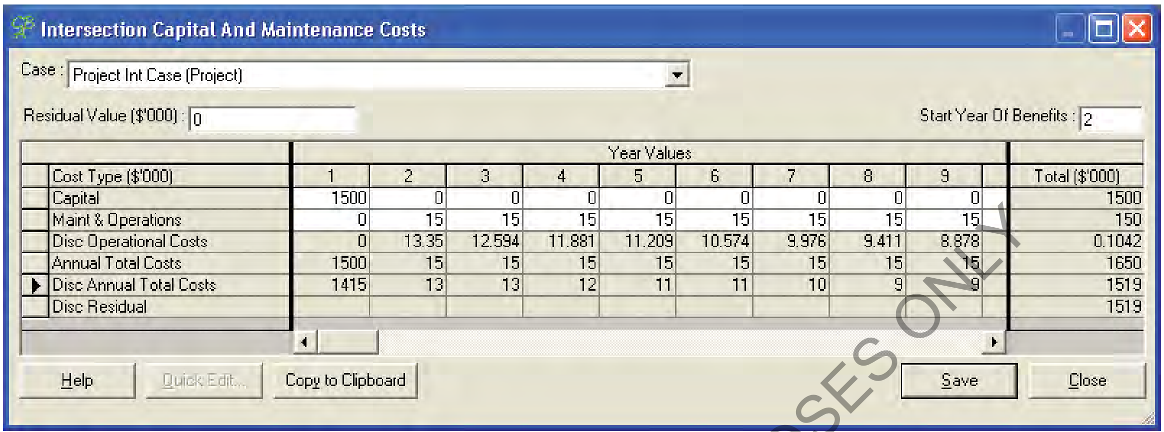

To calculate the SIDRA results for the remaining years, CBA6 interpolates the data from Years 1 to 11. From Figure 138 the system user is required to use the 'calculate other years' button. This process is repeated for the project case SIDRA data.

*Figure 138: Calculate other years*

### 5.6.4 Capital and maintenance costs

Current maintenance and operational costs for the base case (stop sign controlled intersection) is $2000 per annum. The capital costs for the new signalised intersection are estimated at $1.5 million and will cost $15 000 each year to operate, see Figure 139.

*Figure 139: Intersection costs*




| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total ($'000) |
|---|---|---|---|---|---|---|---|---|---|---|
| Capital | 1500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1500 |
| Maint & Operations | 0 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 150 |
| Disc Operational Costs | 0 | 13.35 | 12.594 | 11.881 | 11.209 | 10.574 | 9.976 | 9.411 | 8.878 | 0.1042 |
| Annual Total Costs | 1500 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 1650 |
| Disc Annual Total Costs | 1415 | 13 | 13 | 12 | 11 | 11 | 10 | 9 | 9 | 1519 |
| Disc Residual | | | | | | | | | | 1519 |

### 5.6.5 Accident and other costs

Accident costs in the intersection module have to be calculated manually by the system user. In this case study accident costs for the base case are $50 000 per year. The improved safety conditions in the project case reduced accident costs to $25 000 per year. For detail on the manual calculation of accident costs, see Section 6 of the *Technical Guide*. Accident costs can also be calculated by using DCA codes.

See Section 7 of the *Technical Guide* for further details on externality costs.

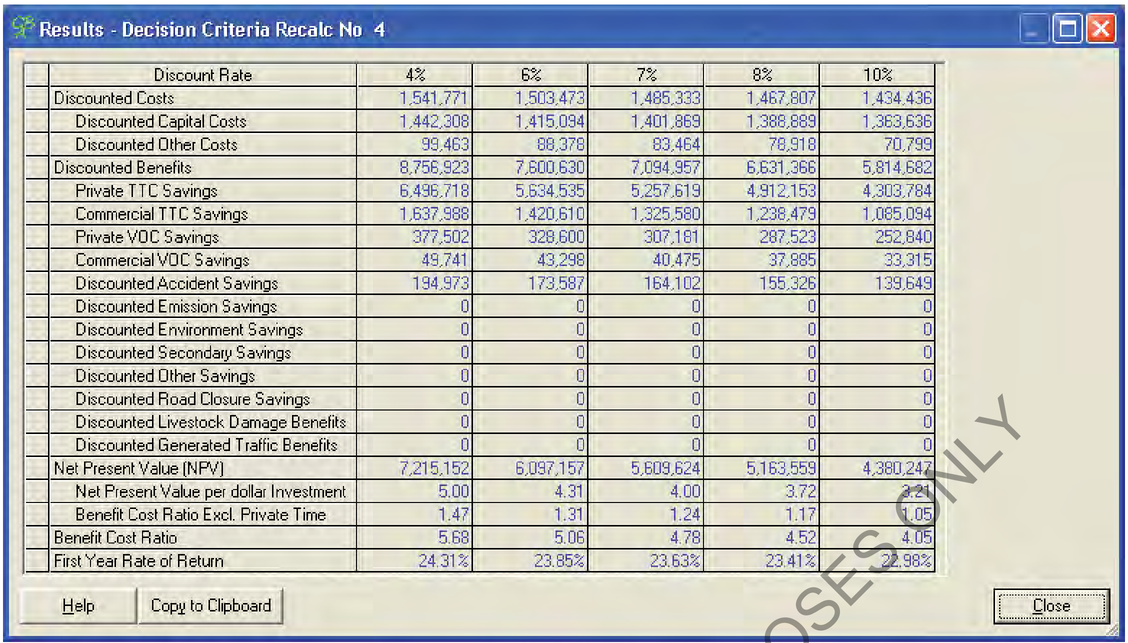
### 5.6.6 Results and decision criteria

In this case study, the proposed project provides a signalised intersection as an alternative to a stop sign controlled environment. The project has a total discounted cost of $1.4 million at the 6% discount rate. There is an increase in the operational costs of the project to account for traffic systems and other costs associated with maintaining a signalised intersection.

TTC savings for private road users represent the majority of the benefits derived from this project. In the base case, road users suffer significant delays in the afternoon peak period. The new signalised intersection will significantly reduce delays and the associated over saturation of the intersection.

The results of this case study provide strong justification for the project. The NPV of $6.0 million at the discount rate of 6%, and a BCR of 5.06 suggest that the signalisation of this intersection will yield significant economic benefits, see Figure 140. The BCR is particularly high due to the significant reduction in travel delays as a result of the signalised intersection.

*Figure 140: Intersection results and decision criteria*




| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 1,541,771 | 1,503,473 | 1,485,333 | 1,467,807 | 1,434,436 |
| Discounted Capital Costs | 1,442,308 | 1,415,094 | 1,401,869 | 1,388,889 | 1,363,636 |
| Discounted Other Costs | 99,463 | 88,378 | 83,464 | 78,918 | 70,799 |
| Discounted Benefits | 8,756,923 | 7,600,630 | 7,094,957 | 6,631,366 | 5,814,682 |
| Private TTC Savings | 6,496,718 | 5,634,535 | 5,257,619 | 4,912,153 | 4,303,784 |
| Commercial TTC Savings | 1,637,988 | 1,420,610 | 1,325,580 | 1,238,479 | 1,085,094 |
| Private VOC Savings | 377,502 | 328,600 | 307,181 | 287,523 | 252,840 |
| Commercial VOC Savings | 49,741 | 43,298 | 40,475 | 37,885 | 33,315 |
| Discounted Accident Savings | 194,973 | 173,587 | 164,102 | 155,326 | 139,649 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 7,215,152 | 6,097,157 | 5,609,624 | 5,163,559 | 4,380,247 |
| Net Present Value per dollar Investment | 5.00 | 4.31 | 4.00 | 3.72 | 3.21 |
| Benefit Cost Ratio Excl. Private Time | 1.47 | 1.31 | 1.24 | 1.17 | 1.05 |
| Benefit Cost Ratio | 5.68 | 5.06 | 4.78 | 4.52 | 4.05 |
| First Year Rate of Return | 24.31% | 23.85% | 23.63% | 23.41% | 22.98% |

## 5.7 Duplication

A road duplication project is designed to double the existing lanes of a road. Road duplications are commonly applied to arterial roads or highways where there is sufficient demand to warrant a major upgrade. The purpose of a road duplication is to provide increased road capacity to enable traffic volumes to continue to grow.

Note: Road duplication projects are sometimes referred to as road widening projects. Road widening refers to increasing only the seal width of a road. Highway upgrades from four to six lanes are not technically referred to as a duplication. Also road duplication projects are often associated with an increase in traffic demand above the underlying growth which results in 'generated traffic'. If a road duplication initiative generates additional traffic, the system user should follow the example set out in Section 5.9.

### 5.7.1 Duplication case study

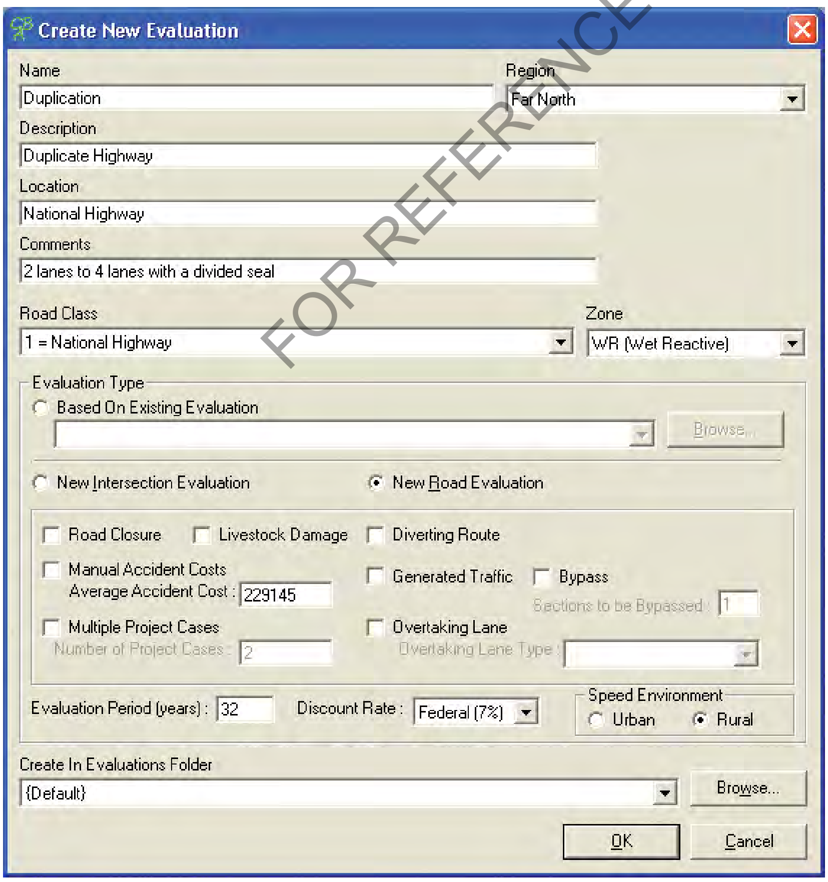
This case study involves the evaluation of a two-lane highway that requires duplication. Currently 12 000 vehicles per day use the highway and growth of 5% per annum is assumed. The proposed project will duplicate the road for 3 km and provide a divided seal to increase safety.



### 5.7.2 Create new evaluation

The 'create new evaluation' screen is similar to other case studies. No advanced modules need to be selected, see Figure 141. All case study data is shown in Appendix A.

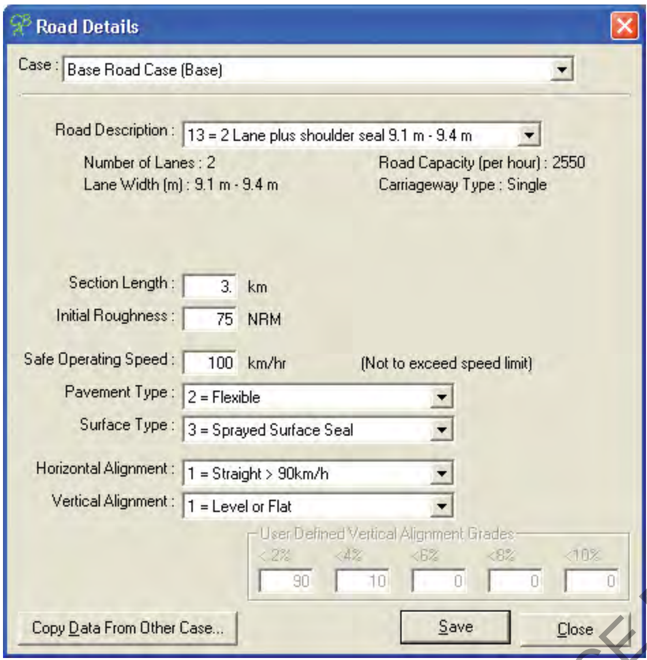
*Figure 141: Duplication evaluation*



## 5.7.3 Road details

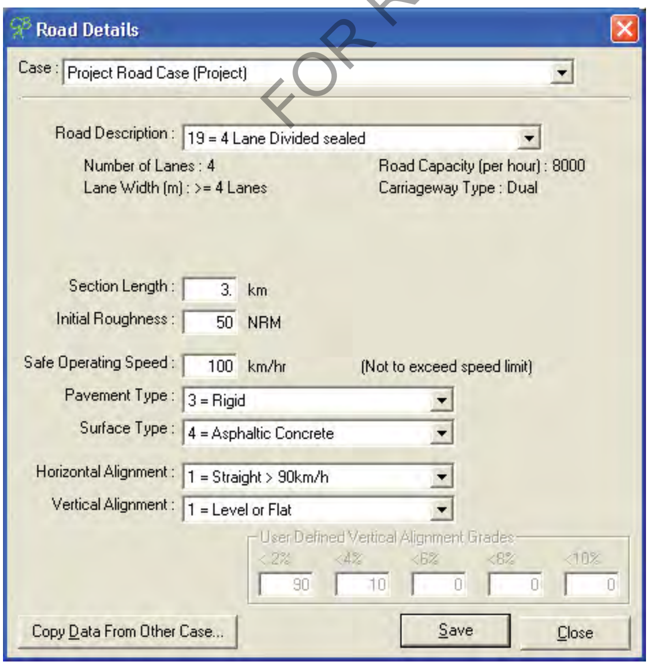
The main input used in a duplication project is the MRS. In the base case, the current road is two lanes with a seal width of 9.4 metres and sealed shoulders, see Figure 142.

*Figure 142: Base case road details 2 lanes*




The project will significantly upgrade the road to a four-lane divided highway with an improved surface. From Figure 143 an MRS of 19 is selected in the project case. The default pavement and surface types for MRS 19 are rigid and concrete respectively.

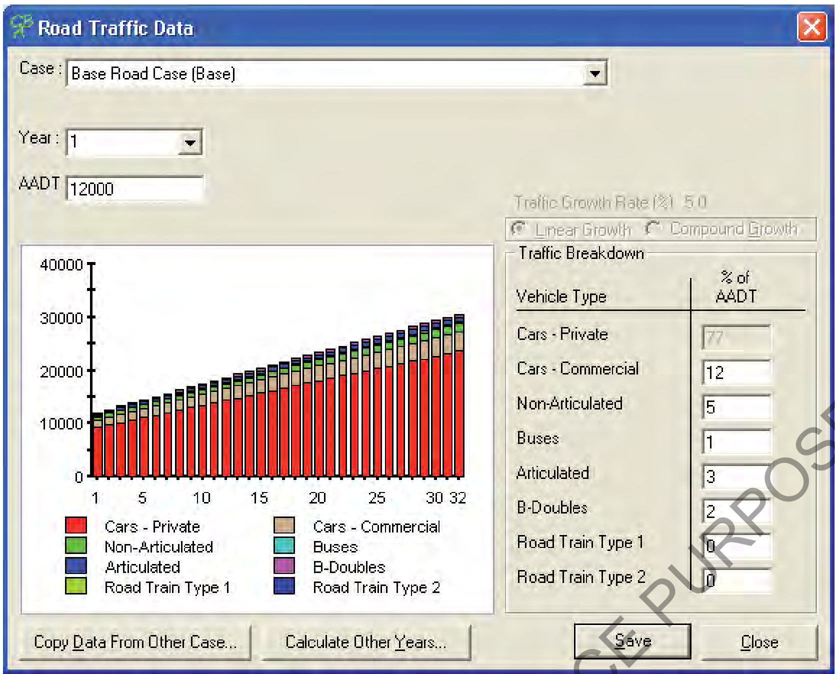
*Figure 143: Duplication details*



### 5.7.4 Road traffic data

The AADT is expected to remain the same between the base and project cases. Initial AADT is 12 000 with an annual growth rate of 5%, see Figure 144.

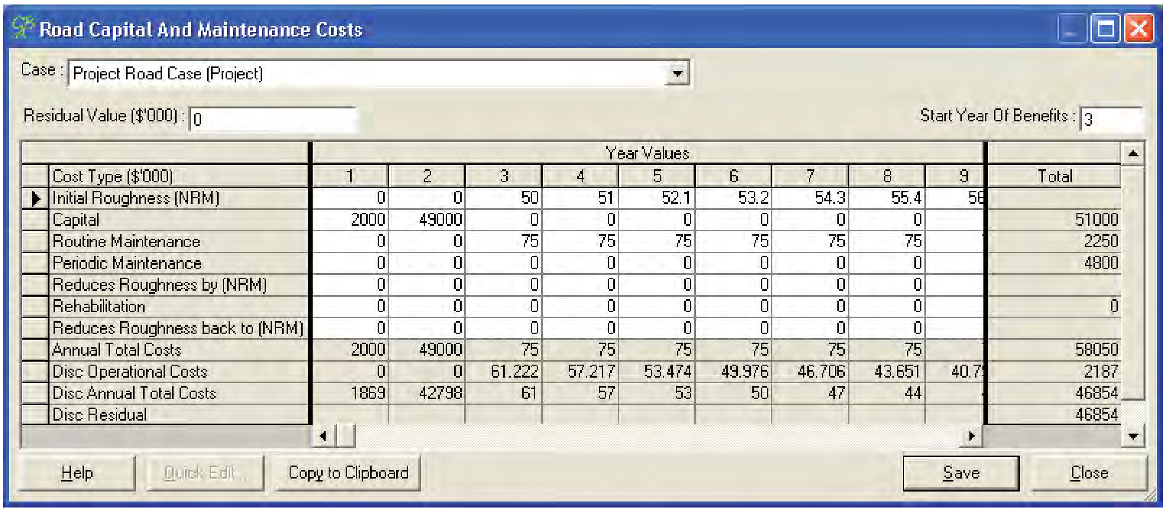
*Figure 144: Duplication road traffic data*




### 5.7.5 Capital and maintenance costs

The capital cost for the duplication is estimated at $51 million over two years. Initial site works will begin in Year 1, with the majority of the capital costs being incurred in construction during Year 2. Maintenance costs in the project case are estimated to more than double. Figure 145 shows the cost distribution for the project. The first year of operation will be in Year 3. All other costs, including base case maintenance costs, are shown in Appendix A.

*Figure 145: Duplication costs*



Road Capital And Maintenance Costs

Case : Project Road Case (Project)

Residual Value ($'000) : 0

Start Year Of Benefits : 3

| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 0 | 0 | 50 | 51 | 52.1 | 53.2 | 54.3 | 55.4 | 58 | |
| Capital | 2000 | 49000 | 0 | 0 | 0 | 0 | 0 | 0 | | 51000 |
| Routine Maintenance | 0 | 0 | 75 | 75 | 75 | 75 | 75 | 75 | | 2250 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 4800 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 2000 | 49000 | 75 | 75 | 75 | 75 | 75 | 75 | | 58050 |
| Disc Operational Costs | 0 | 0 | 61.222 | 57.217 | 53.474 | 49.976 | 46.706 | 43.651 | 40.7 | 2187 |
| Disc Annual Total Costs | 1869 | 42798 | 61 | 57 | 53 | 50 | 47 | 44 | | 46854 |
| Disc Residual | | | | | | | | | | 46854 |

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### 5.7.6 Accident and other costs

The road duplication project and new divided seal will improve safety along the highway. Accident cost savings are estimated at over $3.3 million, see Figure 145. A highway with a divided seal is expected to provide a reduced accident rate. See Section 6 of the *Technical Guide* for further information on accident rates for each MRS.

### 5.7.7 Results and decision criteria

To cope with increasing traffic volumes along the highway, TMR has proposed a duplication to improve highway conditions. The BCR for the project is 1.75 while the NPV is $35 879 544 at the 4% discount rate. At the 7% discount rate, the BCR is 0.99 and the NPV is $593 015, see Figure 146. The large difference in NPV at the two discount rates can be explained by the low FYRR (1.57 and 1.53 at the 4% and 6% discount rates respectively) which implies that project benefits lie in the future. Delaying this project by a few years will improve its economic viability.

The majority of benefits are TTC savings. This is due to congestion in the base case. Private and commercial VOC savings for this project are negative. The results also show that private VOC benefits decrease at higher discount rates while commercial VOC benefits increase at higher discount rates. This is due to the relationship between operating speed and VOC for private vehicles. See Section 3 of the *Technical Guide* for further information on operating speed.



*Figure 146: Duplication results*

Results - Decision Criteria Recalc No 24

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 47,710,621 | 45,755,273 | 44,852,365 | 43,989,754 | 42,365,845 |
| Discounted Capital Costs | 47,226,331 | 45,496,618 | 44,667,657 | 43,861,454 | 42,314,050 |
| Discounted Other Costs | 484,290 | 258,655 | 184,728 | 128,300 | 51,796 |
| Discounted Benefits | 83,590,166 | 54,290,334 | 44,259,370 | 36,366,021 | 25,143,843 |
| Private TTC Savings | 49,020,494 | 31,818,995 | 25,924,981 | 21,284,894 | 14,684,690 |
| Commercial TTC Savings | 31,749,591 | 20,550,056 | 16,717,041 | 13,701,998 | 9,419,028 |
| Private VOC Savings | -1,432,389 | -1,040,125 | -891,815 | -767,851 | -576,451 |
| Commercial VOC Savings | -381,799 | -453,956 | -457,066 | -447,946 | -409,974 |
| Discounted Accident Savings | 4,634,268 | 3,415,364 | 2,966,228 | 2,594,925 | 2,026,550 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 35,879,544 | 8,535,061 | -593,015 | -7,623,733 | -17,222,002 |
| Net Present Value per dollar Investment | 0.76 | 0.19 | -0.01 | -0.17 | -0.41 |
| Benefit Cost Ratio Excl. Private Time | 0.72 | 0.49 | 0.41 | 0.34 | 0.25 |
| Benefit Cost Ratio | 1.75 | 1.19 | 0.99 | 0.83 | 0.59 |
| First Year Rate of Return | 1.57% | 1.54% | 1.53% | 1.51% | 1.48% |

Help | Copy to Clipboard | Close

## 5.8 Bypass

A bypass is a new road which reroutes traffic around a town or built-up area. There are different types of bypass projects, for example a bypass can be due to a rock fall or a flooding event. A bypass project involves the permanent re-route of a road whereas a diversion project is a temporary workaround. Evaluations of bypasses tend to be data intensive depending on the magnitude of the bypass. For example, in a town bypass, the project case has an origin from the proposed deviation and a destination where the bypass rejoins the original route. A bypass of this nature has the capacity to bypass multiple individual road links. In reality, bypassing a town will have a number of commercial and social impacts that may need to be evaluated. Due to the complexity of the bypass evaluations, system users must carefully consider the base case and the bypass option prior to attempting to establish the methodology. It is recommended that specialist advice be sought as early as practical. See Section 2.4.3 of the *Theoretical Guide* for more information on bypass evaluations.

A town bypass provides a separation between highway traffic and local commuters. Town bypasses can reduce local congestion, reduce highway traffic travel time, improve safety, reduce noise and increase air quality. This case study will provide a simple example of a town bypass. In this example the only impacts under consideration are road user costs and capital costs.

Note: This module can be used to evaluate projects where some vehicles need to divert around a road due to lack of proper access. For example, a low clearance bridge, or a bridge with a low load capacity, will require some vehicles to divert around the road via an alternative route.



### 5.8.1 Bypass case study

This case study involves the evaluation of a state-controlled highway that passes through a major rural town. Highway traffic passing through the town is delayed by reduced speed limits, congestion and delays at intersections. A proposed bypass of the town will provide TTC savings for highway traffic.

The new road will bypass four discrete sections of road from the existing highway. The sections to be analysed in the case study are shown in Figure 147. These sections currently carry between 4000 and 8000 vehicles per day. Of these, 2000 are passing through the town and are expected to divert to the proposed bypass. A large proportion of the traffic (around 23% of all trips), is for business purposes.

The capital costs of the proposed bypass are $85 million including simple intersection works at either end. In this case study, the effects of the intersection works on users and safety will be marginal. Note: In reality, intersections could be discretely analysed using the 'intersections' module, and combined with the results of the base case and project case sections using 'link projects'.

#### 5.8.1.1 Base case

The main street funnels highway traffic in both directions through the town. The purpose of this project is to divert highway traffic around the town through the construction of a bypass.

The existing route includes four sections. Sections 2 and 3 comprise the main street. Each section has the same model road state but the traffic volumes differ. Sections 1 and 4 have an AADT of 4000, and Sections 2 and 3 have an AADT of 8000. The first and fourth sections are part of the current highway alignment. These are included so that the base case and the project case have common end points.

The maximum speed along the main street is suppressed as a proxy for the impedance of intersections. To do this the 'posted speed limit' is specified at 40 km/h (this speed estimate will vary depending on the project).

Note: The bypass is not an element of the base case because it is at this stage only a proposal. If the bypass took the form of upgrading an existing route, that existing route with its current MRS, condition and traffic would be part of the base case.

#### 5.8.1.2 Project case

The project case contains five sections. The first section is the proposed bypass or new road. The remaining four sections are the existing sections of road passing through the town. On each base case section, 2000 vehicles are assumed to divert to the project case route.

For simplicity, there is no generated traffic in the project case. Bypass projects such as this may generate traffic. Judgement needs to be made about the scope of analysis which can be achieved. It is usually best to leave generated traffic out of the analysis.

For simplicity, intersection effects at either end of the town are negligible.

*Figure 147: Bypass*

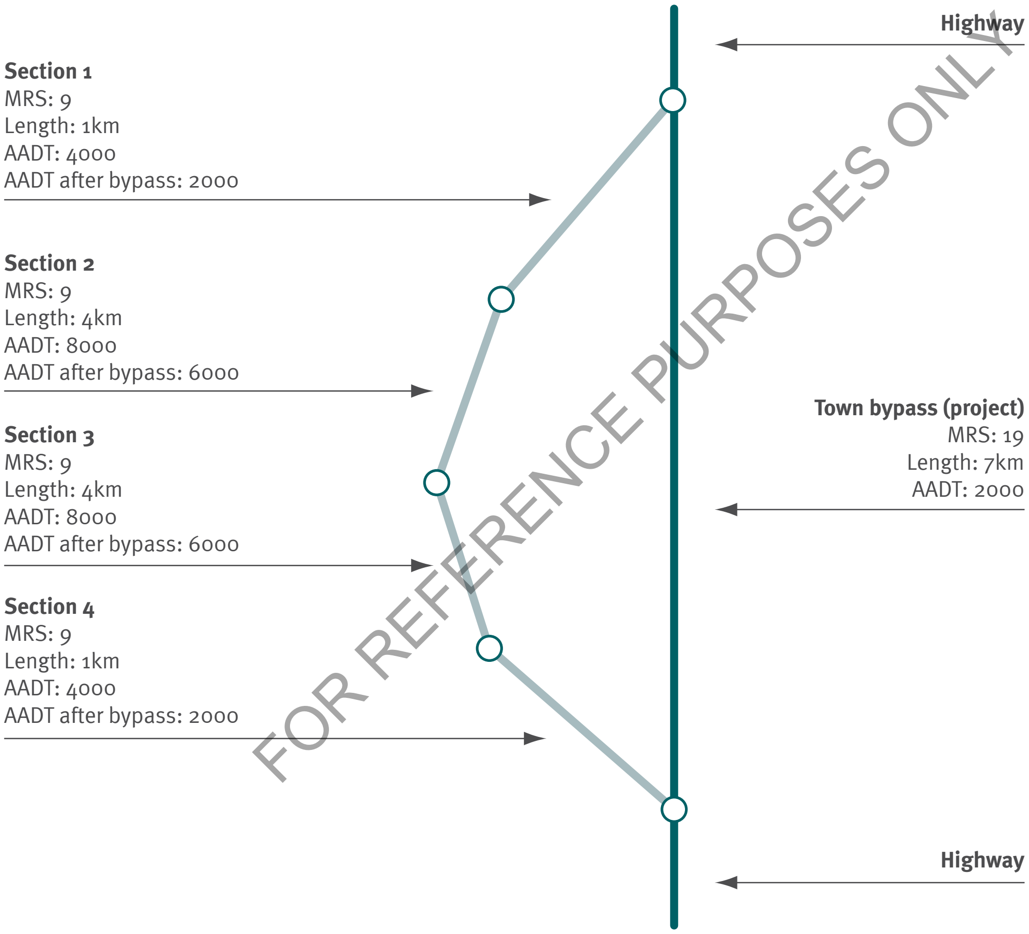





Table 6 shows the sections used in the case study. The first step is to identify the sections or segments making up the base and the project cases. If road descriptions and AADT vary frequently along the routes being evaluated, then the sections will be aggregated on a 'most common characteristics' basis. See Section 2.4.3 of the *Theoretical Guide* for more information on bypass evaluations.

Note: In this simplified case study, the safe operating speed on the existing road is assumed to be 40 for all four sections.

*Table 6: Town bypass base and project case*

| Town bypass | Section 1 | | Section 2 | | Section 3 | | Section 4 | | Bypass | |
|---|---|---|---|---|---|---|---|---|---|---|
| | B | P | B | P | B | P | B | P | B | P |
| Mrs | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | N/a | 15 |
| Section length | 1 | 1 | 4 | 4 | 4 | 4 | 1 | 1 | N/a | 7 |
| Initial roughness | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | N/a | 50 |
| Safe operating speed | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | N/a | 100 |
| Pavement type | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | N/a | 3 |
| Surface type | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | N/a | 4 |
| Horizontal alignment | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | N/a | 1 |
| Vertical alignment | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | N/a | 1 |
| AADT | 4000 | 2000 | 8000 | 6000 | 8000 | 6000 | 4000 | 2000 | 0 | 2000 |
| Private | 82.0% | 88.0% | 82.0% | 84.0% | 82.0% | 84.0% | 82.0% | 88.0% | 0.0% | 76.0% |
| Commercial | 11.0% | 9.0% | 11.0% | 10.3% | 11.0% | 10.3% | 11.0% | 9.0% | 0.0% | 13.0% |
| Non-Aortic | 3.3% | 1.6% | 3.3% | 2.7% | 3.3% | 2.7% | 3.3% | 1.6% | 0.0% | 5.0% |
| Buses | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 0.0% | 1.0% |
| Aortic | 1.1% | 0.2% | 1.1% | 0.8% | 1.1% | 0.8% | 1.1% | 0.2% | 0.0% | 2.0% |
| B-double | 1.6% | 0.2% | 1.6% | 1.1% | 1.6% | 1.1% | 1.6% | 0.2% | 0.0% | 3.0% |
| Rt1 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Rt2 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Growth rate (% pa linear) | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | N/a | 3.0% |

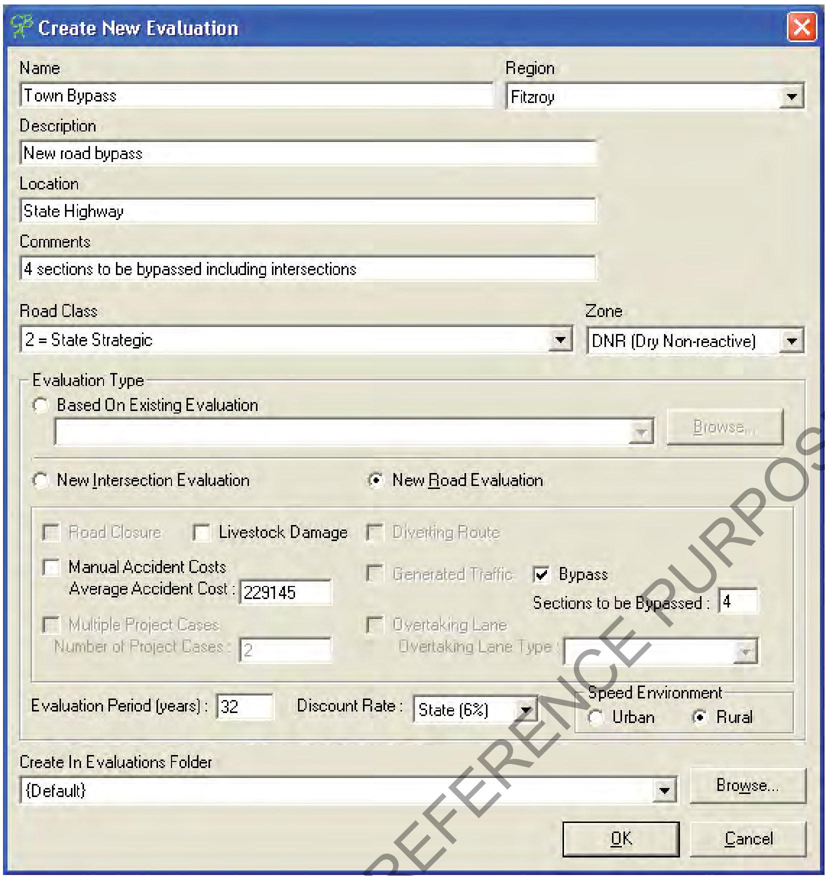
See Section 8.7 of the *Technical Guide* for derivation of AADT calculations.

Note: Bypass costs in the base case are negligible because base case traffic is set to zero (AADT=0).

### 5.8.2 Create new evaluation

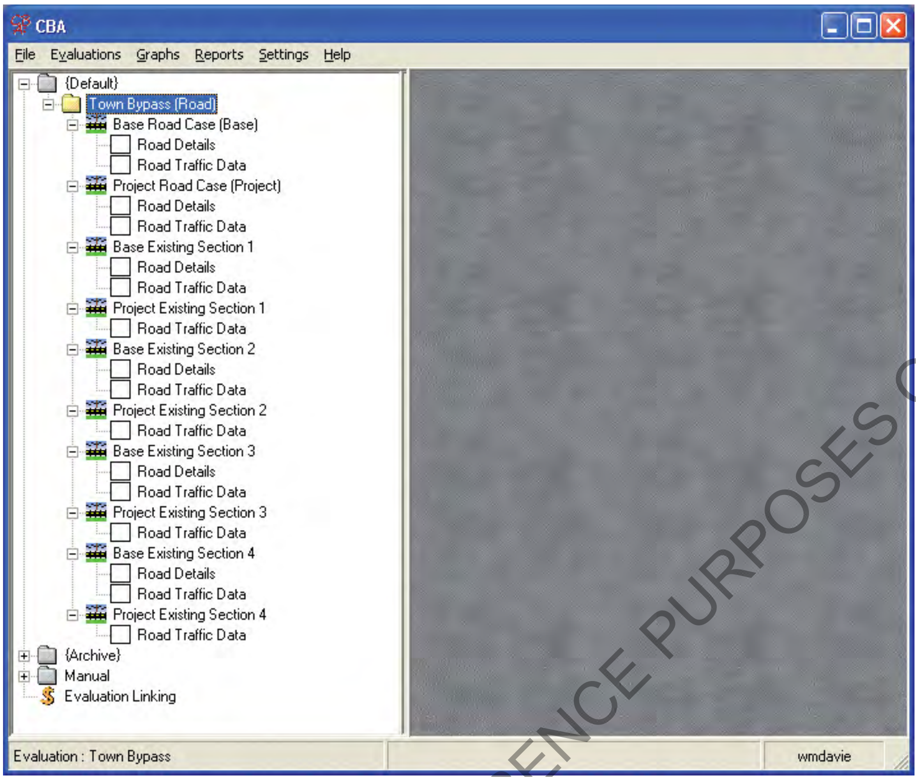
To create a bypass evaluation, the 'bypass' option must be selected. In this case study there will be four sections bypassed. In Figure 148 the bypass box is ticked and '4' has been entered in the 'sections to be bypassed' field.

*Figure 148: Bypass evaluation*



As shown in Figure 148 the bypass evaluation will have a number of data input fields for the various road sections. The new bypass section in the CBA6 node tree is represented by both the 'base road case' and 'project road case' fields. Section 1 in Figure 147 matches the 'base existing Section 1' from Figure 149**,** with other sections following accordingly.

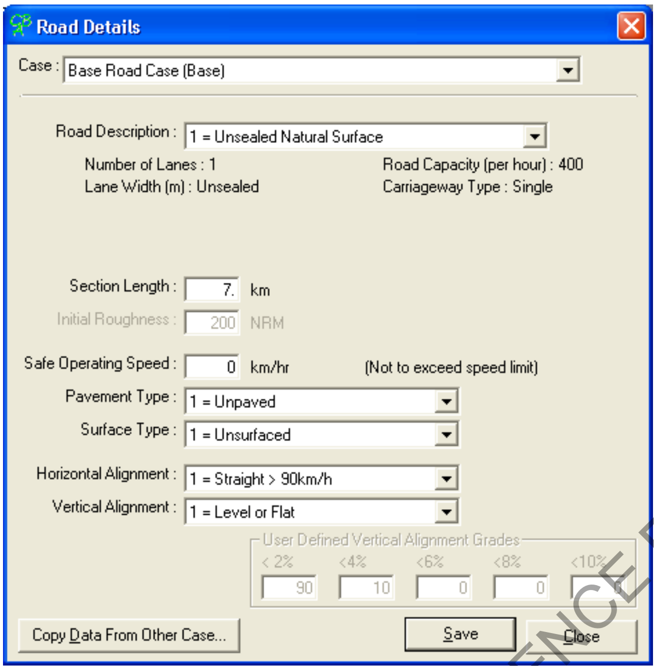
*Figure 149: Bypass workspace*



## 5.8.3 Road details

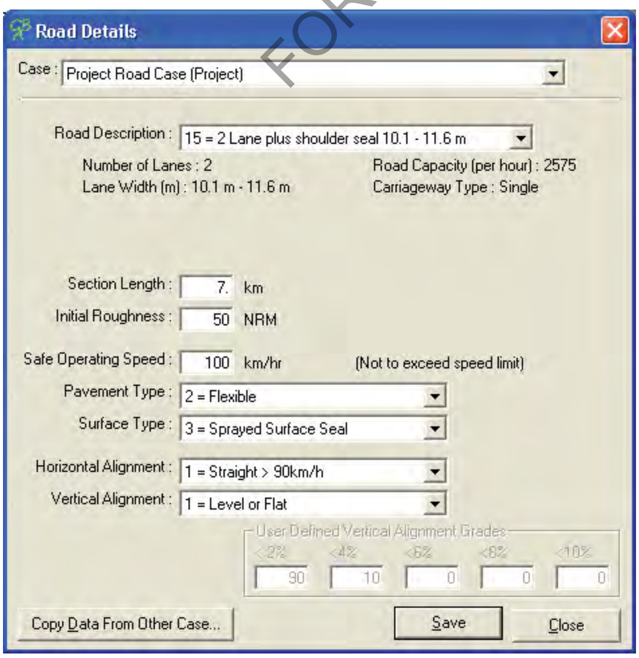
In this case study the bypass will be a newly built road and not an upgrade to an existing route. Therefore, the 'base road case' field is superfluous (likewise the 'road traffic data' screen will show zero traffic). If this project was an upgrade to an existing road the 'road details' screen would need to be correctly completed. For illustrative purposes the base case road details can be entered as shown in Figure 150.

*Figure 150: Bypass base case*




The proposed bypass (project road case) will be a new two-lane highway. Details for the bypass section are shown in Figure 151.

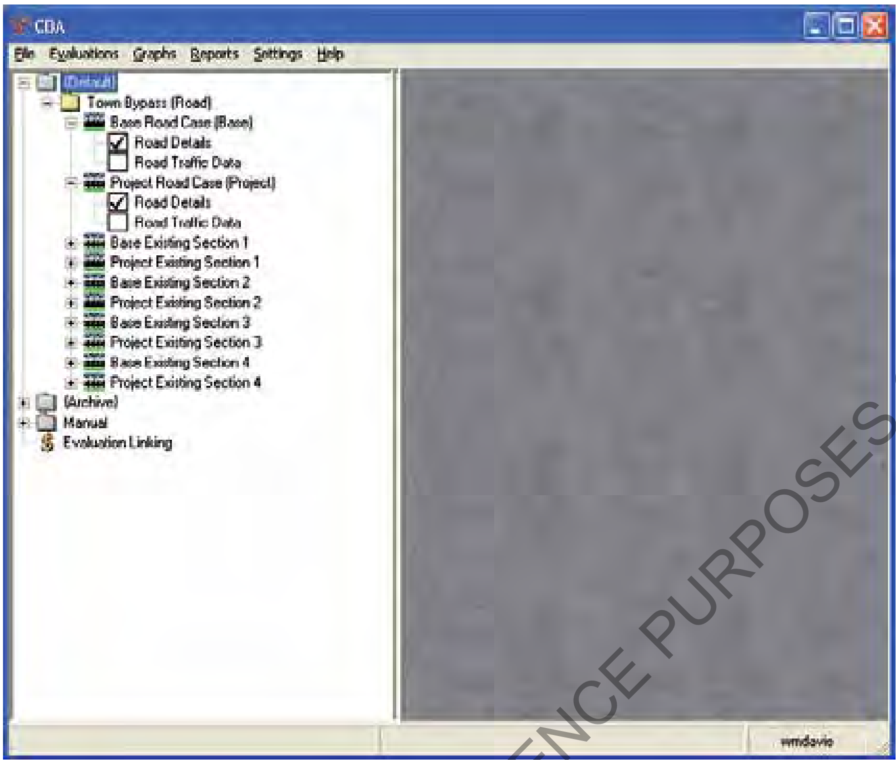
*Figure 151: Bypass road details*



## 5.8.4 Road traffic data

The road traffic data for the bypass is the next input field, see Figure 152.

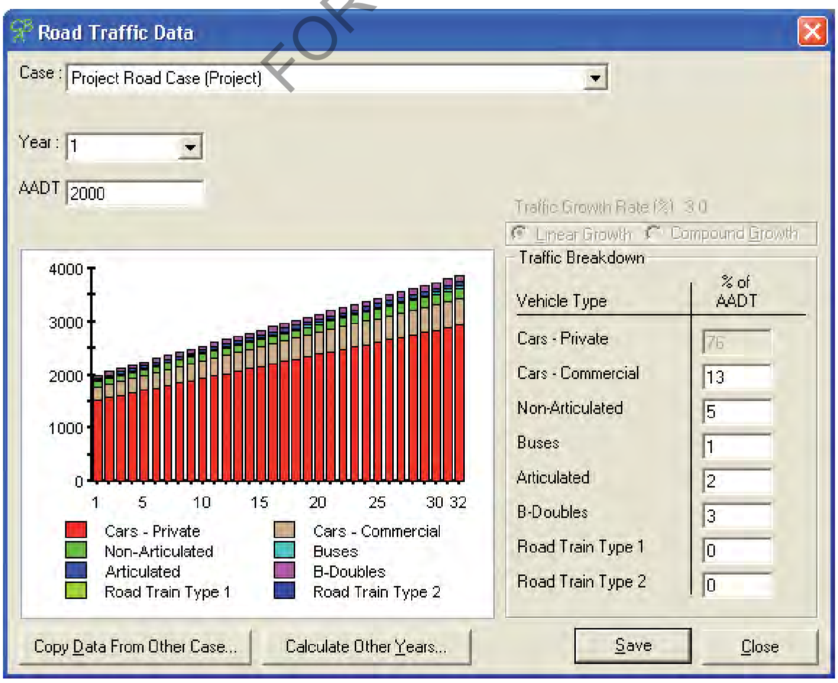
*Figure 152: Bypass road traffic data workspace*






Here the system user is now required to enter the traffic that will divert from the old highway to the new bypass. In Table 5, the breakdown of traffic for the bypass is shown. 2000 vehicles per day will use the new bypass, see Figure 153.

*Figure 153: Traffic on bypass*

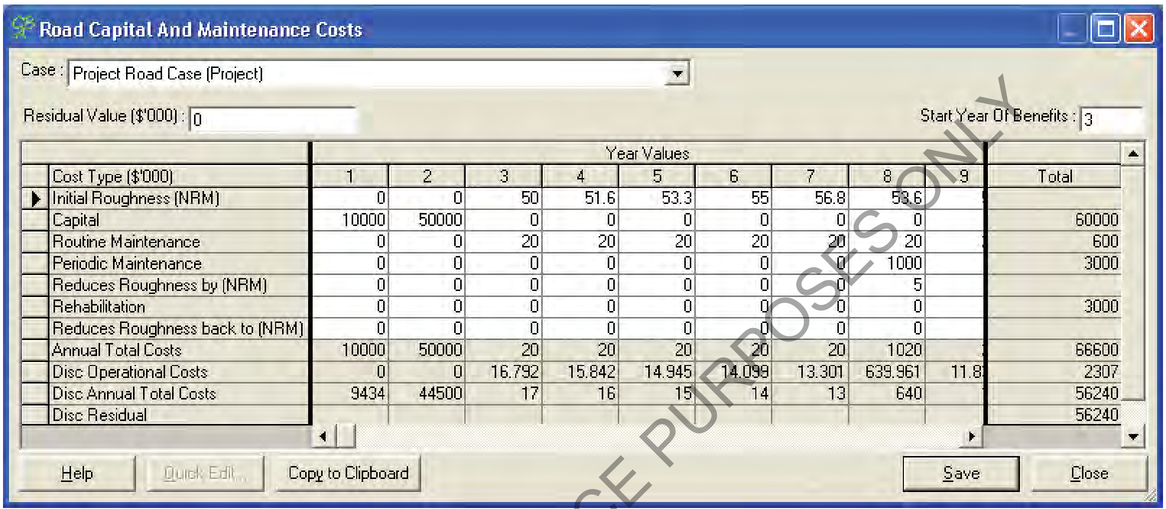


Note: In the base case traffic data screen, 0 must be entered for all years of the evaluation.

## 5.8.5 Capital and maintenance costs

The 'capital and maintenance costs' screen refers to the bypass section only. In the base case maintenance will be $50 000. Roughness deterioration is not calculated in CBA6 for the existing route within the bypass module. The cost to build the new bypass is estimated at $60 million. The new bypass will be resealed every seven years, starting from Year 8 at a cost of $1 million for each reseal with the exception of Year 22. Figure 154 shows the cost forecast for the project.

*Figure 154: Bypass costs*




| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 0 | 50 | 51.6 | 53.3 | 55 | 56.8 | 53.6 | | |
| Capital | 10000 | 50000 | 0 | 0 | 0 | 0 | 0 | 0 | | 60000 |
| Routine Maintenance | 0 | 0 | 20 | 20 | 20 | 20 | 20 | 20 | | 600 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1000 | | 3000 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 3000 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 10000 | 50000 | 20 | 20 | 20 | 20 | 20 | 1020 | | 66600 |
| Disc Operational Costs | 0 | 0 | 16.792 | 15.842 | 14.945 | 14.099 | 13.301 | 639.961 | 11.8 | 2307 |
| Disc Annual Total Costs | 9434 | 44500 | 17 | 16 | 15 | 14 | 13 | 640 | | 56240 |
| Disc Residual | | | | | | | | | | 56240 |

Note: The system user is not required to enter maintenance data for the four existing routes. Maintenance costs for the existing routes are not expected to change between the base and project cases. As a result, the roughness measure on the existing routes will not change between the base and project cases, therefore the net result will be zero.



## 5.8.6 Accident and other costs

Accident costs will be automatically calculated by CBA6. The accident rate on the existing routes will decline due to reduced traffic after the bypass is completed. The accident rate on the new bypass will increase from zero before the bypass is constructed to a positive accident rate after it is opened to traffic. The net result should be an overall reduction in accidents as the bypass is a shorter length compared with the existing routes.

Note: Other costs and benefits relevant to a bypass evaluation may include a reduction in externalities such as noise levels on the existing route, as highway traffic now bypasses local roads and residents. See Section 7 of the *Technical Guide* for further information on calculation of these costs and benefits.

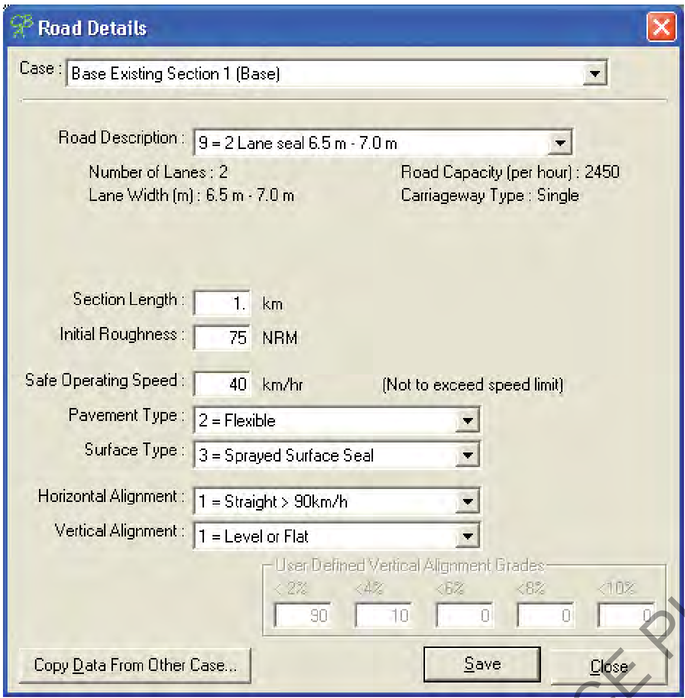
## 5.8.7 Existing sections

The next step after the bypass section details have been completed is to input the data for the existing road sections. The road details and traffic input data for each existing section is shown in Table 6. The input screens for the existing road sections are the same as for previous case studies. With the provision of the bypass, it is assumed that 2000 vehicles will choose to travel along the upgrade (higher throughput and reduced travel cost), while the remaining road users travel along the existing sections (local road users). These 'switching' vehicles are represented in the project case of the bypass in Figure 147.

### 5.8.7.1 Existing Section 1

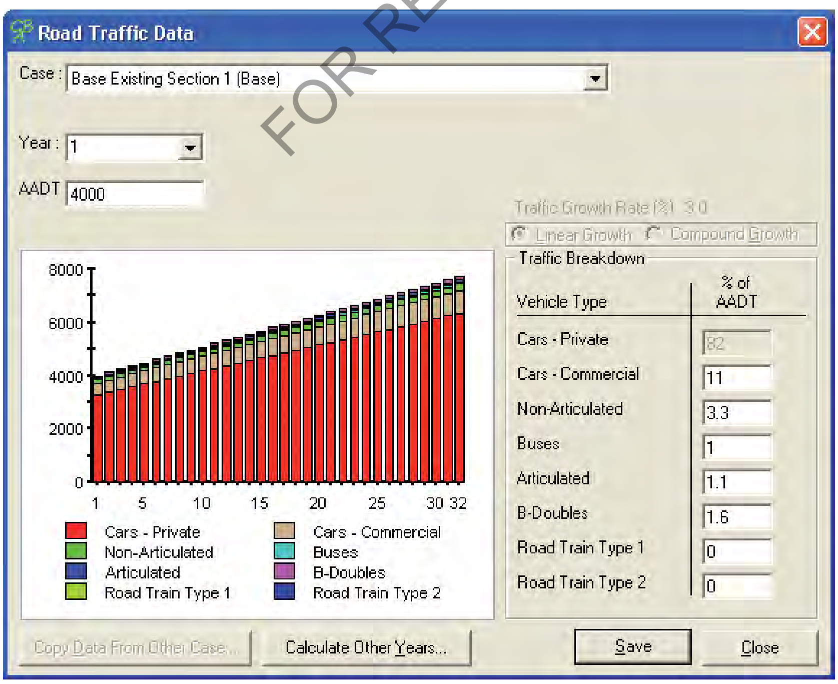
Road details for Section 1 are shown in Figure 155.

*Figure 155: Existing Section 1 road details*




Traffic data for the existing Section 1 in the base case is shown in Figure 156. An estimated average of 4000 vehicles travel on this section every day.

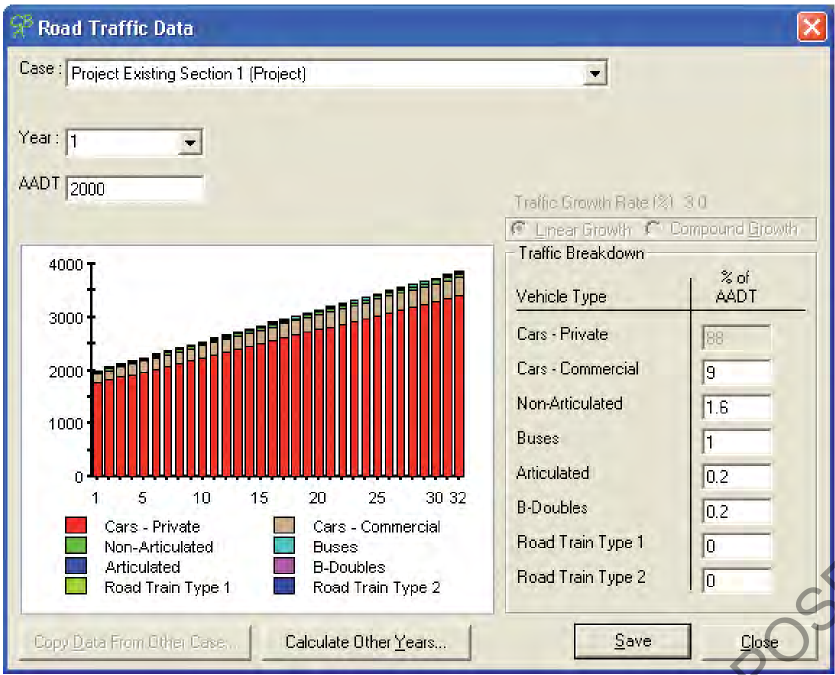
*Figure 156: Existing Section 1 base case traffic*






After the bypass is built, only 2000 vehicles per day will travel on Section 1, see Figure 157.

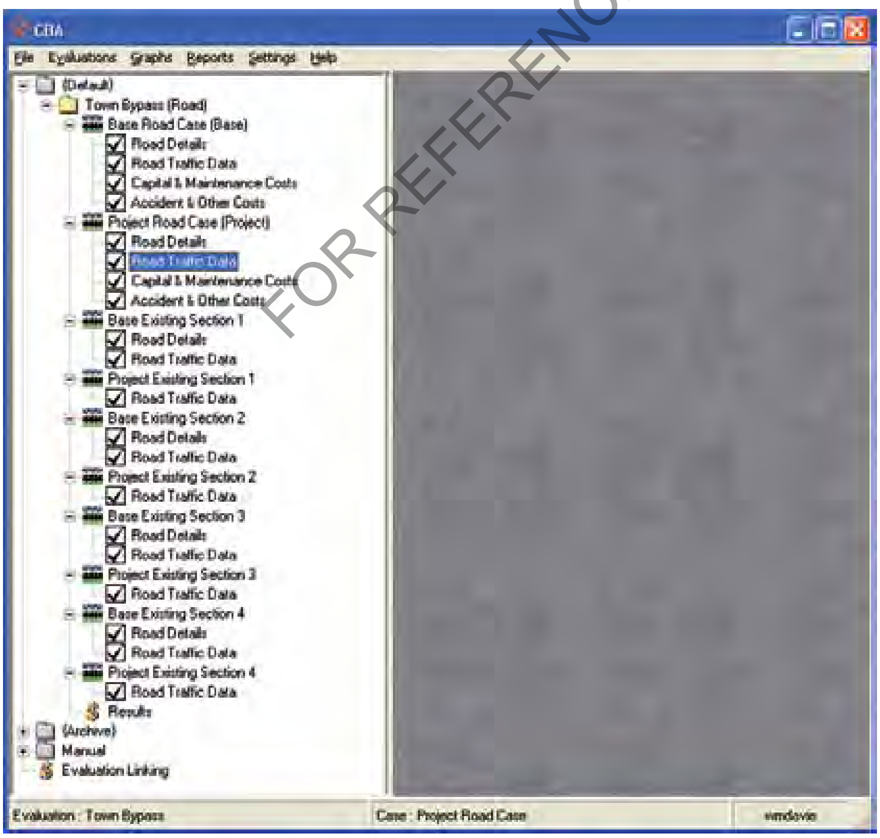
*Figure 157: Existing Section 1 project case traffic*




After all input data has been saved, the results of the bypass evaluation can be calculated, see Figure 158.



*Figure 158: Town bypass workspace*



## 5.8.8 Results and decision criteria

The new $60 million bypass provides a BCR of 1.44 at the 6% discount rate, see Figure 159. The majority of benefits comprise savings in journey time. In the base case, the average speed through the town was 40 km/h which incorporated delays at intersections. The new bypass enables highway traffic to travel at 100 km/h. Commercial vehicles are estimated to gain over $22 million in TTC savings, which satisfies the project objective to better cater for business travel. Around 10% of the project benefits relate to the reduction in accidents through the town. See Section 2.4.3 of the *Theoretical Guide* for more information on bypass evaluations.

*Figure 159: Bypass results*

Results - Decision Criteria Recalc No 7

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 58,141,739 | 55,536,345 | 54,364,331 | 53,262,145 | 51,230,198 |
| Discounted Capital Costs | 55,843,195 | 53,933,784 | 53,017,731 | 52,126,200 | 50,413,223 |
| Discounted Other Costs | 2,298,544 | 1,602,560 | 1,346,600 | 1,135,944 | 816,975 |
| Discounted Benefits | 107,990,809 | 80,232,409 | 69,957,944 | 61,438,312 | 48,337,804 |
| Private TTC Savings | 43,772,571 | 32,623,493 | 28,487,975 | 25,054,042 | 19,763,163 |
| Commercial TTC Savings | 30,799,088 | 22,957,177 | 20,048,376 | 17,633,023 | 13,911,421 |
| Private VOC Savings | 11,824,399 | 8,649,728 | 7,486,205 | 6,527,630 | 5,067,540 |
| Commercial VOC Savings | 10,459,999 | 7,703,333 | 6,688,692 | 5,850,434 | 4,568,378 |
| Discounted Accident Savings | 11,134,752 | 8,298,679 | 7,246,696 | 6,373,182 | 5,027,301 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 49,849,070 | 24,696,064 | 15,593,613 | 8,176,167 | -2,892,394 |
| Net Present Value per dollar Investment | 0.89 | 0.46 | 0.29 | 0.16 | -0.06 |
| Benefit Cost Ratio Excl. Private Time | 1.10 | 0.86 | 0.76 | 0.68 | 0.56 |
| Benefit Cost Ratio | 1.86 | 1.44 | 1.29 | 1.15 | 0.94 |
| First Year Rate of Return | 7.84% | 7.67% | 7.58% | 7.50% | 7.34% |

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Note: For further information on the calculation of bypass benefits, see Section 8.7 of the *Technical Guide*.

## 5.9 Unsealed roads

A large proportion of Queensland's road network comprises unsealed roads; some of these roads have been designated as development roads. Unsealed roads often suffer from corrugation and other surface defects which impact negatively on vehicle ride, speed and safety. Progressively upgrading these roads by sealing the surface will therefore significantly reduce VOC savings and TTC savings. CBA6 values the benefits of road sealing initiatives and also calculates the benefits to livestock transport. Refer to Section 8.6 of the *Technical Guide* for details of livestock calculations.

The primary economic benefits from sealing roads are derived from the reduction in damage to livestock. Other benefits include access to remote areas, especially during the wet season. Rain and flooding can destroy unsealed roads which then require significant costs to rehabilitate. In these instances, a sealed road will have smaller maintenance costs than an unsealed road.

### 5.9.1 Unsealed road case study

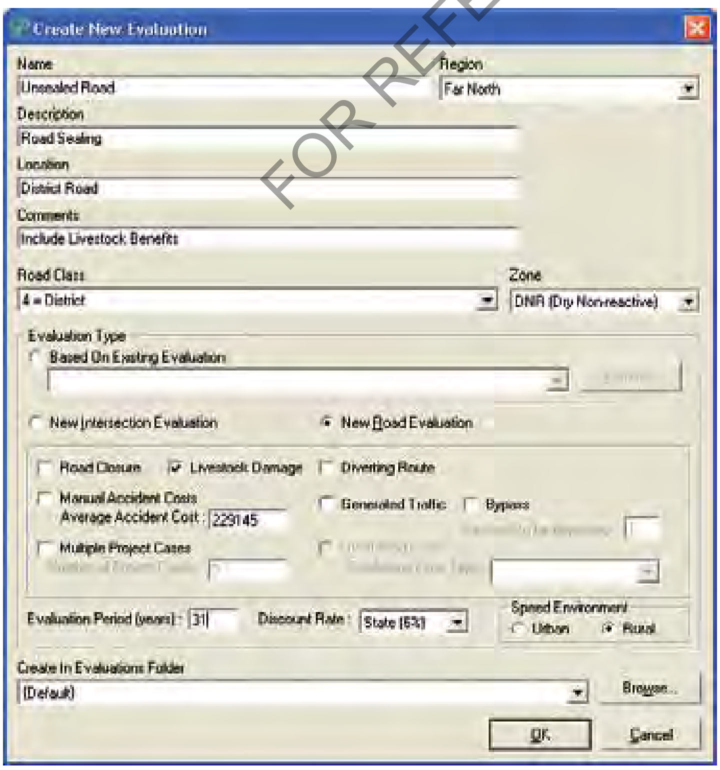
For this case study, it is assumed that connectivity between two remote communities is provided via a 12 km section of unsealed developmental road. The road is not subject to flooding. Sealing the road will provide a better road surface and improved access. This region is reliant on primary production, and consequently there is a high proportion of road train livestock freight in the current vehicle fleet. The AADT for the development road is 125 vehicles per day, 17% of which are road trains. The project will provide a sprayed seal surface with construction occurring over one year at a cost of $6 million.



### 5.9.2 Create new evaluation

This project will benefit livestock operators using the new sealed road. See Section 2.4.4 of the *Theoretical Guide* for further information on livestock impacts. The 'livestock damage' option is ticked as seen in Figure 160. Not all road sealing projects will have livestock benefits. This option should only be used when appropriate.

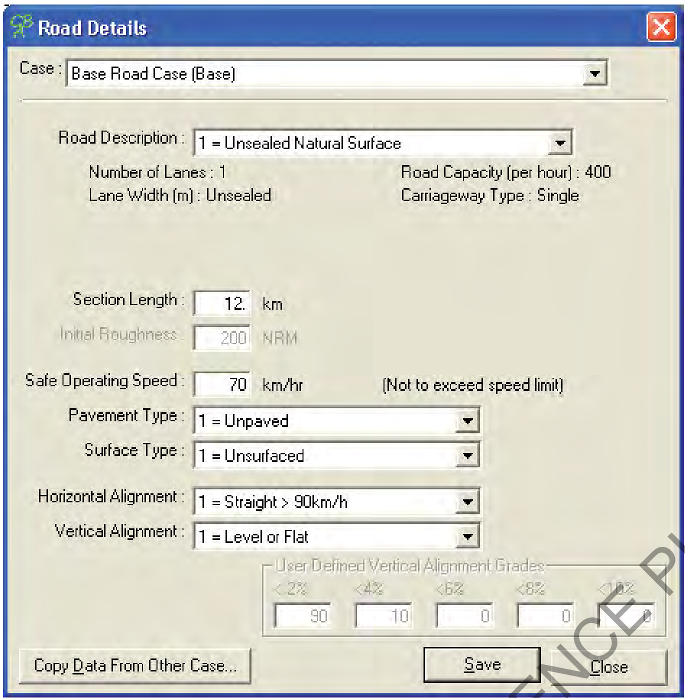
*Figure 160: Unsealed road evaluation*



Note: When the livestock damage option is selected, CBA6 will automatically assign the aprioriate options of MRS available for the base case.

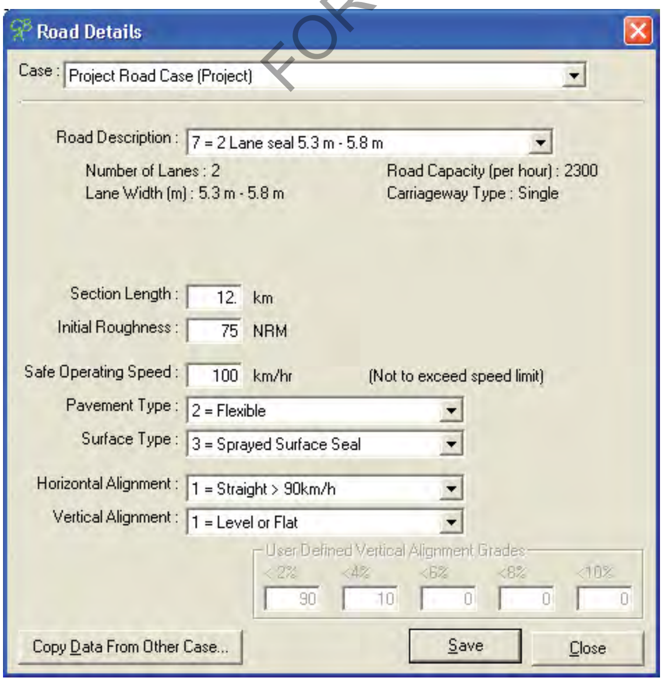
### 5.9.3 Road details

*Figure 161: Unsealed road in the base case*




The project case will provide a new sprayed surface road. Details for the project case are shown in Figure 162. The improved road surface enables an increase in the safe operating speed.

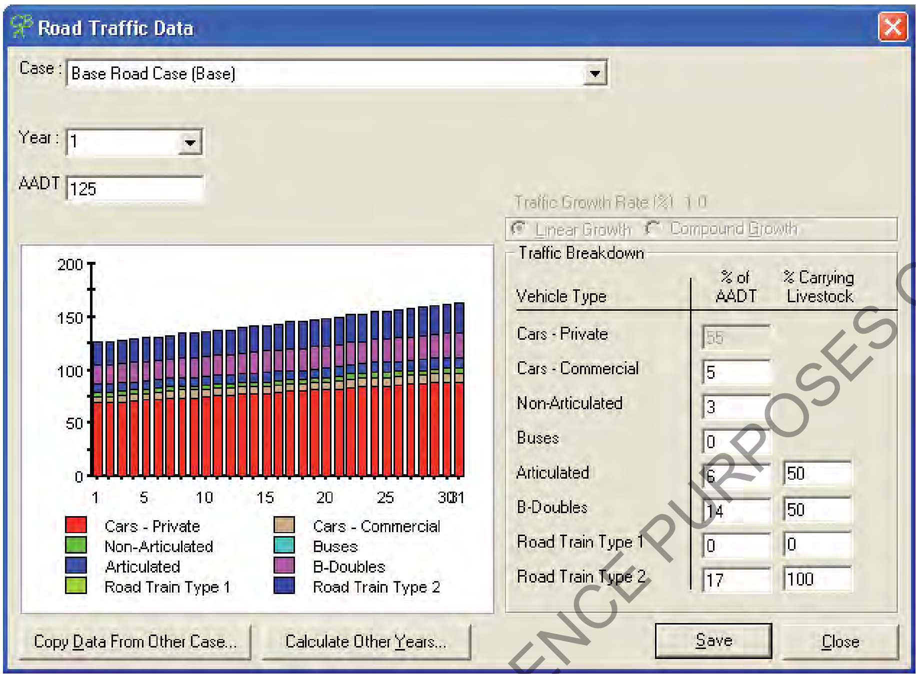
*Figure 162: Sealed project case*



## 5.9.4 Road traffic data

The ‘road traffic data’ screen for road sealing projects is different from other case studies. CBA6 requires data on the proportion of heavy vehicles carrying livestock. The base case traffic data is shown in Figure 163. It is assumed that all road trains carry livestock while only half of the articulated and B-double vehicles transport livestock. Annual traffic growth is 1% linear and traffic data will remain the same between the base and project cases.

*Figure 163: Unsealed road traffic data with livestock*

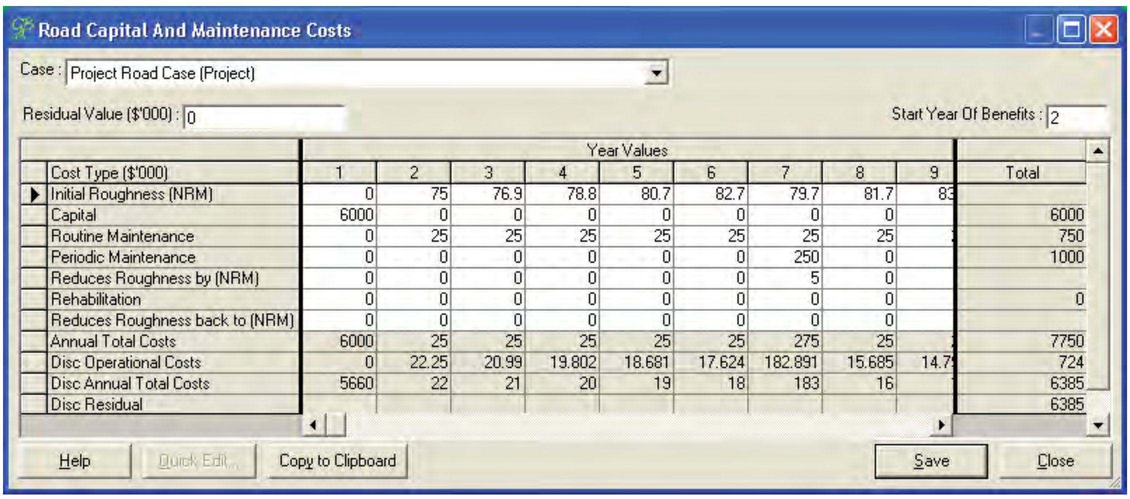





## 5.9.5 Capital and maintenance costs

Routine maintenance costs in the base case are $20 000 per year. The estimated capital cost for the project is $6 million with routine maintenance of $25 000 per year. Periodic maintenance will occur every 7 years which will reduce roughness by 5 NRM. Project case costs are shown in Figure 164.

*Figure 164: Sealed road costs*




| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 75 | 76.9 | 78.8 | 80.7 | 82.7 | 79.7 | 81.7 | 83 | |
| Capital | 6000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 6000 |
| Routine Maintenance | 0 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | | 750 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 250 | 0 | | 1000 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 6000 | 25 | 25 | 25 | 25 | 25 | 275 | 25 | | 7750 |
| Disc Operational Costs | 0 | 22.25 | 20.99 | 19.802 | 18.681 | 17.624 | 182.891 | 15.685 | 14.7 | 724 |
| Disc Annual Total Costs | 5660 | 22 | 21 | 20 | 19 | 18 | 183 | 16 | | 6385 |
| Disc Residual | | | | | | | | | | 6385 |

## 5.9.6 Accident and other costs

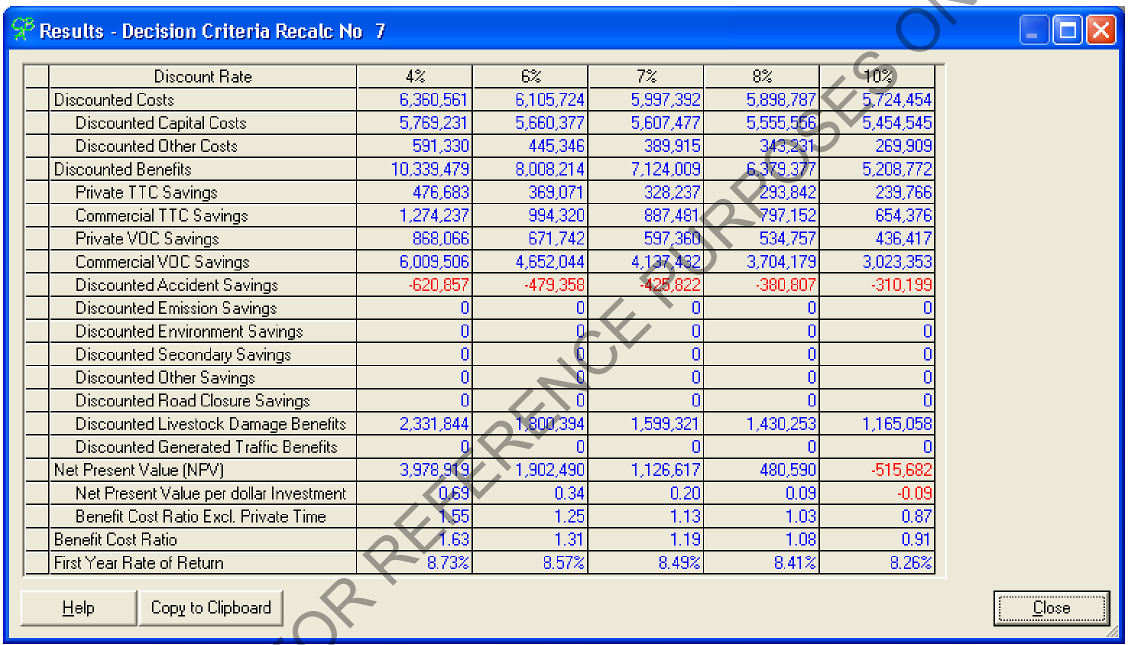
Accident costs are calculated automatically by CBA6 in the base and project cases. As the primary aim of this project is to seal an unsealed road, accident cost savings do not comprise a major benefit.

## 5.9.7 Results and decision criteria

The sealed road project has a BCR of 1.32 at the 6% discount rate. The FYRR is high at 8.6% indicating that the project need not be delayed.

The majority of project benefits accrue from savings in VOC for commercial vehicles. This is not surprising given the condition of an unsealed road. A new sealed road will provide a much smoother ride for freight vehicles. There are also significant livestock benefits for transport operators with savings of around $1.8 million in livestock damage costs.

*Figure 165: Sealed road results*



Results - Decision Criteria Recalc No 7

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 6,360,561 | 6,105,724 | 5,997,392 | 5,898,787 | 5,724,454 |
| Discounted Capital Costs | 5,769,231 | 5,660,377 | 5,607,477 | 5,555,556 | 5,454,545 |
| Discounted Other Costs | 591,330 | 445,346 | 389,915 | 343,231 | 269,909 |
| Discounted Benefits | 10,339,479 | 8,008,214 | 7,124,009 | 6,379,377 | 5,208,772 |
| Private TTC Savings | 476,683 | 369,071 | 328,237 | 293,842 | 239,766 |
| Commercial TTC Savings | 1,274,237 | 994,320 | 887,481 | 797,152 | 654,376 |
| Private VOC Savings | 868,066 | 671,742 | 597,360 | 534,757 | 436,417 |
| Commercial VOC Savings | 6,009,506 | 4,652,044 | 4,137,432 | 3,704,179 | 3,023,353 |
| Discounted Accident Savings | -620,857 | -479,358 | -425,822 | -380,807 | -310,199 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 2,331,844 | 1,800,394 | 1,599,321 | 1,430,253 | 1,165,058 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 3,978,919 | 1,902,490 | 1,126,617 | 480,590 | -515,682 |
| Net Present Value per dollar Investment | 0.69 | 0.34 | 0.20 | 0.09 | -0.09 |
| Benefit Cost Ratio Excl. Private Time | 1.55 | 1.25 | 1.13 | 1.03 | 0.87 |
| Benefit Cost Ratio | 1.63 | 1.31 | 1.19 | 1.08 | 0.91 |
| First Year Rate of Return | 8.73% | 8.57% | 8.49% | 8.41% | 8.26% |





Note: The 'discounted accident savings' row shows disbenefits for accidents. This implies that there will be an increase in accidents in the project case. CBA6 uses data from around the state to determine the accident rate for certain road types to form a representative state average. In this example, the accident frequency of an MRS 1 is less than on an MRS 7. As with every case study, if site specific data exists, the system user should manually calculate accident costs by selecting the 'manual accident cost' option in the 'create new evaluation' screen.

# 5.10 Generated traffic

AADT is normally the same for both the base and project cases. Generated traffic is managed as a separate node and is the additional number of trips expected to be made by road users in response to perceived reductions in costs from a proposed road project initiative. The extent of generated traffic depends upon the sensitivity of road travel to a change in the perceived costs of road travel along a particular route.

CBA6 calculates generated traffic benefits by estimating the increase in consumer surplus attributed to the upgrade. This method of deriving generated traffic benefits is referred to as the 'rule of half' as the gain in the consumer surplus forms a triangle. For more information on generated traffic, see Section 2.4.2 of the *Theoretical Guide*.

## 5.10.1 Generated traffic case study

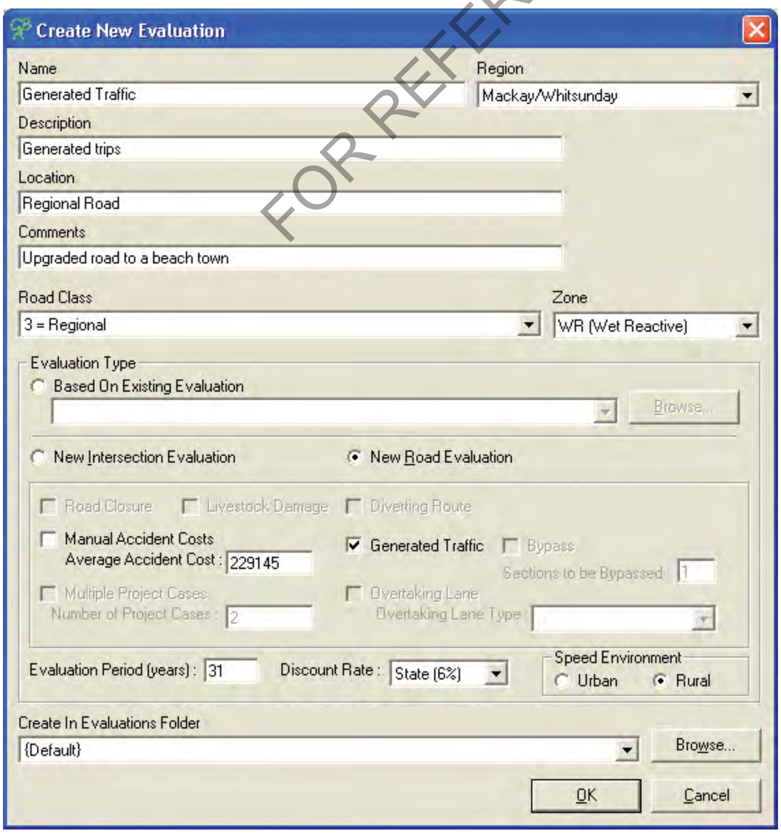
This case study will show a simplified example of generated traffic. In this example, access to a coastal community is only available by a poorly designed narrow road. The condition of the current road results in a slow trip to the community from the main highway. Economic growth is constricted due to lack of proper access. TMR proposes a significant upgrade to the existing road. The new road is anticipated to generate an additional 150 trips per day in the first year of opening. Savings in TTC is the main reason for increased demand in road traffic.

Note: CBA6 only calculates benefits to road users and assumes that the savings in road user costs will be passed on to the community. Therefore additional benefits are implicitly calculated through TTC savings and VOC savings. Additional flow-on effects beyond these benefits should be calculated by an economist.

## 5.10.2 Create new evaluation

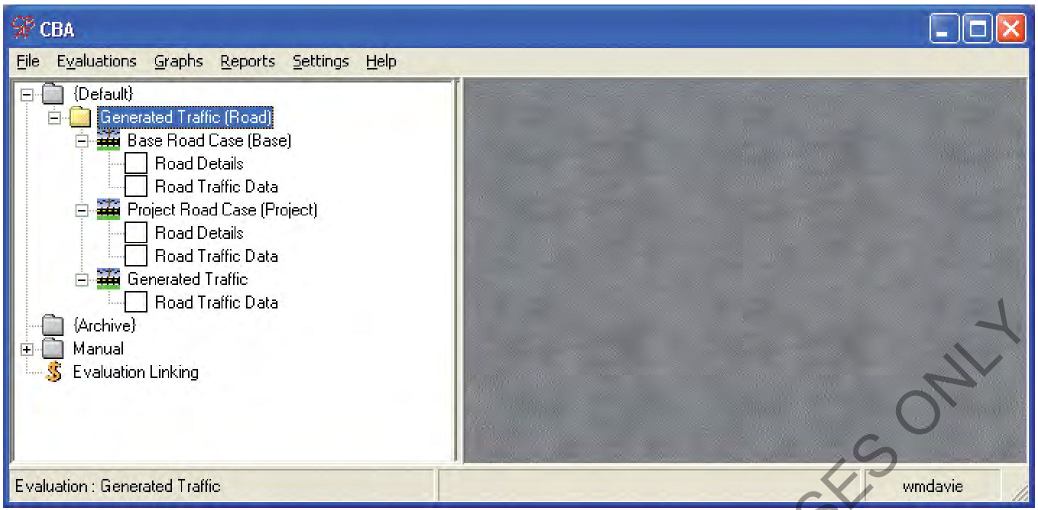
To create a generated traffic evaluation the 'generated traffic' option must be selected as shown in Figure 166.

*Figure 166: Generated traffic evaluation*



The generated traffic node tree is different to other case studies, see Figure 167. The 'generated traffic' data screen requires the system user to enter the estimated number of increased trips made per day.

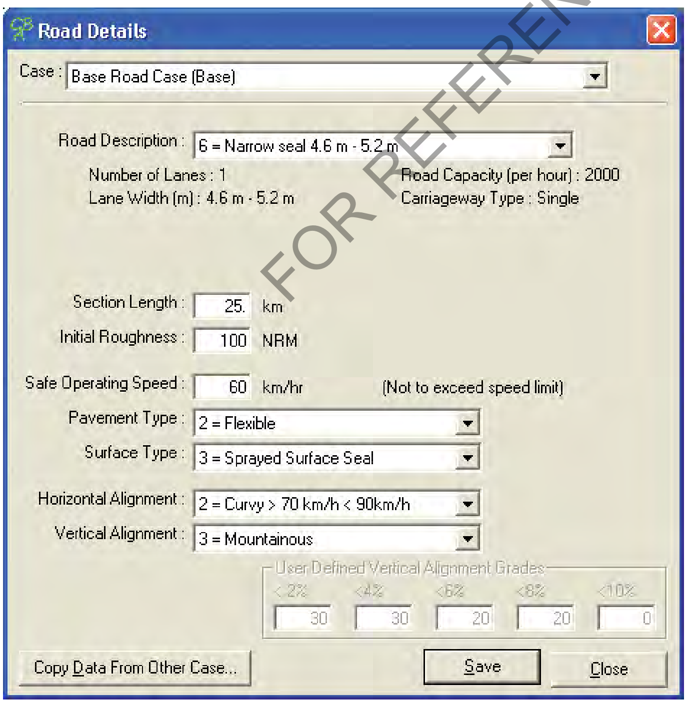
*Figure 167: Generated traffic workspace*




## 5.10.3 Road details

The road details for the current road are shown in Figure 168. The base case is a narrow road with poor horizontal and vertical alignment.

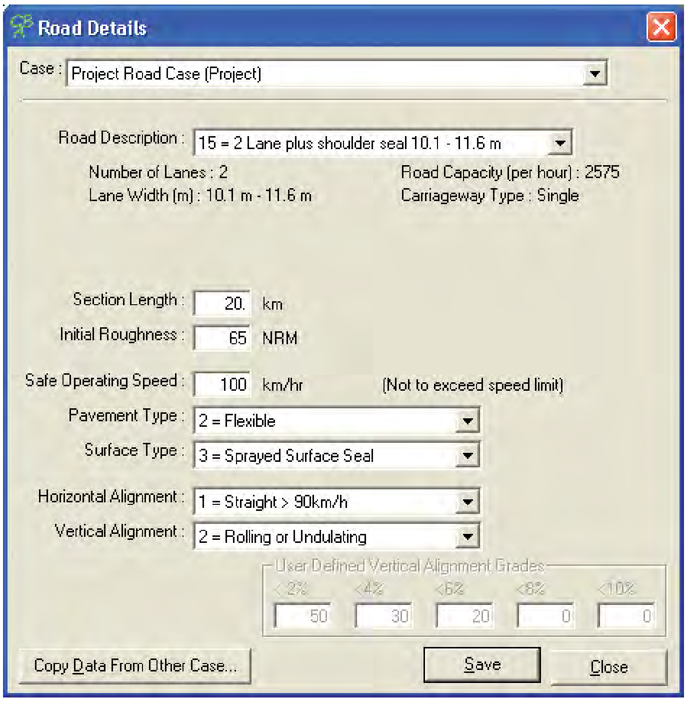
*Figure 168: Base case road to coastal town*






The new road will provide a safer alignment which reduces the length of the journey. With a safer horizontal alignment, the speed limit is increased to 100 km/h. The realignment of the old road reduces the journey length for road users. This will stimulate additional demand for the road. Project case road details are shown in Figure 169.

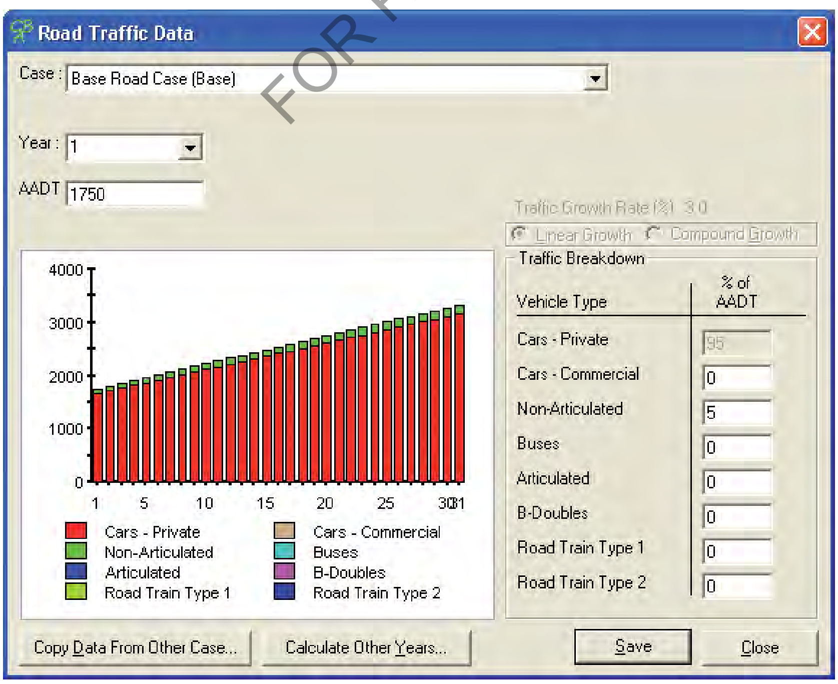
*Figure 169: Project case road details*




## 5.10.4 Road traffic data

The 'road traffic data' screen is used to specify existing traffic demand, therefore the base and project cases traffic data remain the same. The additional trips made when the project is complete will be entered in the 'generated traffic' node. Existing traffic demand is shown in Figure 170.

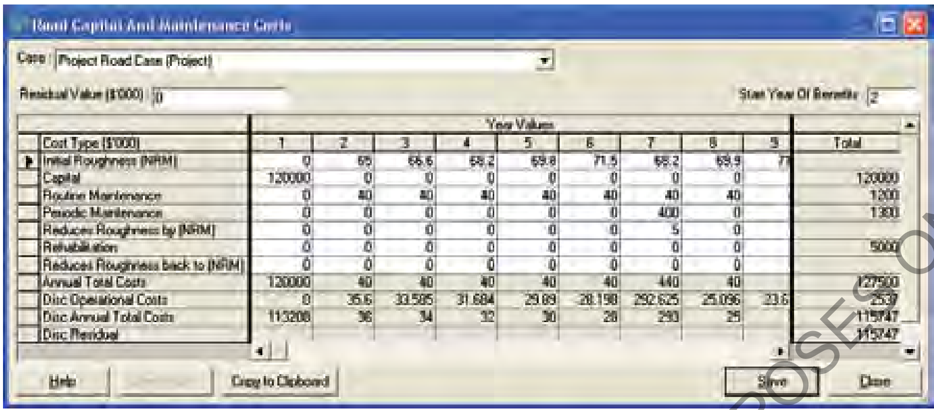
*Figure 170: Existing traffic demand*



## 5.10.5 Capital and maintenance costs

Base case routine maintenance costs are $50 000 per year. Routine maintenance in the project case is estimated at only $40 000 per year. This is due to the shorter road length. The estimated capital cost for the project is $120 million with periodic maintenance of $400 000 for Years 7, 14 and 28. Periodic maintenance will reduce roughness by 5 NRM. Rehabilitation of the new road will occur in Year 21 costing $5 million. This will reduce roughness to a level of 70 NRM. Figure 171 shows the project case costs. Base case costs can be found in Appendix A.

*Figure 171: New road costs*



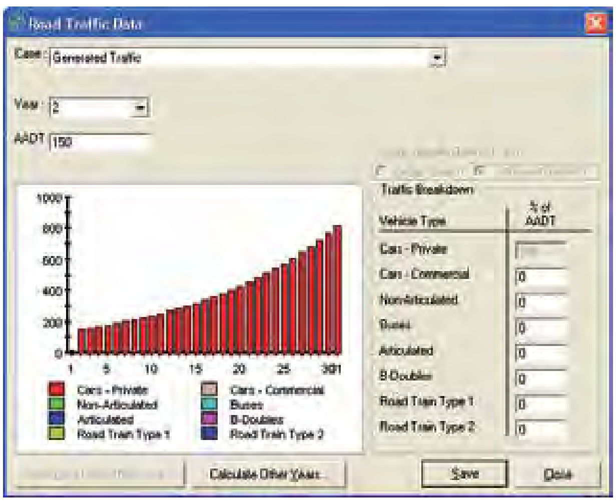

## 5.10.6 Accident and other costs

Accident costs will be automatically calculated by CBA6. These costs should reduce in the project case given the reduction in the distance road users have to travel, and the improvement in the model road state.

## 5.10.7 Generated traffic

It is anticipated that the new road will generate an additional 150 trips by private commuters. Demand is expected to increase each year at 6% from Year 2 (first year of operation). Figure 172 shows the generated traffic demand for the new road. In this example, compound growth has been used to simulate the increasing growth each year. The decrease in travel time to the coastal town is the main reason for increased demand for the road.

*Figure 172: Generated traffic*



## 5.10.8 Results and decision criteria

The new road provides significant TTC savings and VOC savings to existing traffic. Road users who had previously used the old road in the base case, now receive TTC savings of $46 million at the 6% discount rate. The project BCR is 1.13 and the NPV is positive at $13.9 million, see Figure 173.

The additional benefit which is attributed to those generated trips using the new road is $5.3 million. By improving access to the coastal community and thereby lowering road user costs, the project generated an additional 4% worth of economic benefits (generated benefits as a proportion of total benefits).

*Figure 173: Generated traffic results*

Results - Decision Criteria Recalc No 22

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 112,603,563 | 110,912,329 | 110,064,744 | 109,217,105 | 107,525,571 |
| Discounted Capital Costs | 115,384,615 | 113,207,547 | 112,149,533 | 111,111,111 | 109,090,909 |
| Discounted Other Costs | -2,781,053 | -2,295,218 | -2,084,789 | -1,894,006 | -1,565,338 |
| Discounted Benefits | 164,557,161 | 124,833,247 | 109,968,998 | 97,560,465 | 78,300,352 |
| Private TTC Savings | 58,230,257 | 44,221,381 | 38,975,172 | 34,593,520 | 27,787,846 |
| Commercial TTC Savings | 3,445,591 | 2,625,860 | 2,317,920 | 2,060,206 | 1,658,753 |
| Private VOC Savings | 43,088,639 | 32,854,044 | 29,011,012 | 25,795,540 | 20,787,867 |
| Commercial VOC Savings | 8,687,319 | 6,608,565 | 5,829,244 | 5,177,873 | 4,165,036 |
| Discounted Accident Savings | 43,746,490 | 33,210,711 | 29,265,720 | 25,971,182 | 20,854,836 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 7,358,865 | 5,312,685 | 4,569,930 | 3,962,144 | 3,046,013 |
| Net Present Value (NPV) | 51,953,598 | 13,920,918 | -95,746 | -11,656,639 | -29,225,219 |
| Net Present Value per dollar Investment | 0.45 | 0.12 | 0.00 | -0.10 | -0.27 |
| Benefit Cost Ratio Excl. Private Time | 0.94 | 0.73 | 0.65 | 0.58 | 0.47 |
| Benefit Cost Ratio | 1.46 | 1.13 | 1.00 | 0.89 | 0.73 |
| First Year Rate of Return | 5.87% | 5.76% | 5.71% | 5.66% | 5.55% |

Help | Copy to Clipboard | Close

The generated traffic module has an additional result screen called 'generated traffic benefits', see Figure 174. System users can view this screen to see the yearly flow of generated traffic benefits. In this case study it can be seen that private vehicle generated traffic benefits accrue from Year 2.

*Figure 174: Generated traffic benefits*

Total Generated Traffic Benefits

| VehicleGroup | Year1 | Year2 | Year3 | Year4 | Year5 | Year6 | Year7 | Year8 | Year9 | Year10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Private GTB | 0 | 202,018 | 214,246 | 227,160 | 240,788 | 255,332 | 271,014 | 287,495 | 304,802 | 323,020 |
| Cars - Private | 0 | 202,018 | 214,246 | 227,160 | 240,788 | 255,332 | 271,014 | 287,495 | 304,802 | 323,020 |
| Commercial GTB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cars - Commercial | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Non-Articulated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Buses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Articulated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B-Doubles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Road Train Type 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Road Train Type 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total GTB | 0 | 202,018 | 214,246 | 227,160 | 240,788 | 255,332 | 271,014 | 287,495 | 304,802 | 323,020 |
| Discounted Tot GTB | 0 | 179,795 | 179,885 | 179,932 | 179,931 | 179,959 | 180,240 | 180,378 | 180,412 | 180,373 |

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# 5.11 Changes in multi-combination vehicle access

Multi-combination vehicles (MCVs) are an increasingly important component of the road transport industry. An MCV is a large vehicle with at least two articulations. Examples include B-doubles and road trains, as well as many new innovative configurations such as B-triples and AAB-quads. For the road transport industry, MCVs can make an important contribution to improving overall industry efficiency.

CBA6 can be used to estimate the economic efficiency gains that arise as more of the network becomes accessible to multi-combination vehicles, including initiatives according to TMR's higher mass limits policy.

This case study explains how to use CBA6 for that purpose. It is important to note that simply redistributing the heavy vehicle composition between vehicle types while retaining the same total heavy vehicle proportion is not a reliable method of estimating the benefits of improved MCV access. The traffic composition data must first be manipulated outside the model.

This case study shows how to manipulate the traffic composition data and then analyse the benefits of improved freight efficiency using CBA6. For more information on freight efficiency, see Section 5.3 of the *Theoretical Guide*.



## 5.11.1 MCV case study

This case study involves upgrading an existing road to allow access by larger freight vehicles such as road trains. An improved width is required to allow type 2 road trains to operate on this road. In this case study, it is proposed that a section of road is widened to increase road train access from type 1 to type 2.

Table 7 shows the MCV semi-trailer equivalents.

*Table 7: Semi trailer equivalents*

| MCV | Semi – trailer equivalent |
|---|---|
| B-doubles | 1.55 times the payload of a semi-trailer |
| Type 1 road train | 2 times the payload of a semi-trailer |
| Type 2 road train | 3 times the payload of a semi-trailer |

*Source: TMR (2009).*

Table 8 shows how traffic composition will change when the road is opened to type 2 road train access.

*Table 8: Change in access*

| Vehicle type | Base case | | | Project case | | | |
|---|---|---|---|---|---|---|---|
| | AADT | % of total AADT | Semi trailer equivalents | Freight task % | Semi trailer equivalents | AADT | % of total AADT |
| Private cars | 252 | 48.90% | - | - | - | 252 | 51.35% |
| Commercial cars | 108 | 21.00% | - | - | - | 108 | 22.01% |
| Non-Articulated | 31 | 6.00% | - | - | - | 31 | 6.32% |
| Buses | 5 | 1.00% | - | - | - | 5 | 1.02% |
| Articiculated | 52 | 10.10% | 52 | 15.00% | 27.560959 | 27.560959 | 5.62% |
| B-doubles | 5 | 1.00% | 7.739726 | 5.00% | 9.1869863 | 5.9349558 | 1.21% |
| Road trains type 1 | 62 | 12.00% | 124 | 40.00% | 73.49589 | 36.747945 | 7.49% |
| Road trains type 2 | 0 | 0.00% | 0 | 40.00% | 73.49589 | 24.49863 | 4.99% |
| Total | 515 | 100.00% | 183.73973 | 100.00% | 183.73973 | 490.74249 | 100.00% |

Note: AADT values are rounded to whole numbers.

In the base case, the road allows for type 1 road trains. Semi-trailer equivalents are used as a proxy for the heavier vehicle types. This results in the calculated load being 183.74 semi-trailers. The values from which the semi-trailer equivalents are calculated are shown in Table 7. As an example, there are 5 B-doubles in the base case. Because a B-double carries 1.55 times the load (in tonnes) of a semi-trailer, the semi-trailer equivalents value is calculated using the formula:

5 B-doubles x 1.55 = 7.75 semi-trailer equivalents

In the project case, the total semi-trailer equivalents of the base case (183.74) has to be shared between the four vehicle types. The first assumption relates to the proportion of the freight task that will be undertaken by each vehicle type. In this example, semi-trailers are assumed to account for 15% of all freight carried by heavy vehicles in the project case.

The formula for estimating the semi-trailer equivalents to be carried by semi-trailers is:

0.15 x 183.74 = 27.56

For B-doubles the calculation in this example is:

0.05 x 183.74 = 9.19

The same calculations are made for type 1 and type 2 road trains, which in this example are each assumed to carry 40% of all heavy freight on the road. At the completion of these calculations, the total semi-trailer equivalents must be the same in the base and project cases (183.74).

Next, convert the semi-trailer equivalents into the actual vehicle composition in the project case. For semi-trailers, the number of vehicles equals the number of semi-trailer equivalents (that is, the conversion factor is one).

To estimate the number of:

- B-doubles, divide semi-trailer equivalents by 1.55
- type 1 road trains, divide semi-trailer equivalents by 2
- type 2 road trains, divide semi-trailer equivalents by 3.

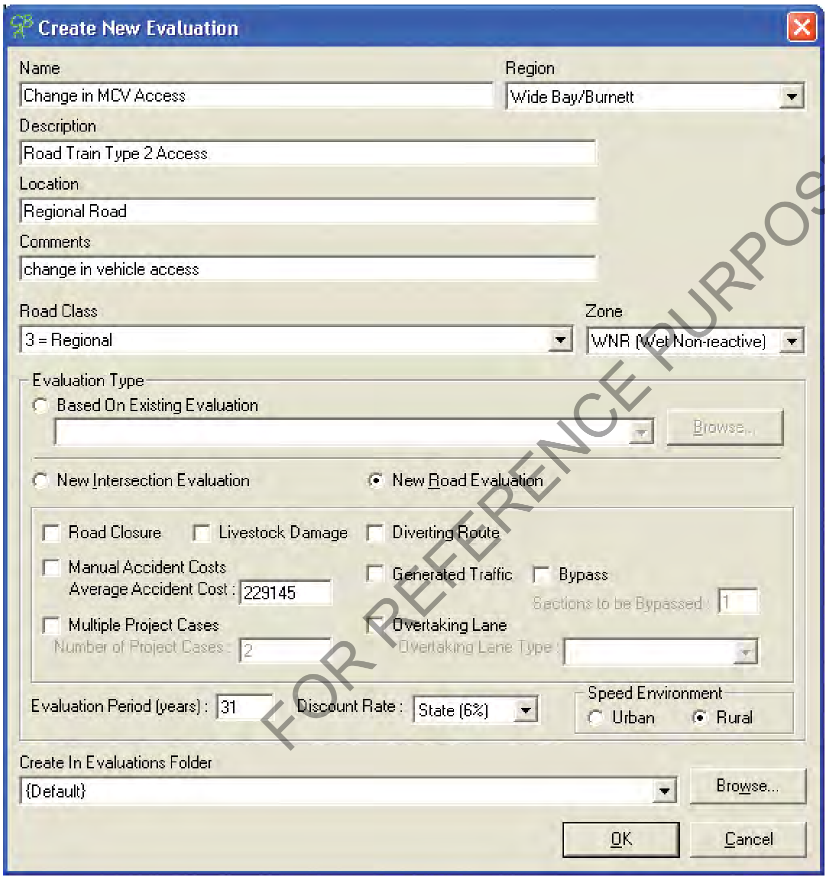
Having completed this conversion, calculate the total project case AADT (494 vehicles in the example), and use this to calculate traffic composition as a percentage of total AADT.

The percentages of total AADT for each vehicle type for base and project cases are entered into the 'road traffic data' screen in CBA6. The effect of the increase in road train status is to reduce AADT from the base case to the project case, thereby increasing the benefits.

### 5.11.2 Create new evaluation

The 'create new evaluation' screen for this case study is shown in Figure 175. No advanced modules need to be selected to create a multi-combination vehicle access evaluation.

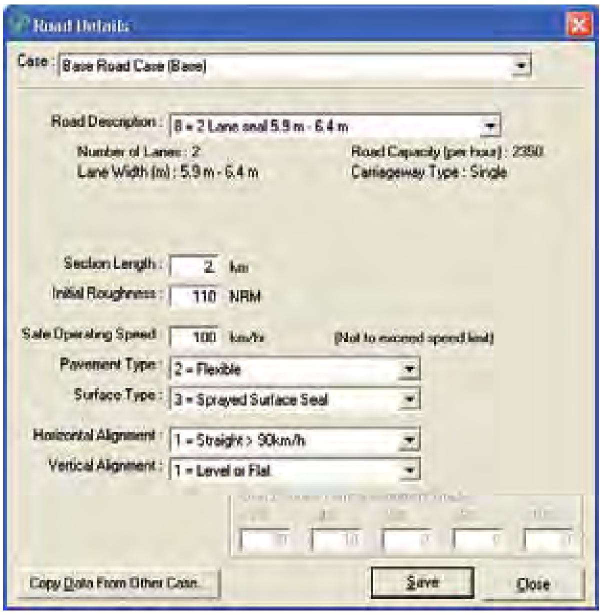
*Figure 175: Change in MCV evaluation*



## 5.11.3 Road details

The road details for the current road are shown in Figure 176. The base case is a narrow 5.9 m sealed road that does not allow access for type 2 road trains.

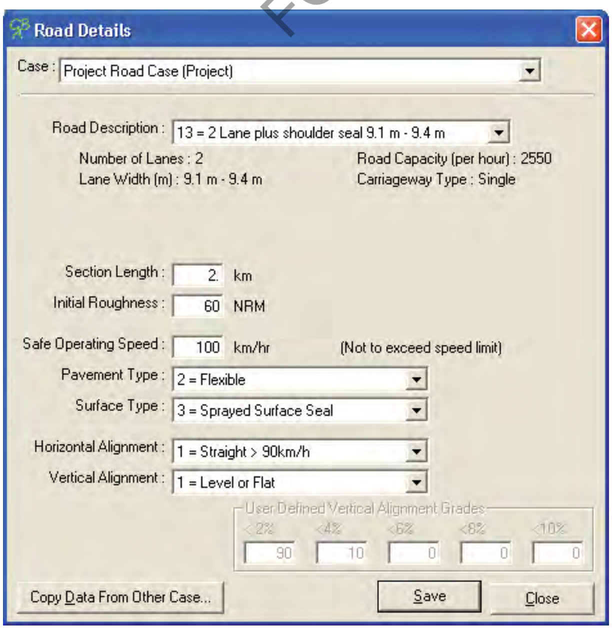
*Figure 176: Case case road details with road train access*




The new road will provide a wider 9.1 m seal to allow safe access for type 2 road trains. The road details of the project case are shown in Figure 177.

Note: The *Route Assessment Guidelines for Multi-combination Vehicles in Queensland* (DMR 2007) states that for vehicles such as type 2 road trains, the desired seal width should be a minimum of 7 to 9 metres depending on traffic volumes.

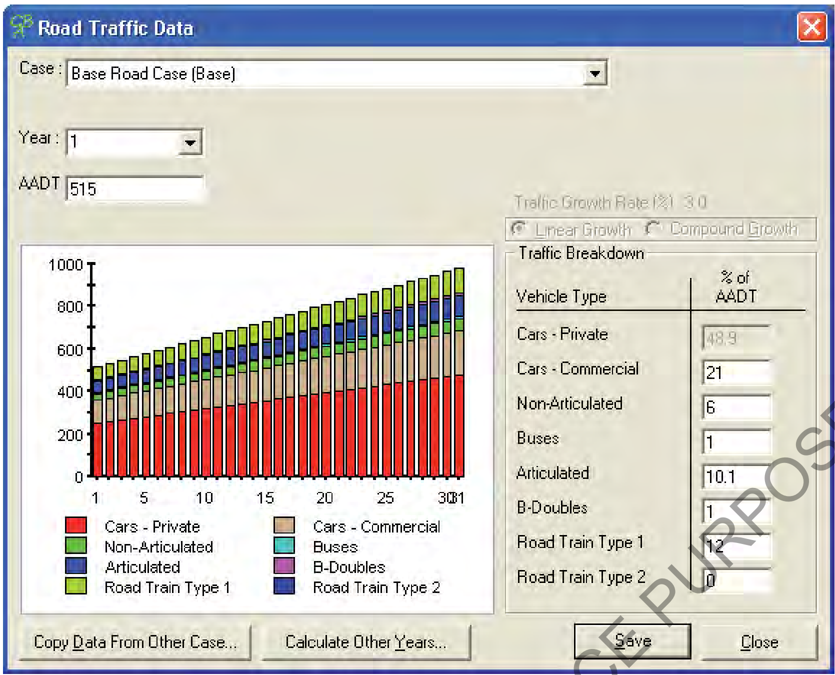
*Figure 177: Road details with road train access*



## 5.11.4 Road traffic data

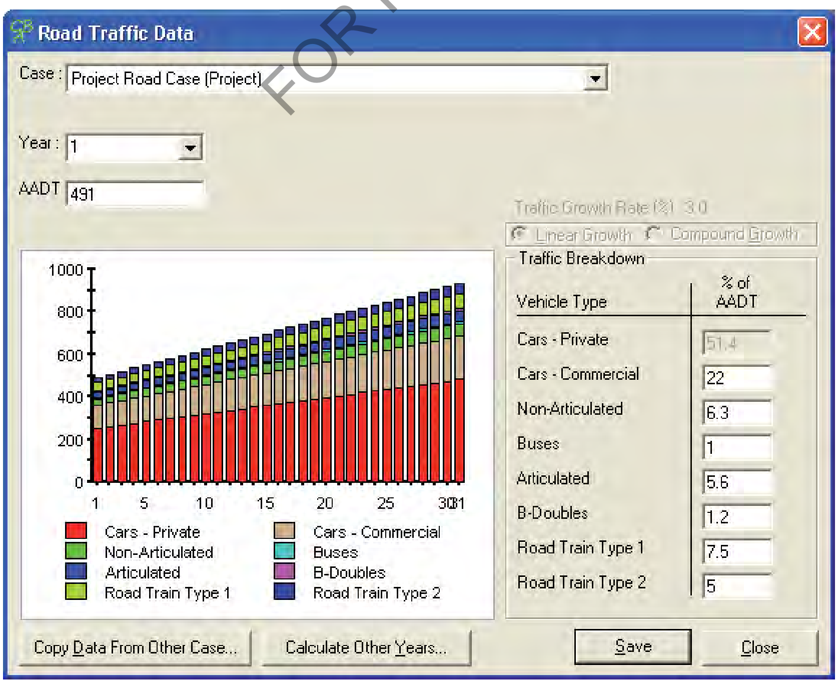
Table 8 provides the traffic composition assumptions for the base and project cases due to the change in vehicle access. The corresponding data for the base case is shown in Figure 178.

*Figure 178: Case case traffic without road train type 2*




The project case traffic data is shown in Figure 179. Total AADT is lower than in the base case because fewer vehicles are required to undertake the same freight task. A warning message will appear to highlight the differing base and project cases traffic data. As the difference is a consequence of the changed traffic mix, click the 'ok' button.

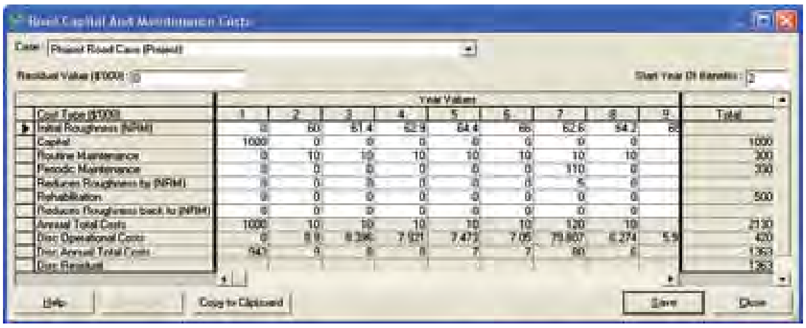
*Figure 179: Project case with road train type 2 access*



## 5.11.5 Capital and maintenance costs

Routine maintenance costs in the base case are $5000 per year. Routine maintenance in the project case will increase because of the wider road. The estimated capital cost for the project is $1 million with periodic maintenance of $110 000 for Years 7, 14 and 28. Each periodic maintenance event will reduce roughness by 5 NRM. There will be rehabilitation in Year 21, which will reduce roughness back to 60 NRM. Figure 180 shows the project case costs.

*Figure 180: Road train access costs*



| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 0 | 60 | 61.4 | 62.9 | 64.4 | 66 | 62.6 | 64.2 | 66 | |
| Capital | 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1000 |
| Routine Maintenance | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | 300 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 110 | 0 | | 330 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 500 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 1000 | 10 | 10 | 10 | 10 | 10 | 120 | 10 | | 2130 |
| Disc Operational Costs | 0 | 8.9 | 8.396 | 7.921 | 7.473 | 7.05 | 79.807 | 6.274 | 5.9 | 420 |
| Disc Annual Total Costs | 943 | 9 | 8 | 8 | 7 | 7 | 80 | 6 | | 1363 |
| Disc Residual | | | | | | | | | | 1363 |

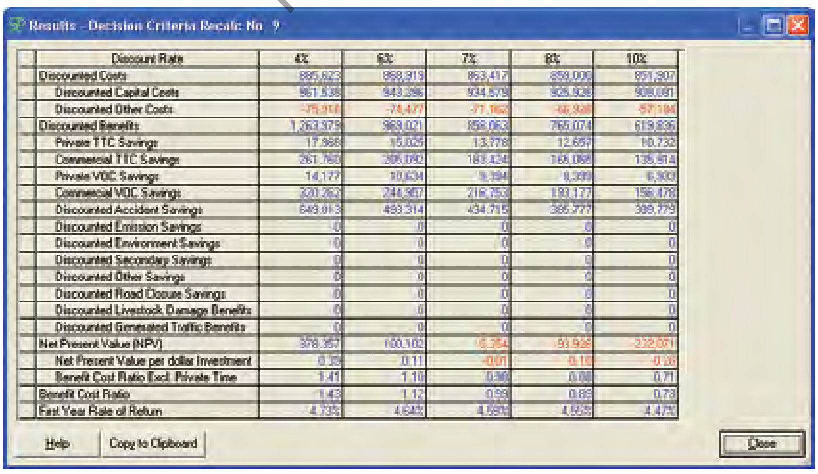
## 5.11.6 Accident and other costs

Accident costs will be automatically calculated by CBA6. With a wider seal and less traffic, the project case should provide additional accident savings. Similarly, the change in vehicle fleet configuration should result in reductions in vehicle emissions and air pollution, although these changes may be small.

## 5.11.7 Results and decision criteria

The results of the project are shown in Figure 181. At the 6% discount rate, the project BCR is 1.12 and the NPV is $100 102. The results indicate that the project is economically viable, which is encouraging considering the low traffic volumes on this road. With the change to more efficient vehicles, freight operators will save both time costs and vehicle running costs. The new road also provides an additional safety benefit.

*Figure 181: Road train type 2 access results*



| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 885,623 | 868,919 | 863,417 | 859,000 | 851,907 |
| Discounted Capital Costs | 961,538 | 943,396 | 934,579 | 925,926 | 909,091 |
| Discounted Other Costs | -75,915 | -74,477 | -71,162 | -66,926 | -57,184 |
| Discounted Benefits | 1,263,979 | 969,021 | 858,063 | 765,074 | 619,836 |
| Private TTC Savings | 17,968 | 15,025 | 13,778 | 12,657 | 10,732 |
| Commercial TTC Savings | 261,760 | 205,092 | 183,424 | 165,098 | 135,914 |
| Private VOC Savings | 14,177 | 10,634 | 9,394 | 8,399 | 6,903 |
| Commercial VOC Savings | 320,262 | 244,957 | 216,753 | 193,177 | 156,478 |
| Discounted Accident Savings | 649,813 | 493,314 | 434,715 | 385,777 | 308,779 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 378,357 | 100,102 | -5,354 | -93,926 | -232,071 |
| Net Present Value per dollar Investment | 0.39 | 0.11 | -0.01 | -0.10 | -0.26 |
| Benefit Cost Ratio Excl. Private Time | 1.41 | 1.10 | 0.98 | 0.88 | 0.71 |
| Benefit Cost Ratio | 1.43 | 1.12 | 0.99 | 0.89 | 0.73 |
| First Year Rate of Return | 4.73% | 4.64% | 4.59% | 4.55% | 4.47% |

Note: Benefits accrued from this project are from a combination of improved road surface and the change in vehicle fleet. The improved road surface now allows type 2 road trains to use this road. Freight operators will experience both savings in TTC and VOC.

## 5.12 Multiple project cases

The ‘multiple project cases’ module in CBA6 is used to compare mutually exclusive project options in order to identify the best option. Options analysis can be defined as a process that identifies alternative solutions that promote or address the same problem. CBA6 is useful in this context where there are alternative treatments that may suitably address a defined transport need. CBA6 compares the incremental benefits and costs of different project options and provides a recommendation on the economically preferred option.

The CBA6 ‘multiple project cases’ module is limited in the scope of project options that can be assessed. For example if there are two project options which require use of other advanced modules in CBA6, these projects will need to be created separately and then linked using the ‘incremental analysis’ module. Section 5.12 provides an incremental analysis case study using advanced modules in CBA6.

### 5.12.1 Multiple project case study

This case study involves the evaluation of a rural highway with AADT of 10 000 vehicles per day. The current road is a narrow seal of 5.8 metres and does not adequately cater for current traffic volumes. TMR proposes three options that will provide a better standard highway for road users. Only one of the three options can be implemented.

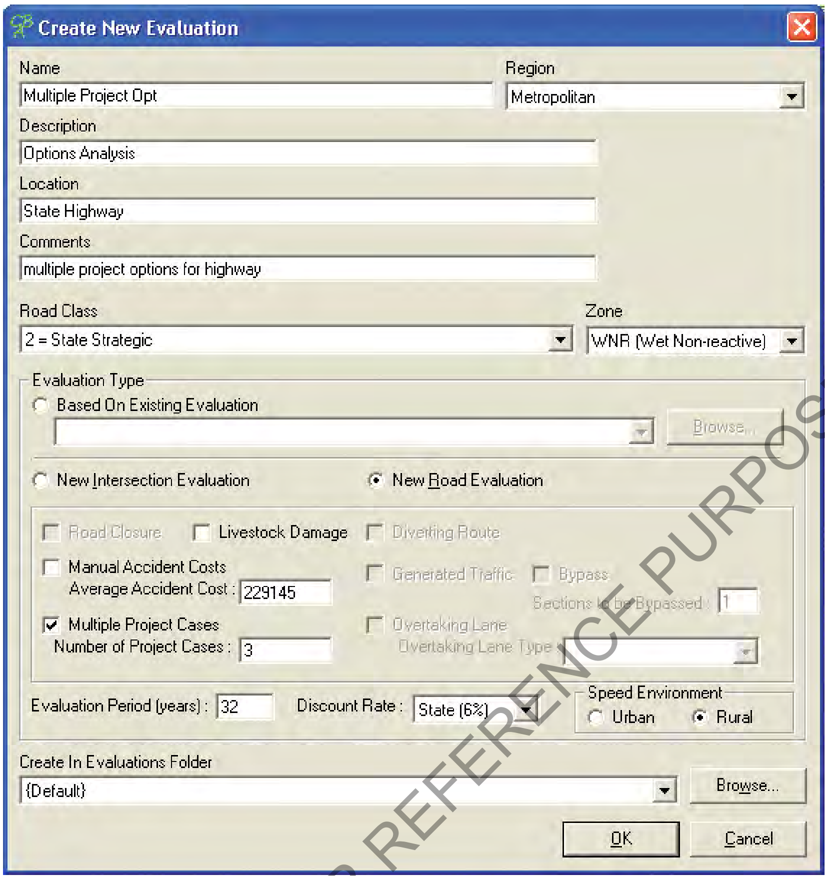
The base case and project options are:

- Base case: a do-minimum strategy has been assumed for the base case. Annual routine maintenance and periodic maintenance in Years 14, 21 and 28 are assumed to occur, while the design of the road will remain constant throughout the evaluation period.
- Option 1: widen the road to 7.6 m over two years. Capital costs at $5 million. Project opening in Year 3 will delay rehabilitation until Year 23. Provide periodic maintenance in Years 9, 16 and 30.
- Option 2: widen the road to 11.6 m over two years. Capital costs at $10 million. Project opening in Year 3 will delay rehabilitation until Year 23. Provide periodic maintenance in Years 9, 16 and 30.
- Option 3: build new four-lane highway (undivided) over two years. Capital costs at $18 million. Project opening in Year 3 will delay rehabilitation until Year 23. Provide periodic maintenance in Years 9, 16 and 30.

## 5.12.2 Create new evaluation

To create an options analysis in CBA6 the 'multiple project cases' module must be selected from the 'create new evaluation' screen. The system user is required to enter in the number of mutually exclusive project options to be evaluated. In this case study there are three project options, see Figure 182.

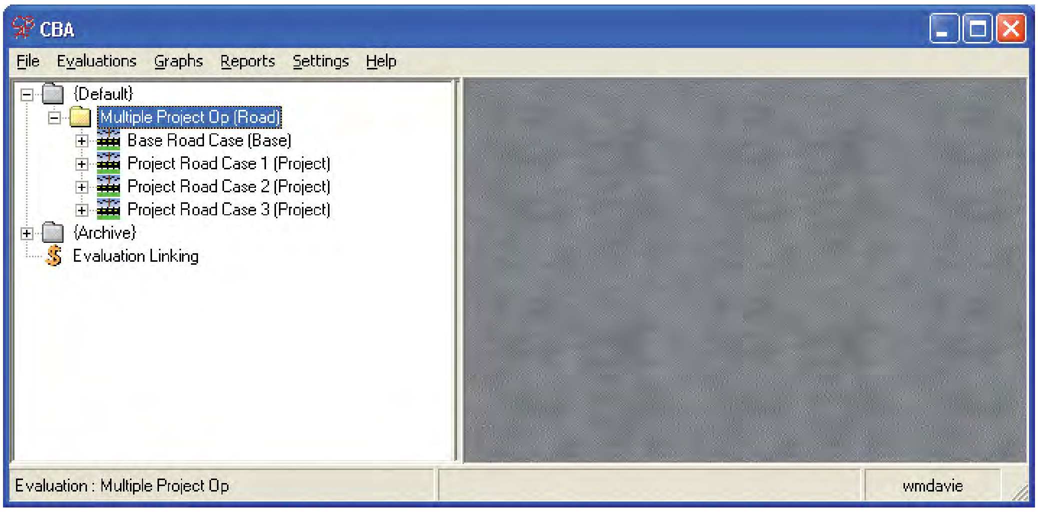
*Figure 182: Multiple project cases evaluation*






The node tree for this case study is shown in Figure 183. There are three project options that will be assessed against the same base case.

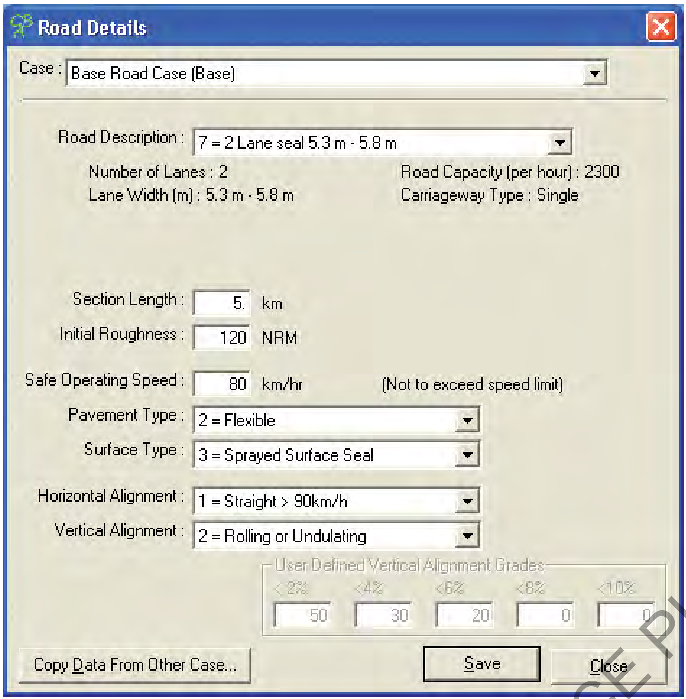
*Figure 183: Multiple project workspace*



## 5.12.3 Road details

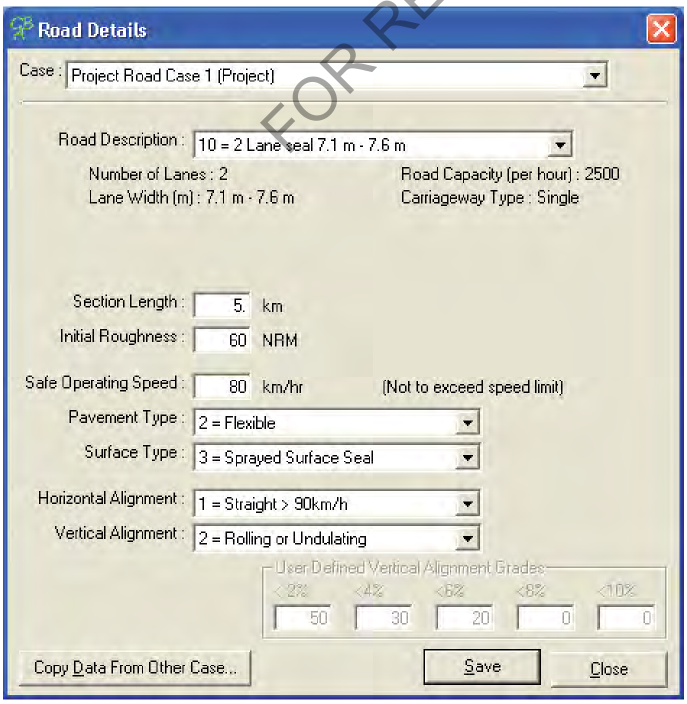
The ‘road details’ screen for the base case is shown in Figure 184. The current road is a narrow two-lane highway.

*Figure 184: Base case option*



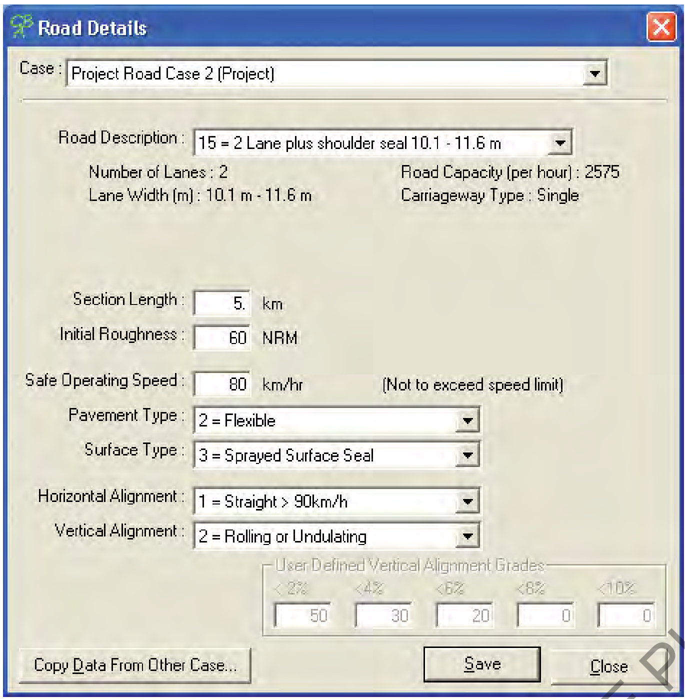

The first project option will widen the road from 5.8 metres to 7.6 metres. The new road will be built to a 60 NRM standard. Road details for option 1 are shown in Figure 185.

*Figure 185: Project case option 1*



The second proposed upgrade to the road involves a significant widening of the base case. Project option 2 involves widening the base case from 5.8 to 11.6 metres, see Figure 186.

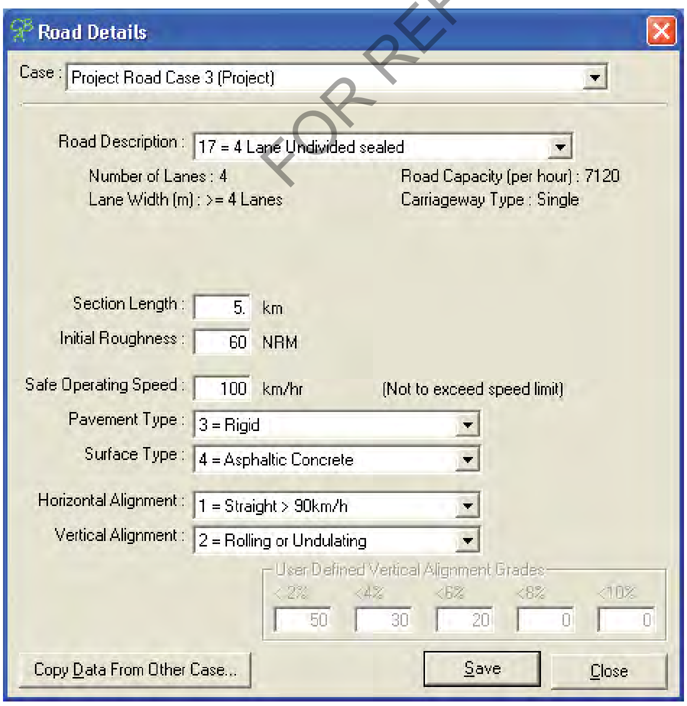
*Figure 186: Project case option 2*






The final project option involves building a new four-lane highway. Project option 3 also involves increasing the speed limit on the road from 80 km/h to 100 km/h. Details for option 3 are shown in Figure 187.

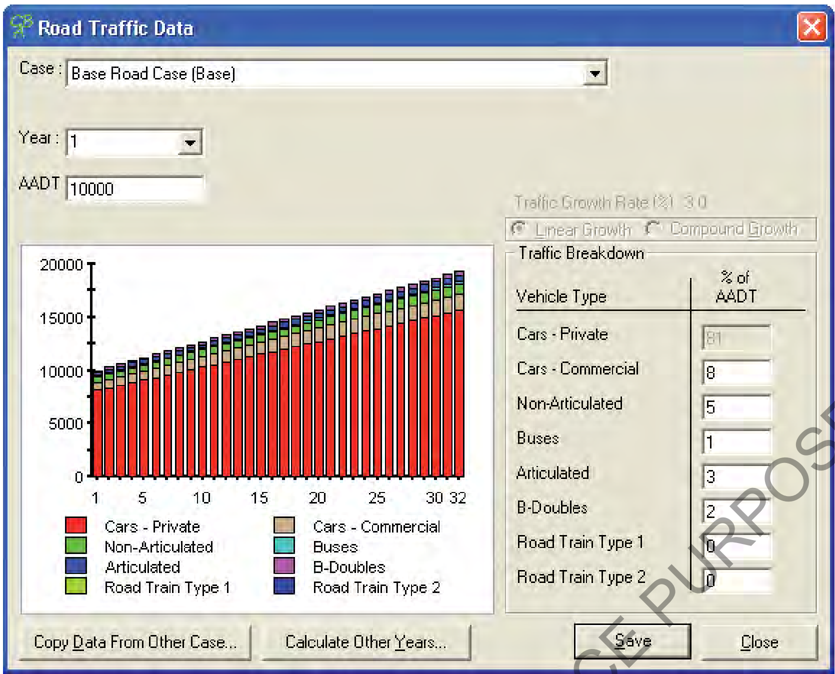
*Figure 187: Project case option 3*



### 5.12.4 Road traffic data

Traffic on the current road is 10 000 vehicles per day, with an assumed 3% linear annual growth. Traffic data is shown in Figure 188. The traffic assumptions for the project options will remain the same as the base case.

*Figure 188: Road traffic data multiple base case*

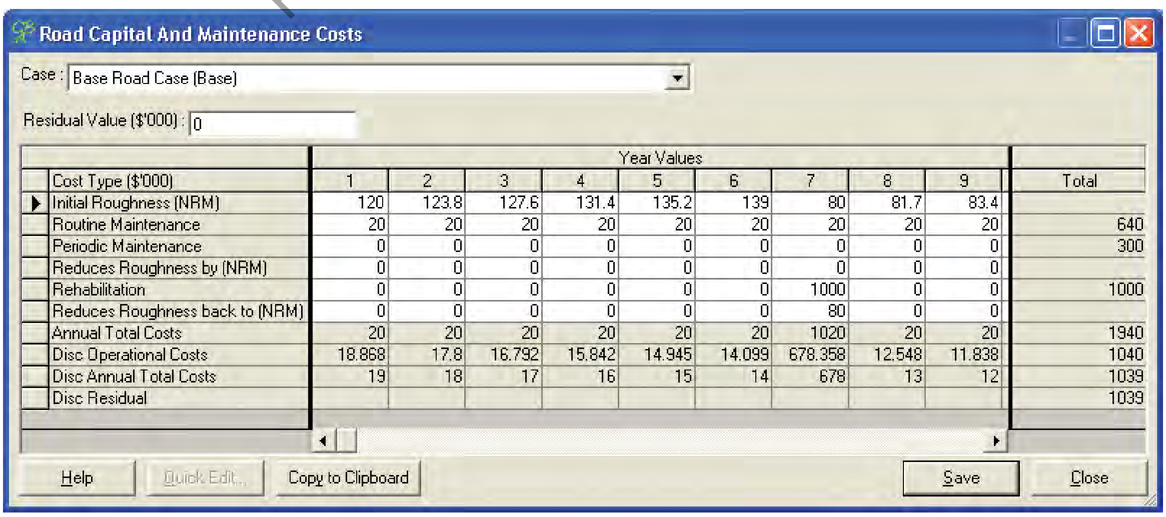





### 5.12.5 Capital and maintenance

Maintenance costs for the base case are shown in Figure 189. Rehabilitation will take place in Year 7 and will reduce roughness of the road to 80 NRM.

*Figure 189: Base case costs*



Road Capital And Maintenance Costs

Case : Base Road Case (Base)

Residual Value ($'000) : 0

| Cost Type ($'000) | Year Values 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 120 | 123.8 | 127.6 | 131.4 | 135.2 | 139 | 80 | 81.7 | 83.4 | |
| Routine Maintenance | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 640 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 300 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 1000 | 0 | 0 | 1000 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | |
| Annual Total Costs | 20 | 20 | 20 | 20 | 20 | 20 | 1020 | 20 | 20 | 1940 |
| Disc Operational Costs | 18.868 | 17.8 | 16.792 | 15.842 | 14.945 | 14.099 | 678.358 | 12.548 | 11.838 | 1040 |
| Disc Annual Total Costs | 19 | 18 | 17 | 16 | 15 | 14 | 678 | 13 | 12 | 1039 |
| Disc Residual | | | | | | | | | | 1039 |

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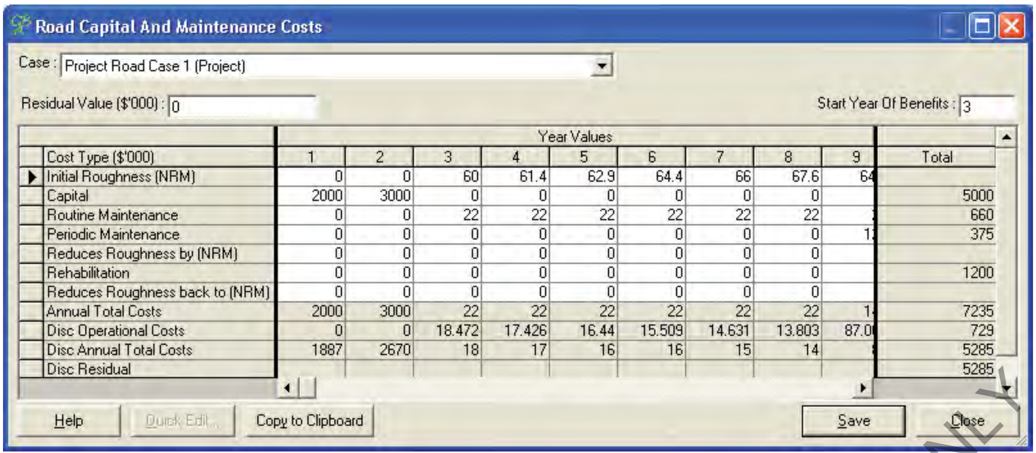
Project option 1 has total capital costs of $5 million. Figure 190 shows the capital and maintenance costs for option 1.

*Figure 190: Project option 1 costs*



Road Capital And Maintenance Costs

Case : Project Road Case 1 (Project)

Residual Value ($'000) : 0 Start Year Of Benefits : 3

| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 0 | 0 | 60 | 61.4 | 62.9 | 64.4 | 66 | 67.6 | 64 | |
| Capital | 2000 | 3000 | 0 | 0 | 0 | 0 | 0 | 0 | | 5000 |
| Routine Maintenance | 0 | 0 | 22 | 22 | 22 | 22 | 22 | 22 | | 660 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 375 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1200 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 2000 | 3000 | 22 | 22 | 22 | 22 | 22 | 22 | 1 | 7235 |
| Disc Operational Costs | 0 | 0 | 18.472 | 17.426 | 16.44 | 15.509 | 14.631 | 13.803 | 87.0 | 729 |
| Disc Annual Total Costs | 1887 | 2670 | 18 | 17 | 16 | 16 | 15 | 14 | | 5285 |
| Disc Residual | | | | | | | | | | 5285 |

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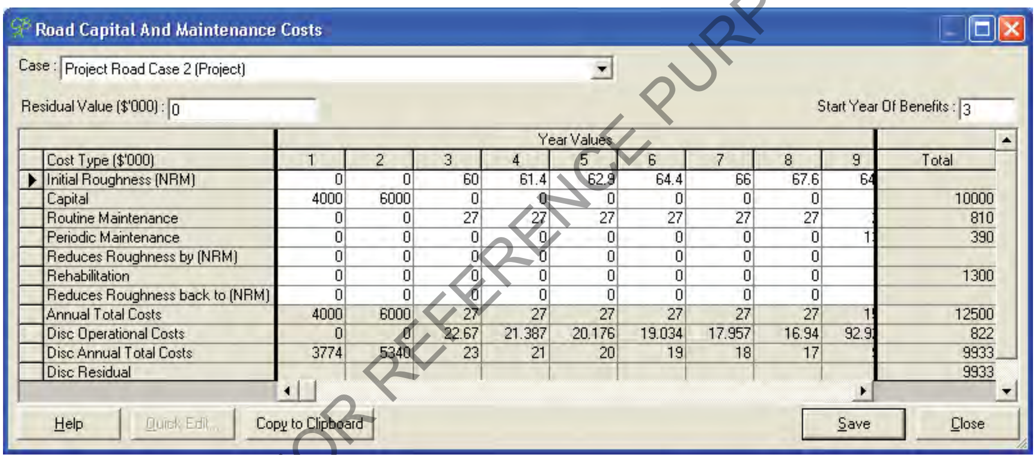
Project option 2 involves widening the current road to 11.6 metres. This is expected to cost $4 million in Year 1 with an additional $6 million in Year 2. These costs are shown in Figure 191.

*Figure 191: Project option 2 costs*



Road Capital And Maintenance Costs

Case : Project Road Case 2 (Project)

Residual Value ($'000) : 0 Start Year Of Benefits : 3

| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 0 | 0 | 60 | 61.4 | 62.9 | 64.4 | 66 | 67.6 | 64 | |
| Capital | 4000 | 6000 | 0 | 0 | 0 | 0 | 0 | 0 | | 10000 |
| Routine Maintenance | 0 | 0 | 27 | 27 | 27 | 27 | 27 | 27 | | 810 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 390 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1300 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 4000 | 6000 | 27 | 27 | 27 | 27 | 27 | 27 | 1 | 12500 |
| Disc Operational Costs | 0 | 0 | 22.67 | 21.387 | 20.176 | 19.034 | 17.957 | 16.94 | 92.9 | 822 |
| Disc Annual Total Costs | 3774 | 5340 | 23 | 21 | 20 | 19 | 18 | 17 | | 9933 |
| Disc Residual | | | | | | | | | | 9933 |

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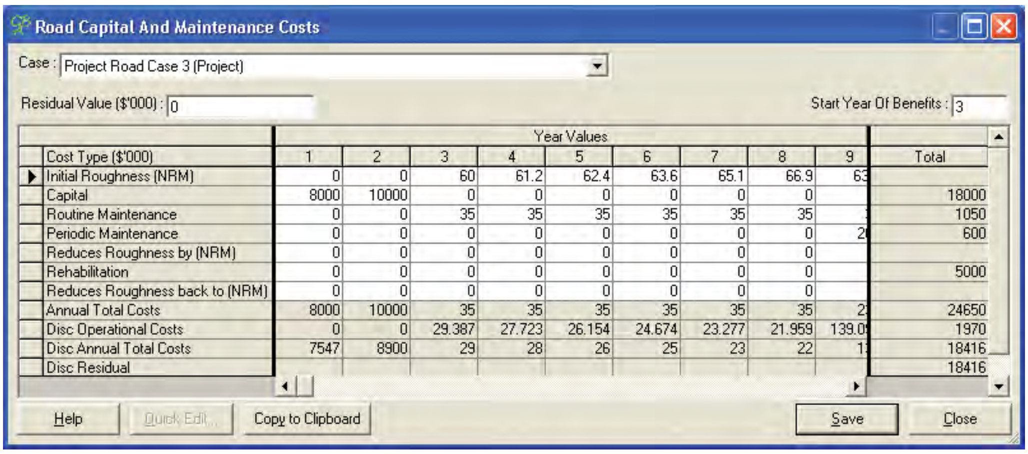
The highest cost project option is the new four-lane highway. This option will cost $18 million and take two years to construct. Figure 192 shows the capital and maintenance costs for option 3.

*Figure 192: Project option 3 costs*



Road Capital And Maintenance Costs

Case : Project Road Case 3 (Project)

Residual Value ($'000) : 0 Start Year Of Benefits : 3

| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Roughness (NRM) | 0 | 0 | 60 | 61.2 | 62.4 | 63.6 | 65.1 | 66.9 | 63 | |
| Capital | 8000 | 10000 | 0 | 0 | 0 | 0 | 0 | 0 | | 18000 |
| Routine Maintenance | 0 | 0 | 35 | 35 | 35 | 35 | 35 | 35 | | 1050 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 600 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 5000 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 8000 | 10000 | 35 | 35 | 35 | 35 | 35 | 35 | 2 | 24650 |
| Disc Operational Costs | 0 | 0 | 29.387 | 27.723 | 26.154 | 24.674 | 23.277 | 21.959 | 139.0 | 1970 |
| Disc Annual Total Costs | 7547 | 8900 | 29 | 28 | 26 | 25 | 23 | 22 | 1 | 18416 |
| Disc Residual | | | | | | | | | | 18416 |

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### 5.12.6 Accident and other costs

Accident costs are automatically calculated by CBA6. Project options 2 and 3 will provide the highest accident cost savings due to wider seal widths.

### 5.12.7 Results and decision criteria

The 'results' tab from the node tree provides a breakdown of costs for each option and the results of the incremental analysis, see Figure 193.

The 'incremental analysis' tab shows the final results of the comparison between each project option. The individual results for each project option are shown in project road case 1, project road case 2, and project road case 3 columns respectively. CBA6 automatically arranges project options on a capital costs basis, hence column 1 contains the project option with the lowest capital costs and column 5 contains the project option with the highest capital costs. All results are shown at the discount rate specified in the 'create new evaluation' screen. A discount rate of 6% is used for this example.

In the second column (incremental from project road case 1 to project road case 2), CBA6 calculates the incremental benefit and cost results. This column shows that option 2 costs $4.6 million more than option 1. On the other hand option 2 has an additional $12.9m in benefits. The IBCR for option 1 to option 2 is 2.78, therefore option 2 is preferred over option 1.

In the fourth column (incremental from project road case 2 to project road case 3), CBA6 calculates the incremental benefit and cost for option 2 and option 3. This result shows that option 3 costs $8.4 million more than option 2 but only provides $3.15 million more benefits. The IBCR is 0.37, therefore option 2 is preferred over option 3. In cases where the IBCR does not suitably identify a preferred option, the NPV can be used to select the preferred option.

The results of this incremental analysis show option 2 to be the preferred choice to upgrade the current highway.



*Figure 193: Multiple project case results*

Results - Incremental Analysis

| Case Name | Project Road Case 1 | Increment from Project Road Case 1 -> Project Road Case 2 | Project Road Case 2 | Increment from Project Road Case 2 -> Project Road Case 3 | Project Road Case 3 |
|---|---|---|---|---|---|
| Discounted Costs | 4,245,463 | 4,650,013 | 8,895,476 | 8,481,402 | 17,376,878 |
| Discounted Capital Costs | 4,556,782 | 4,556,782 | 9,113,564 | 7,333,571 | 16,447,134 |
| Discounted Other Costs | -311,319 | 93,231 | -218,087 | 1,147,831 | 929,743 |
| Discounted Benefits | 29,232,431 | 12,923,520 | 42,155,951 | 3,148,314 | 45,304,265 |
| Private TTC Savings | 2,062,192 | 594,565 | 2,656,757 | 12,852,146 | 15,508,903 |
| Commercial TTC Savings | 1,548,276 | 206,501 | 1,754,777 | 3,321,217 | 5,075,994 |
| Private VOC Savings | 1,629,284 | 35,079 | 1,664,363 | -2,008,067 | -343,703 |
| Commercial VOC Savings | 1,112,566 | 28,938 | 1,141,504 | 732,264 | 1,873,768 |
| Discounted Accident Savings | 22,880,112 | 12,058,438 | 34,938,550 | -11,749,247 | 23,189,303 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 24,986,968 | 8,273,507 | 33,260,475 | -5,333,087 | 27,927,388 |
| Net Present Value per dollar | 5.48 | 1.82 | 3.65 | -0.73 | 1.70 |
| Benefit Cost Ratio Excl. Private Time | 6.40 | 2.65 | 4.44 | -1.14 | 1.71 |
| Benefit Cost Ratio | 6.89 | 2.78 | 4.74 | 0.37 | 2.61 |

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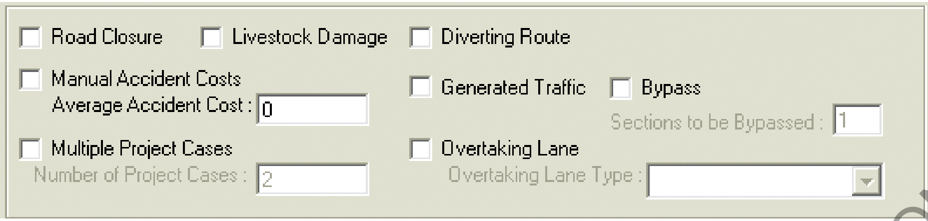
Note: Section 9.5 of the *Technical Guide* provides background information on calculation of the IBCR.

## 5.13 Incremental analysis

The 'evaluation linking' incremental analysis function in CBA6 is usually engaged to evaluate and compare project options which require the use of the advanced module in CBA6. This function is only available for system users who are evaluating options comprising one of the six project types listed in Figure 194. For example, a comparison between different types of overtaking lanes (e.g. head-to-head in comparison to side-by-side) cannot be evaluated using the 'multiple project case' option.

*Figure 194: CBA6 advanced modules*




This case study will use the bypass project presented in Section 5.7. This case study involves a proposal to build a new two-lane highway to bypass a local town. As an alternative, it is proposed that a four-lane undivided highway be constructed to allow for additional capacity.

### 5.13.1 Incremental case study

A new evaluation will be created in CBA6 and then compared with the original bypass case study (original proposal) in Section 5.7. A four-lane undivided highway (alternative option) has also been proposed as a comparison. This alternative option allows for an increased road capacity but has higher capital costs than the original proposal.

Note: The new base case to be created in CBA6 must remain consistent with the original proposal. The only changes will be the project case MRS, pavement type, surface type and capital cost. The changes need to be entered into CBA6 through the 'road details' and the 'capital and maintenance costs' functions. The alternative option can be created in CBA6 using the original proposal as a basis, see Section 3.1.8.1.

## 5.13.2 Create new evaluation

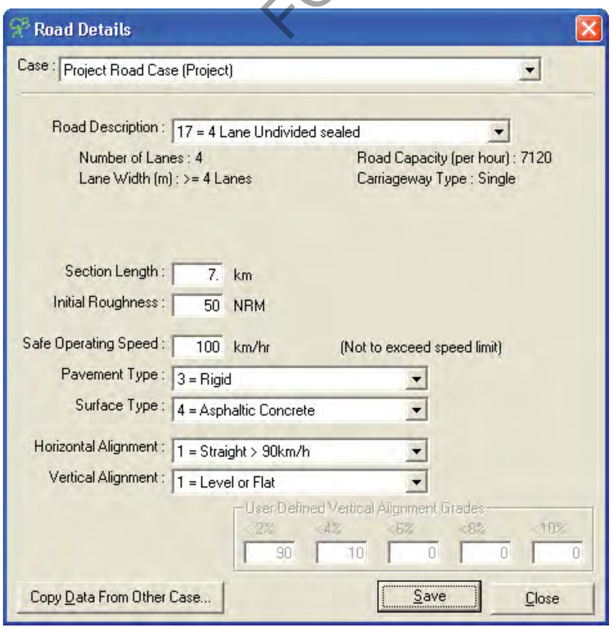
The alternative option is based on the original proposal in Section 5.7, therefore the system user should select the 'based on existing evaluation' option, see Figure 195.

*Figure 195: Town bypass option 2*


## 5.13.3 Road details

The alternative option will have an MRS of 17. The pavement type and surface type are changed to rigid and asphaltic concrete respectively. Figure 196 shows the road details for all options.

*Figure 196: Undivided bypass option*



## 5.13.4 Capital and maintenance costs

The only other change needed within CBA6 relates to the capital costs. The capital costs for the alternative proposal are $80 million, see Figure 197.

*Figure 197: Undivided bypass option costs*

**Road Capital And Maintenance Costs**

Case : Project Road Case (Project)

Residual Value ($'000) : 0    Start Year Of Benefits : 3

| | Year Values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Type ($'000) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total |
| Initial Roughness (NRM) | 0 | 0 | 50 | 51.3 | 52.6 | 53.9 | 55.2 | 51.5 | 52 | |
| Capital | 10000 | 70000 | 0 | 0 | 0 | 0 | 0 | 0 | | 80000 |
| Routine Maintenance | 0 | 0 | 20 | 20 | 20 | 20 | 20 | 20 | | 600 |
| Periodic Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1000 | | 3000 |
| Reduces Roughness by (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | | |
| Rehabilitation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 3000 |
| Reduces Roughness back to (NRM) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Annual Total Costs | 10000 | 70000 | 20 | 20 | 20 | 20 | 20 | 1020 | | 86600 |
| Disc Operational Costs | 0 | 0 | 16.792 | 15.842 | 14.945 | 14.099 | 13.301 | 639.961 | 11.8 | 2307 |
| Disc Annual Total Costs | 9434 | 62300 | 17 | 16 | 15 | 14 | 13 | 640 | | 74040 |
| Disc Residual | | | | | | | | | | 74040 |

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Note: When the costs of both options are compared, all maintenance costs have remained the same.

## 5.13.5 Results and decision criteria

The results of the alternative option are shown in Figure 198. At the 6% discount rate, the project BCR is 1.06 and the NPV is $4.13 million. These results indicate the alternative option is economically justified. To determine which of the project options is preferred, the system user should compare the evaluation results.

*Figure 198: Undivided bypass option results*

**Results - Decision Criteria Recalc No 2**

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 76,632,863 | 73,336,273 | 71,833,106 | 70,408,921 | 67,759,124 |
| Discounted Capital Costs | 74,334,320 | 71,733,713 | 70,486,505 | 69,272,977 | 66,942,149 |
| Discounted Other Costs | 2,298,544 | 1,602,560 | 1,346,600 | 1,135,944 | 816,975 |
| Discounted Benefits | 104,305,331 | 77,470,986 | 67,540,379 | 59,306,875 | 46,648,605 |
| Private TTC Savings | 43,772,571 | 32,623,493 | 28,487,975 | 25,054,042 | 19,763,163 |
| Commercial TTC Savings | 31,174,794 | 23,234,873 | 20,289,720 | 17,844,201 | 14,076,206 |
| Private VOC Savings | 12,245,777 | 8,954,878 | 7,748,958 | 6,755,568 | 5,242,713 |
| Commercial VOC Savings | 10,391,512 | 7,648,854 | 6,639,789 | 5,806,359 | 4,532,161 |
| Discounted Accident Savings | 6,720,677 | 5,008,889 | 4,373,937 | 3,846,704 | 3,034,362 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | 27,672,468 | 4,134,713 | -4,292,726 | -11,102,046 | -21,110,519 |
| Net Present Value per dollar Investment | 0.37 | 0.06 | -0.06 | -0.16 | -0.32 |
| Benefit Cost Ratio Excl. Private Time | 0.79 | 0.61 | 0.54 | 0.49 | 0.40 |
| Benefit Cost Ratio | 1.36 | 1.06 | 0.94 | 0.84 | 0.69 |
| First Year Rate of Return | 5.67% | 5.55% | 5.49% | 5.43% | 5.32% |

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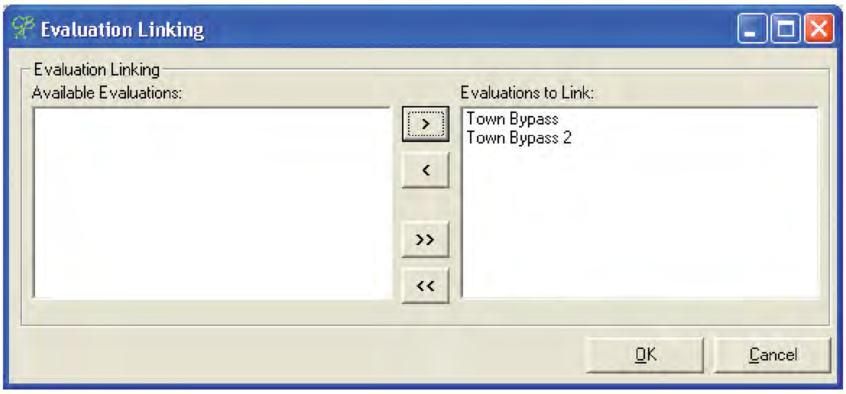
## 5.13.6 Linking

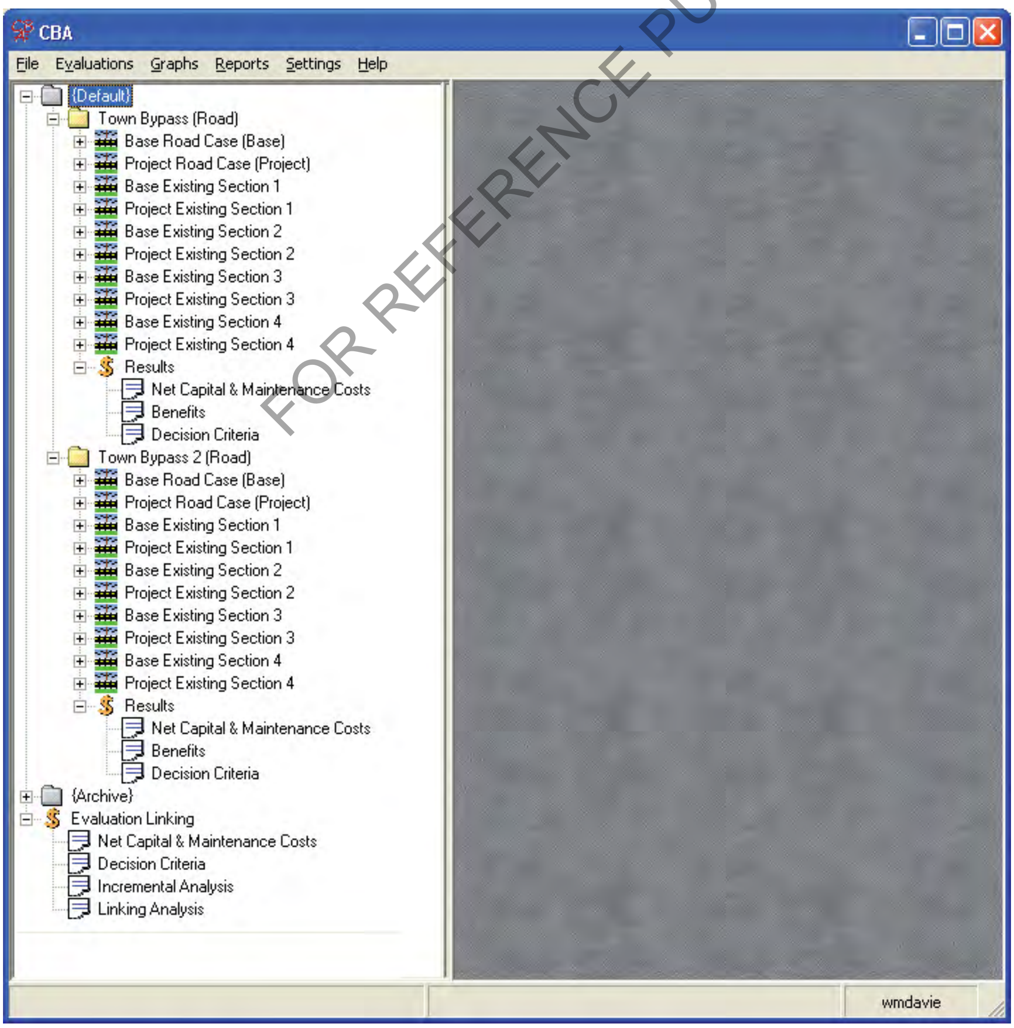
The original proposal and the alternative option are compared using the 'evaluation linking' option, see Figure 199.

*Figure 199: Evaluation linking*




The 'incremental analysis' tab presents the comparison of the evaluation results for both project options, see Figure 200.

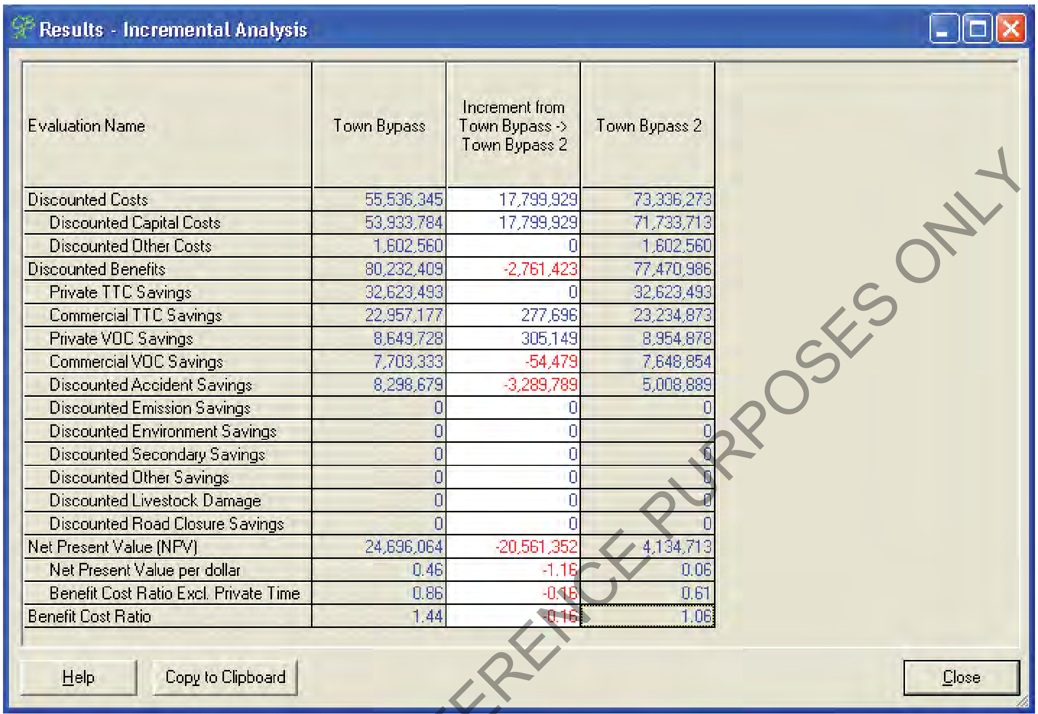
*Figure 200: Incremental analysis*



The results of the incremental analysis are presented in Figure 201. The second column (incremental from town bypass to town bypass 2) presents the incremental analysis of the original proposal and the alternative option.

The results suggest that the alternative option will cost an additional $17.8 million more than the original proposal. The original proposal has an estimated $2.76 million more benefits than the alternative option. The IBCR of -0.16 suggests that the lower cost original proposal is the preferred option.

*Figure 201: Incremental analysis results for town bypass options*




| Evaluation Name | Town Bypass | Increment from Town Bypass -> Town Bypass 2 | Town Bypass 2 |
|---|---|---|---|
| Discounted Costs | 55,536,345 | 17,799,929 | 73,336,273 |
| Discounted Capital Costs | 53,933,784 | 17,799,929 | 71,733,713 |
| Discounted Other Costs | 1,602,560 | 0 | 1,602,560 |
| Discounted Benefits | 80,232,409 | -2,761,423 | 77,470,986 |
| Private TTC Savings | 32,623,493 | 0 | 32,623,493 |
| Commercial TTC Savings | 22,957,177 | 277,696 | 23,234,873 |
| Private VOC Savings | 8,649,728 | 305,149 | 8,954,878 |
| Commercial VOC Savings | 7,703,333 | -54,479 | 7,648,854 |
| Discounted Accident Savings | 8,298,679 | -3,289,789 | 5,008,889 |
| Discounted Emission Savings | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 |
| Discounted Livestock Damage | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 |
| Net Present Value (NPV) | 24,696,064 | -20,561,352 | 4,134,713 |
| Net Present Value per dollar | 0.46 | -1.16 | 0.06 |
| Benefit Cost Ratio Excl. Private Time | 0.86 | -0.16 | 0.61 |
| Benefit Cost Ratio | 1.44 | -0.16 | 1.06 |

## 5.14 Linking projects

The 'linking projects' function in CBA6 is used to combine the results of mutually dependent projects. For example, two single projects may not achieve sufficient benefits as standalone projects to warrant construction. However, sufficient benefits may be obtained when the results of these projects are combined. A practical example could include combining a bridge upgrade with an approach, combining an intersection with a road upgrade, or combining a sequence of programmed works.

### 5.14.1 Linking projects case study

This case study will describe the process of using CBA6 to combine the results of an intersection project and an arterial road upgrade.

There are two proposed upgrades:

- Intersection upgrade – from case study in Section 5.5, a stop sign intersection is upgraded to signalised operations.
- Upgrade the approaches to the intersection – the main arterial road will be upgraded to coincide with the upgrade to the intersection.

The approach to this intersection is quite narrow and could become congested with the onset of additional traffic, as the intersection acts as a direct feeder of traffic onto the road. Upgrading the intersection as a standalone project may result in severe congestion issues for motorists using the arterial road. These design features suggest that these two projects have a high degree of mutual dependency and overall transport objectives may only be met if both projects are initiated.

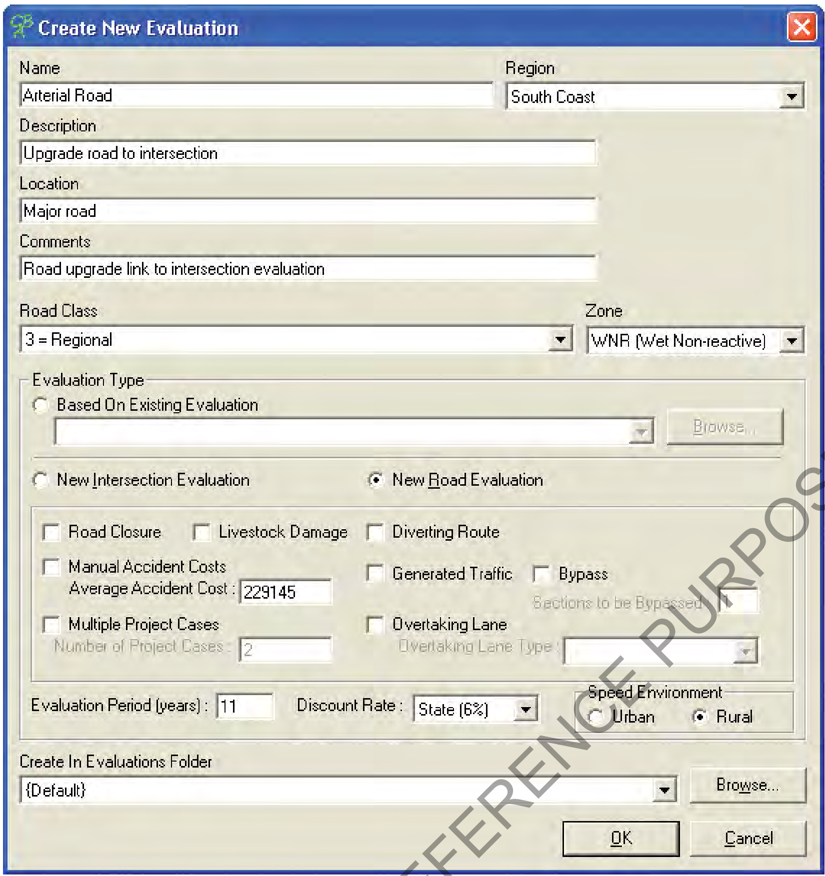
This case study will work through and describe the steps required to link the results of both projects. As the intersection project has already been completed in CBA6, the only new evaluation that needs to be created is the arterial road upgrade.

### 5.14.2 Create new evaluation

The 'create new evaluation' screen for the arterial road upgrade is shown in Figure 202. System users should ensure that the results of all linked projects are evaluated and discounted using the same discount rate. The arterial road upgrade uses an evaluation period of 11 years which is the evaluation period used for the intersection upgrade. The evaluation period for road projects is usually set at around 30 years. A residual value will be calculated for the road upgrade in this case study.

The details for the arterial road upgrade are entered into CBA6 as per the previous case studies and via the instruction shown in Section 3. All project input data is shown in Appendix A .

*Figure 202: Arterial road evaluation*

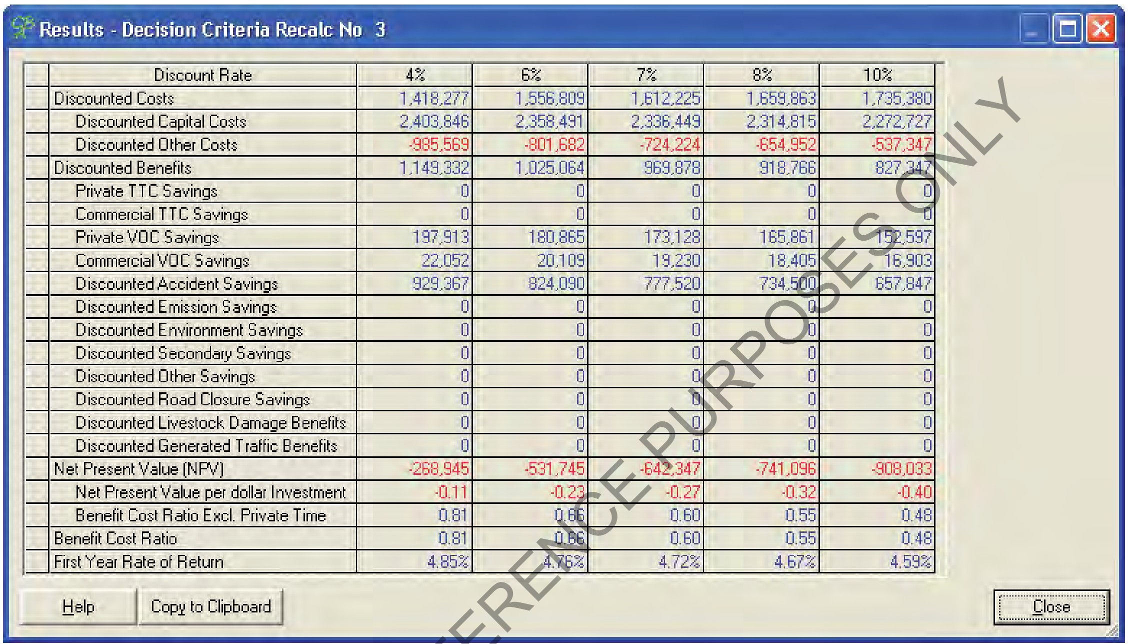


## 5.14.3 Results and decision criteria

After the input data has been entered and saved, the evaluation results can be calculated for the arterial road upgrade. As shown in Figure 203, the BCR for the arterial road upgrade is 0.66. As a standalone evaluation, it is doubtful that this project is economically viable.

To investigate the viability of combining the evaluation results of the two projects, it is necessary to link the results of both the arterial road upgrade and intersection upgrade.

*Figure 203: Arterial road results*


Results - Decision Criteria Recalc No 3

| Discount Rate | 4% | 6% | 7% | 8% | 10% |
|---|---|---|---|---|---|
| Discounted Costs | 1,418,277 | 1,556,809 | 1,612,225 | 1,659,863 | 1,735,380 |
| Discounted Capital Costs | 2,403,846 | 2,358,491 | 2,336,449 | 2,314,815 | 2,272,727 |
| Discounted Other Costs | -985,569 | -801,682 | -724,224 | -654,952 | -537,347 |
| Discounted Benefits | 1,149,332 | 1,025,064 | 969,878 | 918,766 | 827,347 |
| Private TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Commercial TTC Savings | 0 | 0 | 0 | 0 | 0 |
| Private VOC Savings | 197,913 | 180,865 | 173,128 | 165,861 | 152,597 |
| Commercial VOC Savings | 22,052 | 20,109 | 19,230 | 18,405 | 16,903 |
| Discounted Accident Savings | 929,367 | 824,090 | 777,520 | 734,500 | 657,847 |
| Discounted Emission Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 | 0 | 0 |
| Discounted Livestock Damage Benefits | 0 | 0 | 0 | 0 | 0 |
| Discounted Generated Traffic Benefits | 0 | 0 | 0 | 0 | 0 |
| Net Present Value (NPV) | -268,945 | -531,745 | -642,347 | -741,096 | -908,033 |
| Net Present Value per dollar Investment | -0.11 | -0.23 | -0.27 | -0.32 | -0.40 |
| Benefit Cost Ratio Excl. Private Time | 0.81 | 0.66 | 0.60 | 0.55 | 0.48 |
| Benefit Cost Ratio | 0.81 | 0.66 | 0.60 | 0.55 | 0.48 |
| First Year Rate of Return | 4.85% | 4.76% | 4.72% | 4.67% | 4.59% |

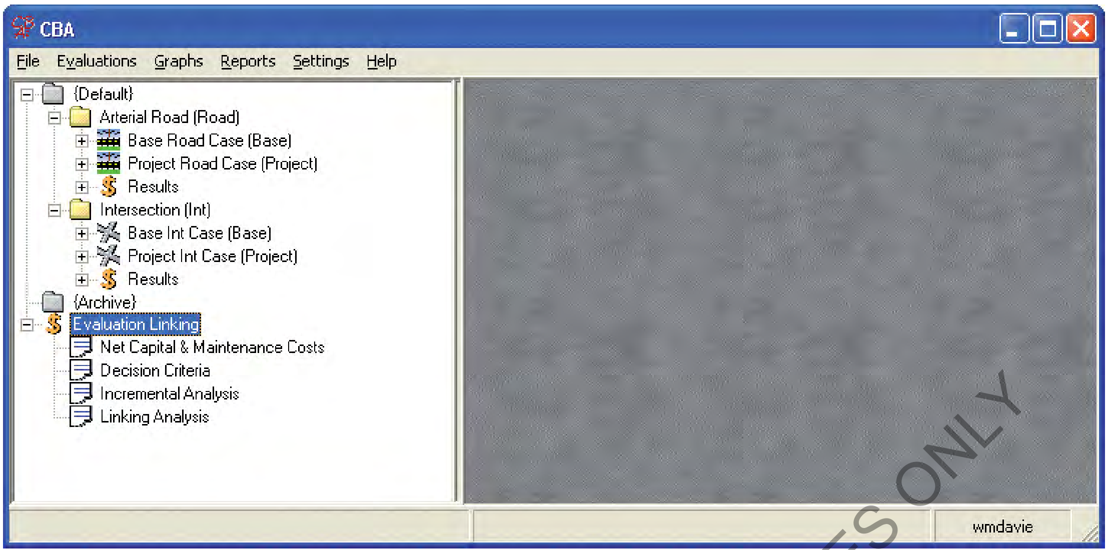




## 5.14.4 Linking analysis

When the evaluation results of both projects have been completed and saved, the results are linked using the 'evaluations' menu. After the evaluation files have been successfully linked, a new node tree appears under the 'evaluation linking' tab. To run the combined analysis of the arterial road and intersection upgrades, the system user selects the 'linking analysis' tab, see Figure 204.

*Figure 204: Linking analysis*




From the 'linking analysis' tab, CBA6 combines the results of both the intersection and arterial road evaluation files, see Figure 205.

The combined BCR for both projects is 2.82 with an NPV of $5.56 million, using the 6% discount rate. This suggests that upgrading the arterial road and the intersection as a joint initiative will significantly lower TTC and VOC, and reduce accidents.

This demonstration highlights that although the intersection project is viable as a standalone project (BCR = 5.06), the construction of the arterial road upgrade is not (BCR = 0.66). If the evaluation results of these projects are assessed individually, the intersection upgrade would be economically viable, but the proposal to upgrade the arterial road upgrade would fail. CBA6 can be used to link the evaluation results of two mutually dependent projects. The arterial road project may not be viable unless the evaluation results of both projects are assessed as a joint initiative.

*Figure 205: Linking results – arterial road and intersection*

Results - Linking

| Evaluation Name | Intersection | Arterial Road | Totals |
|---|---|---|---|
| Discounted Costs | 1,503,473 | 1,556,809 | 3,060,282 |
| Discounted Capital Costs | 1,415,094 | 2,358,491 | 3,773,585 |
| Discounted Other Costs | 88,378 | -801,682 | -713,303 |
| Discounted Benefits | 7,600,630 | 1,025,064 | 8,625,694 |
| Private TTC Savings | 5,634,535 | 0 | 5,634,535 |
| Commercial TTC Savings | 1,420,610 | 0 | 1,420,610 |
| Private VOC Savings | 328,600 | 180,865 | 509,465 |
| Commercial VOC Savings | 43,298 | 20,109 | 63,407 |
| Discounted Accident Savings | 173,587 | 824,090 | 997,677 |
| Discounted Emission Savings | 0 | 0 | 0 |
| Discounted Environment Savings | 0 | 0 | 0 |
| Discounted Secondary Savings | 0 | 0 | 0 |
| Discounted Other Savings | 0 | 0 | 0 |
| Discounted Livestock Damage | 0 | 0 | 0 |
| Discounted Road Closure Savings | 0 | 0 | 0 |
| Net Present Value (NPV) | 6,097,157 | -531,745 | 5,565,412 |
| Net Present Value per dollar | 4.31 | -0.23 | 1.47 |
| Benefit Cost Ratio Excl. Private Time | 1.31 | 0.66 | 0.98 |
| Benefit Cost Ratio | 5.06 | 0.66 | 2.82 |

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3

# 6 Support

With the creation of the project evaluation team, TMR has established a well resourced group. It comprises a team of full-time economists and advisors with specialised skills for supporting all aspects of road project evaluations and for technical support of the CBA6 tool.

The team provides comprehensive training and support in road project appraisal to all system users, as well as fixing any issues with the CBA tool. New functionalities, program fixes and enhancements are delivered annually or as required in a CBA release.

## 6.1 Training

Training in the CBA6 tool is provided by the team to all department regions upon request, either in the region or in Brisbane. The training covers topics such as state and federal project appraisal processes, as well as comprehensive training in the use of the CBA6 tool. Training request forms can be obtained from the project evaluation team

## 6.2 Intranet site

A well resourced intranet site at http://rams/cba has up-to-date information including scheduled training events, upcoming new releases of the tool, research papers, CBA newsletters and components such as updates to pricing.

The intranet site also provides sample evaluation files and examples of project evaluation work undertaken by the project evaluation team.

## 6.3 Contact

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# 7 Future software development

The CBA tool, as with any software, will need to adapt to changes in business rules and the system environment (Microsoft Windows), in order to stay current. CBA6 is developed with a programming language version which is outdated. The Microsoft database management system used by CBA6 is also outdated.

Another TMR software tool, SCENARIO, depends on the same database management system. At some stage during 2011-2014, CBA6 will need to migrate to a newer version of database (sql express), together with SCENARIO, an example of internal changes that will be required in a changing Microsoft Windows environment.

Functionally, developments are also likely to arise from federal and state issues. The project evaluation team monitors such developments and related research. The team has an ongoing liaison role in discussing these developments with counterparts in other states.

CBA6 has been extensively tested, but some very specific user scenarios could still highlight errors or opportunity for improvements. There are also known limitations of the tool which are under consideration to be addressed.

## 7.1 CBA6 Evaluation framework

The design of CBA6 allows for the evaluation of road projects located on isolated or discreet sections of the network. As such, the tool does not cater for the evaluation of those projects with network effects. In addition, the CBA6 tool is not suitable for evaluation of projects located on roads/links suffering from congestion, or stop/start traffic conditions.

## 7.2 Future CBA6 releases

Future releases are likely to have to address:

- many of the CBA6 limitations
- enhancements and errors reported by users, such as better support for externalities, wider economic benefits and traffic network effects
- changes required by changing business requirements and standardisations, state and federal
- internal system performance and windows standards.

The CBA Team regularly investigates methods for improving and updating the CBA6 tool. An example is trying to find a suitable method that will allow for hourly capacity flows so the tool can cater for the effects of a stop-start traffic environment.

The CBA Team communicates directly with system users for feedback, and to improve the functionality and useability of the CBA6 system. Enhancement suggestions, as well as any errors reported by users, will be incorporated in future CBA maintenance releases.

Some enhancements have already been identified (October 2009). such as improving how we specify vertical alignment and use this to calculate tyre wear. There are also parts of the CBA6 reporting that can be improved; these changes and other similar changes are logged in the tracker program change requests system which is the major single source register of future software releases.

Depending on departmental priorities, the tool would benefit from some major updates. Performance can be vastly improved through some re-factoring of the program code. CBA6 could be made into a web service, so that it can be installed and run from the intranet. Currently, having CBA6 distributed, licensed, installed and supported on individual user workstations throughout the network is very costly.

Requests for change to be included in future releases will be driven and documented through our program change request procedures.


# Technical guide

Technical guide


4

# 1 Introduction to the technical guide

The *Technical Guide* provides detailed information and explanations on calculations underlying CBA6. This document is a useful resource for anyone involved in testing and comparing project evaluation models, for example, researchers, consultants, economists, engineers and software developers.

## 1.1 Introduction

The purpose of the *Technical Guide* is to provide a complete breakdown of all algorithms, formulae and parameters in CBA6. This includes important outputs such as operating speed, VOC, TTC, accident costs and the decision criteria.

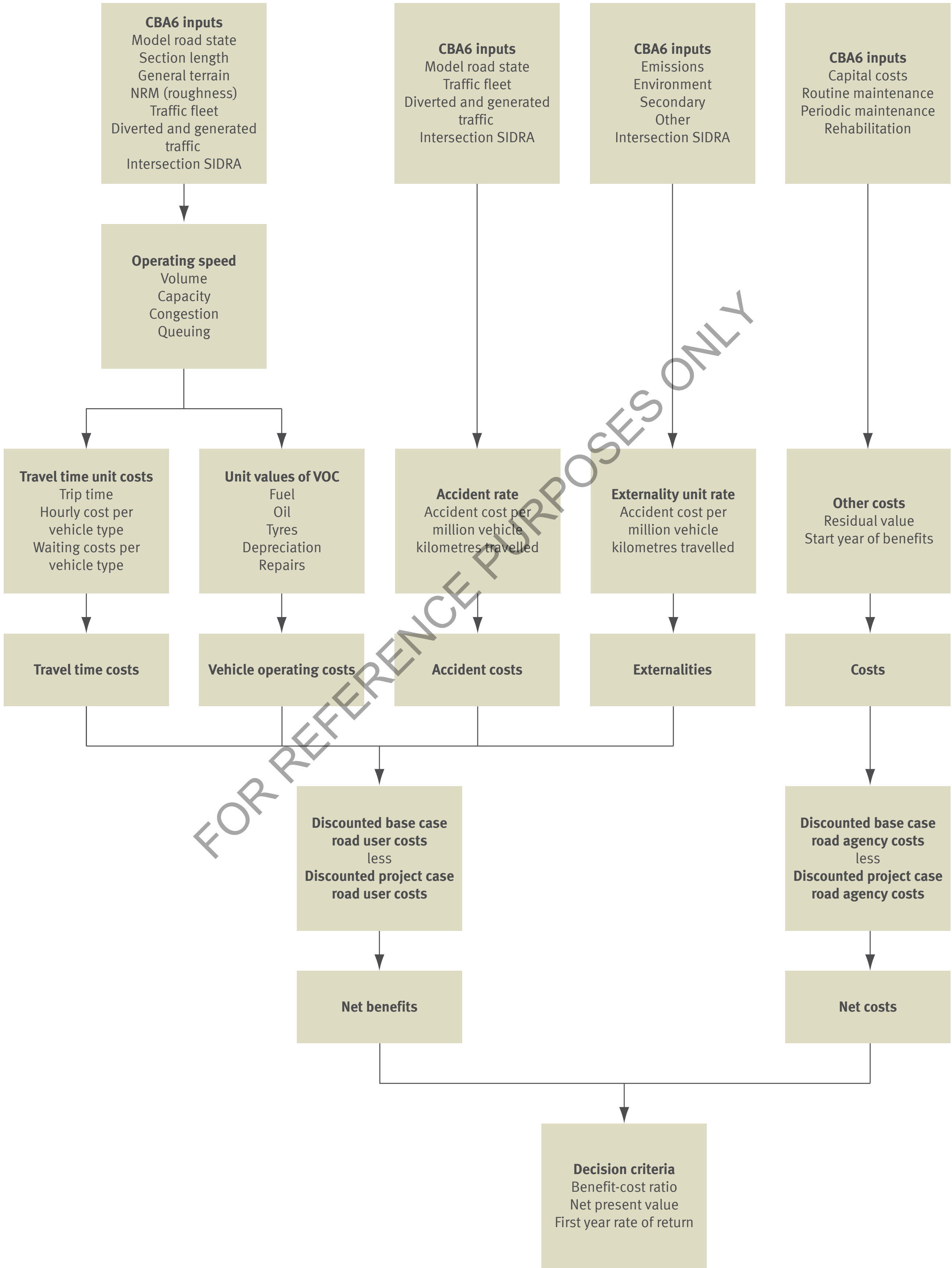
CBA6 pricing, common structures and unit values are created, maintained and updated periodically and internally by TMR and as such cannot be modified by the system user. To maintain the integrity of the tool, CBA6 pricing, common structures and unit values are derived from external sources such as Austroads and ATC guidelines.

The *Technical Guide* also provides the relevant algorithms and methodology for advanced modules available in CBA6, including:

- road closures with a diverting route
- road closures with no diverting route
- generated traffic
- bypass
- overtaking lanes
- livestock damage
- intersections.

The process structure of CBA6 is illustrated by Figure 1. This figure highlights the relationships between inputs entered by system users and CBA6 calculations and outputs. The *Technical Guide* discusses these relationships in further detail and shows how inputs influence outputs, which can then be used to demonstrate the overall economic justification for a project.

*Figure 1: CBA6 structural processes*



## 1.2 Harmonisation summary

CBA6 has been developed consistent with, and based on, NAASRA Improved Model for Project Assessment and Costing (NIMPAC) standards as documented in the Austroads harmonisation paper AP-R264/05, to derive road user costs. AP-R264/05 was created in conjunction with research undertaken by the Austroads Road User Effects Reference Group (RUERG). RUERG was comprised of technical representatives and evaluation system users from all state jurisdictions and the private sector, and had the intention of testing and harmonising the calculations in NIMPAC evaluation models with the international highway demand management (HDM) model. AP-R264/05 consequently compared state models to the international HDM model.

RUERG established and revised NIMPAC algorithms for adoption in each state which derived comparable results to the HDM model. Each jurisdiction, subsequently, incorporated the changes into their respective project evaluation models to ensure the consistency and transparency of the results. The harmonisation process continued in 2006 with the federal government and ARRB investigating a process to consider using the updated HDM-4 as a tool to conduct all road project evaluation work across the national highway network.

## 1.3 Outline of the *Technical Guide*

The layout of the *Technical Guide* is set out in the same order as the calculations within CBA6, which is shown by Figure 1.

**2 Volume capacity ratio** sets out the formulae used by CBA6 to calculate the level of congestion based on traffic inputs and road characteristics. The VCR incorporates traffic volume and growth rates and the road capacity based on peak hour usage. CBA6 calculates the operating speed of the fleet based on the VCR.

**3 Operating speed** shows the formulae and assumptions made in this calculation. Operating speed is one of the most important calculations made in CBA6, as it has a direct effect on the value of VOC and TTC.

**4 Vehicle operating costs** sets out the formulae and unit values used to calculate VOC. These costs are made up of fuel, oil, tyre, repairs and maintenance, depreciation and interest costs. These costs vary according to operating speed, road roughness and road alignment.

**5 Travel time costs** shows the TTC incurred by motorists according to journey time and the economic value of time.

**6 Accident costs** contains the average accident cost for Queensland and the accident rate for each road stereotype, and discusses accident and crash costs.

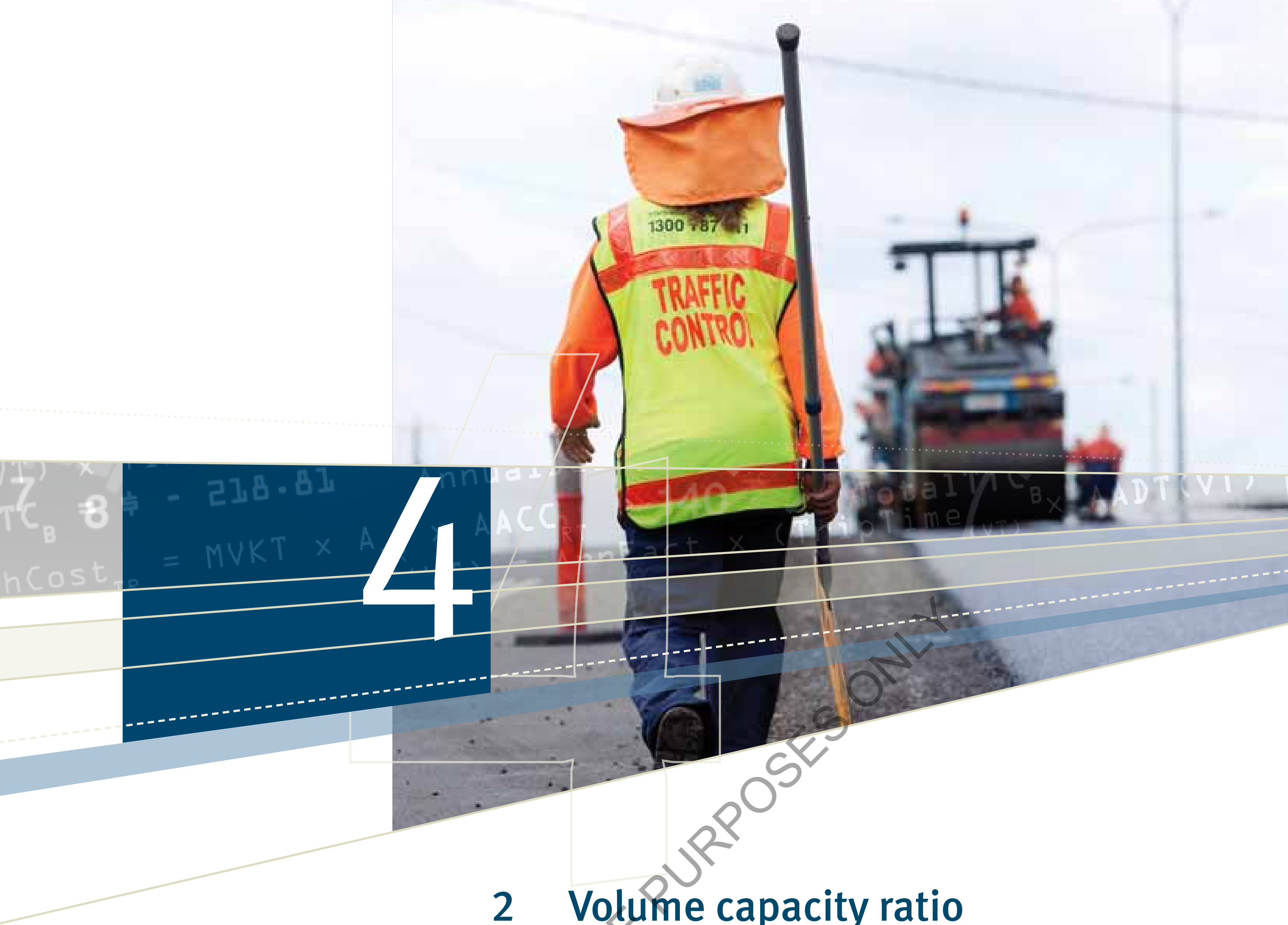
**7 Externalities** presents information on the calculation of externalities. This includes calculations for air pollution, greenhouse gas, noise, water, nature and landscape, urban separation and upstream and downstream costs.

**8 Advanced projects** applies these calculations to the advanced project modules used in CBA6 including road closures, intersections, overtaking lanes, generated traffic, livestock and bypasses.

**9 Decision criteria** used by CBA6 are mathematically defined. These criteria include BCR, NPV, FYRR, IBCR and NPVI.

**10 Sensitivity testing** explains the formulae applied to the sensitivity testing of the parameters in CBA6.

**11 Effects of intermediate outputs** contains a final summary of the effect inputs have on CBA6 outputs.




## 2 Volume capacity ratio

This section of the *Technical Guide* outlines the equations used in the derivation of the VCR and the calculations of traffic volume and road capacity. The VCR is an important calculation in CBA6 as it is central to the calculation of operating speed and many of the congestion adjustments in the VOC algorithms.

## 2.1 Traffic volume

AADT and vertical alignment inputs to CBA6 are used to calculate the volume of traffic on the road using passenger car equivalents (PCE). The AADT value is converted into PCEs to measure traffic volume.

PCE factors for each vehicle type are shown by Table 1 for example, a B-double on a section of road with an entire grade of 4% is equivalent in volume to 8.1 passenger cars.

*Table 1: Passenger car equivalent factors*

| Vehicle type | Flat | Grade 4% | Grade 6% | Grade 8% | Grade 10% |
|---|---|---|---|---|---|
| Cars– private | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Cars – commercial | 1.0667 | 1.1667 | 1.3333 | 1.6667 | 2.0000 |
| Non-Articulated | 1.4000 | 2.1000 | 2.8000 | 4.2000 | 5.2222 |
| Buses | 1.7000 | 3.0000 | 4.0000 | 6.0000 | 7.0000 |
| Articulated | 2.4000 | 4.8000 | 7.2000 | 9.6000 | 12.0000 |
| B-double | 4.1000 | 8.1000 | 12.2000 | 16.2000 | 20.3000 |
| Road train 1 | 4.9500 | 9.8500 | 14.8500 | 19.7500 | 24.7000 |
| Road train 2 | 8.8000 | 17.6000 | 26.5000 | 35.3000 | 44.1000 |

*Source: adapted from Austroads (2005) page 20.*



The formula to calculate the traffic volume is shown by Equation 1.

*Equation 1: Traffic volume*

$$Volume = \sum_i AADT_i \times PCE_i$$

Where:

- $AADT_i$ = annual average daily traffic count
- $PCE_i$ = passenger car equivalent for vehicle type i

*Example: Traffic volume*

On a flat road (100% flat) with AADT of 1000, made up of 616 private cars, 264 commercial cars, 50 rigid vehicles, 10 buses, 50 semis and 10 B-doubles, the corresponding traffic volume is given by:

$$Volume = (616 \times 1) + (264 \times 1.0667) + (50 \times 1.4) + (10 \times 1.7) + (50 \times 2.4) + (10 \times 4.1)$$

$$Volume = 1146$$

Therefore the traffic volume of the road in PCE is 1146. This is notably different from the AADT of 1000.

## 2.2 Traffic growth rate

CBA6 uses the traffic growth rate to calculate the VCR in future years. CBA6 provides two growth options when predicting future traffic volumes, linear growth and compound growth. For further details on the suitability of either growth rate option, see Section 3.5.3.2 of the *User Guide*. The calculation of linear and compound growth rates is given in Section 2.2.1 and Section 2.2.2 respectively.

### 2.2.1 Linear traffic growth

The formula to calculate AADT when the traffic growth rate is linear is given in Equation 2.

*Equation 2: Linear traffic growth*

$$AADT_x = AADT_{y1} + (x - y1) \times \left(\left(AADT_{y1} \times (1 + GR)\right) - AADT_{y1}\right)$$

Where:

- $AADT_{y1}$ = AADT in the first year of evaluation
- $AADT_x$ = AADT in year x
- GR = growth rate
- y1 = first year (1)
- x = year of calculation

*Example: Linear traffic growth*

AADT for a given road is 1000 and the linear growth rate is assumed to be 3% p.a. AADT in Year 5 is given by:

$$AADT_5 = 1000 + (5 - 1) \times \left(\left(1000 \times (1 + 0.03)\right) - 1000\right)$$

$$AADT_5 = 1120$$

Note: When using the linear growth forecast, future trends are based solely on the AADT in the year selected for extrapolation.



### 2.2.2 Compound traffic growth

The formula for compound traffic growth is shown by Equation 3.

*Equation 3: Compound traffic growth*

$$AADT_x = AADT_{y1} \times (1 + GR)^{(x-y1)}$$

A compound growth rate is a growth rate which is compounded annually, whereas a linear growth rate results in a constant increase in traffic each year.

*Example: Compound traffic growth*

Using an AADT of 1000, compounded annually at 4% for 5 years, the calculated AADT is given below:

$$AADT_5 = 1000 \times (1 + 0.04)^4$$

$AADT_5 = 1169.86$

As demonstrated in this example, AADT can vary substantially depending on the type of growth rate applied. Compound growth in AADT is based on a constant percentage increase in the number of vehicles per year, while linear growth in AADT is based on a constant increase in the actual number of vehicles per year.

## 2.3 Road capacity

Road capacity is dependent on both the hourly capacity, measured in PCEs, and a peak hour capacity factor by model road state (MRS).

Table 2 lists the hourly capacities in PCE for each MRS. Hourly capacity is dependent on the seal type (undivided or divided) and the seal width.

*Table 2: Hourly PCE capacity*

| MRS | Road width description | Hourly capacity (PCE/hr) |
|---|---|---|
| 1 | Unsealed natural surface | 400 |
| 2 | Unsealed formed road | 400 |
| 3 | Paved < 4.5 m | 500 |
| 4 | Paved >= 4.5 m | 700 |
| 5 | Narrow seal <= 4.5 m | 1 500 |
| 6 | Narrow seal 4.6 m–5.2 m | 2 000 |
| 7 | 2 lane seal 5.3 m–5.8 m | 2 300 |
| 8 | 2 lane seal 5.9 m–6.4 m | 2 350 |
| 9 | 2 lane seal 6.5 m–7.0 m | 2 450 |
| 10 | 2 lane seal 7.1 m–7.6 m | 2 500 |
| 11 | 2 lane plus shoulder seal 7.7 m–8.2 m | 2 525 |
| 12 | 2 lane plus shoulder seal 8.3 m–9.0 m | 2 550 |
| 13 | 2 lane plus shoulder seal 9.1 m–9.4 m | 2 550 |
| 14 | 2 lane plus shoulder seal 9.5 m–10 m | 2 565 |
| 15 | 2 lane plus shoulder seal 10.1 m–11.6 m | 2 575 |
| 16 | 3 lane for overtaking | 4 000 |
| 17 | 4 lane undivided sealed | 7 120 |
| 18 | 6 lane undivided sealed | 12 000 |
| 19 | 4 lane divided sealed | 8 000 |
| 20 | 6 lane divided sealed | 12 000 |
| 21 | 4 lane divided (limited access) | 8 000 |
| 22 | 6 lane divided (limited access) | 12 000 |
| 23 | 8 lane divided (limited access) | 16 000 |



*Source: adapted from Austroads (2005) page 22.*

Note: MRS is derived from the Western Australia MRS classification: Austroads (AP-R264/05).

Default peak hour capacity percentages are shown by Table 3. These default figures are used to assess the percentage of AADT that travel during peak periods.

*Table 3: Road type and peak hour capacity factor*

| Road type | Capacity factor |
|---|---|
| National highway | 10 |
| Urban single carriageway | 10 |
| Urban dual carriageway | 12.5 |
| Rural single carriageway | 8.33 |
| Rural dual carriageway | 10 |

*Source: TMR.*

TMR assumes that 10% of AADT on a national highway travels during peak periods. Similarly, 12.5% of daily traffic travels in peak periods on urban dual carriageways.

Equation 4 is used to calculate the capacity for a given road.

*Equation 4: Road capacity*

$$Capacity = \frac{Hourly\ Capacity}{Capacity\ Factor\ \%}$$

Where:

- Hourly Capacity = hourly capacity in PCE/hr by MRS
- Capacity Factor% = proportion of daily traffic in the peak periods

The hourly capacity rate is set by the corresponding MRS and is a function of the seal width. In CBA6, roads with larger seal widths are assumed to accommodate more vehicles per hour.

*Example: Road capacity*

A national highway with a model road state of 10 would have an hourly capacity of 2500, see Table 2, and a peak hour capacity factor of 10%, see Table 3. In this example, the road capacity is given below:

$$Capacity = \frac{2500}{10\%}$$

$$Capacity = 25{,}000$$

Note: Peak period (1 hour) is determined in CBA6 based on the system user's selection of road description and MRS. The capacity factor is thus used to determine the capacity of the road which in turn influences the VCR. This form of modelling is known as free flow.

## 2.4 Volume capacity ratio

VCR is calculated using the volume calculations shown by Section 2.1 and the capacity calculations shown by Section 2.3.

*Equation 5: Volume capacity ratio*

$$VCR = \frac{Volume}{Capacity}$$

Where:

- For further information on VCR, see Section 2.1

The VCR is a measure of the level of congestion on a road given the traffic volume and road capacity. When the VCR reaches 1, this indicates that the road is operating at 100% capacity.

Note: The maximum VCR in CBA6 is 1.25.

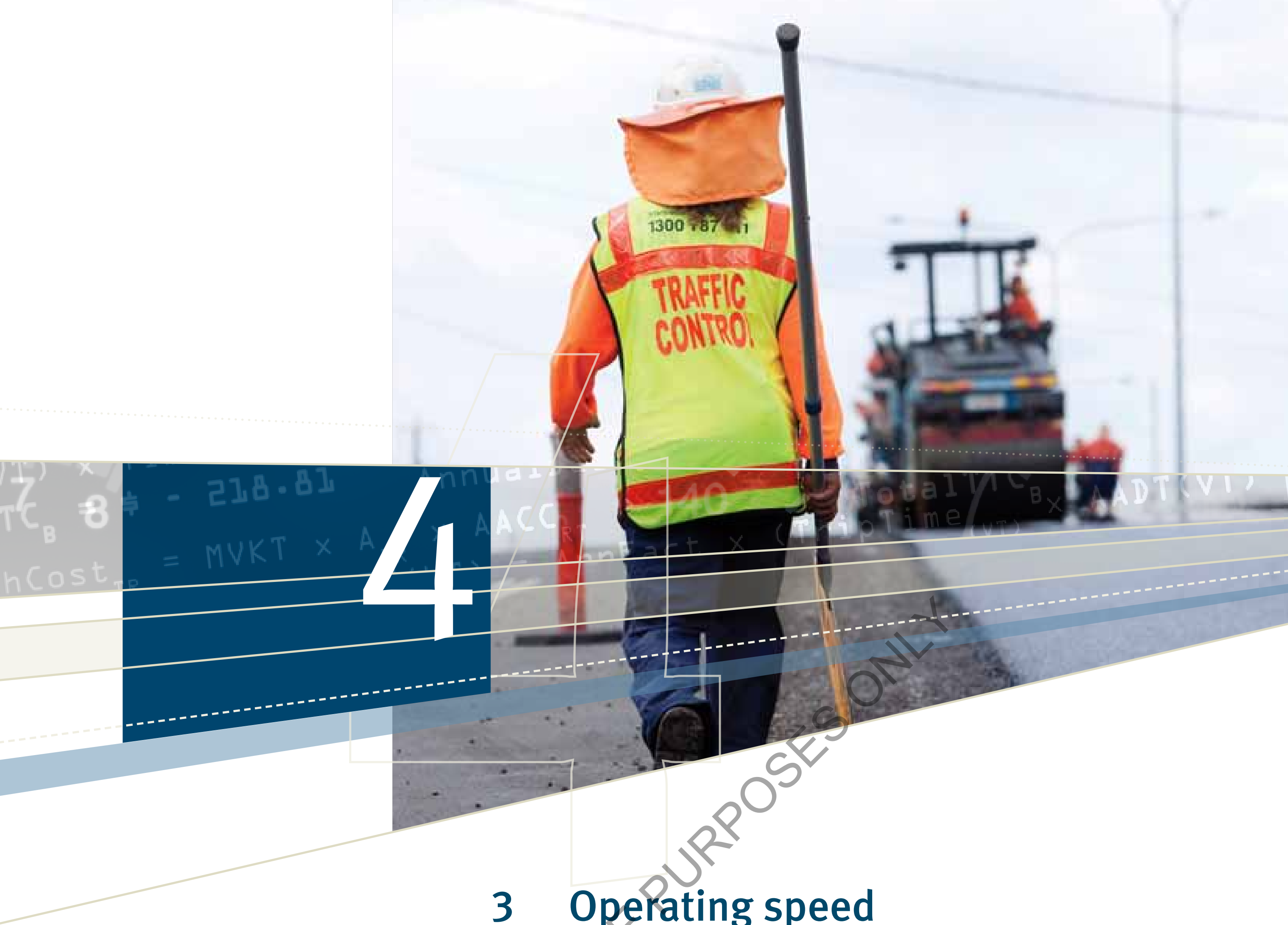
*Example: Volume capacity ratio*

Using the examples provided in Sections 2.1 and 2.3, the corresponding VCR is:

$$VCR = \frac{1145}{25{,}000}$$

$$VCR = 0.046$$

This example illustrates that the current road volume is approximately 4.6% of total road capacity.




# 3 Operating speed

Operating speed is one of the most important components used in the road user cost calculations of CBA6. Operating speed influences both the VOC and TTC of the base and project cases.

Operating speed is the estimated average speed for each vehicle type on a particular road once adjustments are made for congestion and other road characteristics. Operating speed differs substantially from the posted speed, which is defined as the maximum 'sign posted' speed that vehicles may travel legally.

Operating speed calculation is a function of the following:

- free speed – 3.1
- roughness adjustment – 3.2
- congestion adjustment – 3.3

## 3.1 Free speed

Free speed is the average speed of a vehicle not subject to roughness, congestion or sign posted speed constraints. Free speed is related to the vehicle type, MRS and vertical and horizontal alignment as per Table 4.

A roughness correction is applied to free speed when the road roughness count is greater than 60 NRM. Finally, free speed is adjusted for congestion, according to the VCR, to give the operating speed for each vehicle type.

*Table 4: Free speed array*

| Vehicle type | Road type | Straight grad 0–2% | Straight grad 4% | Straight grad 6% | Straight grad 8% | Straight grad 10% | Curvy grad 0–2% | Curvy grad 4% | Curvy grad 6% | Curvy grad 8% | Curvy grad 10% | V/curvy grad 0–2% | V/curvy grad 4% | V/curvy grad 6% | V/curvy grad 8% | V/curvy grad 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cars – private | <= 4.5 m | 83 | 82 | 76 | 66 | 56 | 77 | 76 | 72 | 64 | 55 | 69 | 68 | 66 | 60 | 53 |
| Cars– commercial | <= 4.5 m | 82 | 79.3 | 72 | 61.7 | 52 | 75 | 73 | 68 | 59.7 | 51 | 67 | 65.3 | 62.3 | 56.3 | 49.3 |
| Non-Articulated | <= 4.5 m | 82.4 | 68.8 | 55.6 | 44.6 | 36 | 73 | 63.4 | 53.2 | 43.4 | 35.8 | 64.2 | 57.6 | 49.8 | 42.2 | 35.6 |
| Buses | <= 4.5 m | 86 | 72 | 57 | 45 | 37 | 77 | 67 | 55 | 45 | 37 | 67 | 61 | 53 | 44 | 36 |
| Articulated | <= 4.5 m | 86 | 49 | 39 | 32 | 24 | 71 | 45 | 38 | 32 | 24 | 59 | 41 | 36 | 31 | 24 |
| B-double | <= 4.5 m | 88 | 38 | 27 | 20 | 16 | 72 | 35 | 27 | 19 | 16 | 59 | 32 | 26 | 19 | 16 |
| Road train 1 | <= 4.5 m | 88 | 38 | 27 | 20 | 16 | 72 | 35 | 27 | 19 | 16 | 59 | 32 | 26 | 19 | 16 |
| Road train 2 | <= 4.5 m | 88 | 38 | 27 | 20 | 16 | 72 | 35 | 27 | 19 | 16 | 59 | 32 | 26 | 19 | 16 |
| Cars – private | > 4.5 m | 105 | 102 | 88 | 72 | 59 | 90 | 89 | 81 | 68 | 57 | 75 | 74 | 71 | 63 | 55 |
| Cars – commercial | > 4.5 m | 99.7 | 95 | 81.3 | 66.3 | 54.3 | 85.7 | 83.3 | 75 | 63 | 52.7 | 72 | 70.3 | 66.3 | 58.7 | 51 |
| Non-Articulated | > 4.5 m | 93.8 | 74.2 | 58 | 45.4 | 36.2 | 79.8 | 67.2 | 55 | 44.2 | 36 | 67.2 | 60.2 | 51.4 | 42.8 | 35.8 |
| Buses | > 4.5 m | 100 | 78 | 59 | 46 | 37 | 85 | 71 | 57 | 45 | 37 | 70 | 63 | 54 | 44 | 36 |
| Articulated | > 4.5 m | 100 | 52 | 40 | 32 | 24 | 75 | 47 | 39 | 32 | 24 | 60 | 42 | 36 | 31 | 24 |
| B-double | > 4.5 m | 100 | 40 | 28 | 20 | 16 | 75 | 36 | 27 | 19 | 16 | 60 | 33 | 26 | 19 | 16 |
| Road train 1 | > 4.5 m | 100 | 40 | 28 | 20 | 16 | 75 | 36 | 27 | 19 | 16 | 60 | 33 | 26 | 19 | 16 |
| Road train 2 | > 4.5 m | 100 | 40 | 28 | 20 | 16 | 75 | 36 | 27 | 19 | 16 | 60 | 33 | 26 | 19 | 16 |
| Cars – private | Freeway | 110 | 106 | 90 | 72 | 59 | 93 | 90 | 82 | 69 | 58 | 76 | 75 | 71 | 63 | 55 |
| Cars – commercial | Freeway | 105 | 99.3 | 83.3 | 66.3 | 54.3 | 88.7 | 84.7 | 76 | 63.7 | 53.3 | 73 | 71.3 | 66.7 | 58.7 | 51 |
| Non-Articulated | Freeway | 99 | 77.2 | 58.8 | 45.4 | 36.2 | 82 | 68.4 | 55.6 | 44.2 | 36 | 68.6 | 60.8 | 51.6 | 42.8 | 35.8 |
| Buses | Freeway | 110 | 82 | 60 | 46 | 37 | 89 | 73 | 58 | 46 | 37 | 72 | 64 | 54 | 44 | 37 |
| Articulated | Freeway | 106 | 53 | 40 | 32 | 24 | 77 | 47 | 39 | 32 | 24 | 60 | 42 | 36 | 31 | 24 |
| B-double | Freeway | 105 | 41 | 28 | 20 | 16 | 76 | 36 | 27 | 19 | 16 | 60 | 33 | 26 | 19 | 16 |
| Road train 1 | Freeway | 105 | 41 | 28 | 20 | 16 | 76 | 36 | 27 | 19 | 16 | 60 | 33 | 26 | 19 | 16 |
| Road train 2 | Freeway | 105 | 41 | 28 | 20 | 16 | 76 | 36 | 27 | 19 | 16 | 60 | 33 | 26 | 19 | 16 |

*Source: adapted from Austroads (2005) pages 13–16.*

Note:

- < 4.5 m= model road state 1–5
- > 4.5 m= model road state 6–14, 16, 18
- freeway = model road state 15, 17, 19

*Example: Free speed*

A B-double travelling on a curvy road with a gradient of 0%–2% and an MRS of 10 would have an unadjusted free speed of 75 km/h as per Table 4. An MRS of 10 is greater than 4.5 m.

CBA6 provides the option of entering either a default value or a user-specified value for the terrain profile. Free speed is calculated using a weighted average of values relating to the grade selected. The percentage of each grade for each default terrain profile is shown by Table 5.

*Table 5: Terrain grade percentages*

| General terrain description | Percentage of each grade | | | | |
|---|---|---|---|---|---|
| | Grade factor 1 <2% | Grade factor 2 <4% | Grade factor 3 <6% | Grade factor 4 <8% | Grade factor 5 <10% |
| Level or flat terrain | 90 | 10 | 0 | 0 | 0 |
| Rolling or undulating | 50 | 30 | 20 | 0 | 0 |
| Mountainous terrain | 30 | 30 | 20 | 20 | 0 |

*Source: TMR.*

The free speed formula used in CBA6 is derived as a weighted average of time travelled over a section of road rather than a weighted average of the section length of the road. For more detail, see ARRB research report ARR 279.

*Equation 6: Free speed*

$$Free\ speed\ (VT) = 1/\sum_{i}(Grade\%_i / Free\ Speed\ Array\ (VT, Grade_i, HorizAlign, MRS)$$



Where:

- Free speed (VT) = free speed per vehicle type
- Grade% = vertical alignment factors of the road
- Free speed array = corresponding free speed per vehicle type for horizontal alignment and MRS

The formula incorporates the horizontal alignment, vertical alignment and MRS of the road to determine the free speed of each vehicle type.

*Example: Free speed*

The adjusted free speed for a B-double travelling on a curvy flat road with an MRS of 10 is calculated as follows:

$$Free\ speed\ (VT) = 1\ \ (0.9/75 + 0.1/36)$$

$$Free\ speed\ (VT) = 67.6km/h$$

After adjusting for the alignment of the road, the free speed for a B-double changes from 75 km/h to 67.6 km/h.

## 3.2 Roughness adjustment

The values applied to derive the roughness adjustment parameters are listed in Table 6 and Table 7. The values given by the tables for each vehicle type are dependent on the width (‹ 4.5 m and › 4.5 m), curvature and gradient of the road, similar to the free speed calculation. The road roughness adjustment is weighted on distance rather than time.

*Table 6: FSRG1 – Pavement speed condition factor at 110 NRM*

| Vehicle type | Road type | Straight flat Fsrg1 | Straight grad 4% Fsrg1 | Straight grad 6% Fsrg1 | Straight grad 8% Fsrg1 | Straight grad 10% Fsrg1 | Curvy flat Fsrg1 | Curvy grad 4% Fsrg1 | Curvy grad 6% Fsrg1 | Curvy grad 8% Fsrg1 | Curvy grad 10% Fsrg1 | V/curvy flat Fsrg1 | V/curvy grad 4% Fsrg1 | V/curvy grad 6% Fsrg1 | V/curvy grad 8% Fsrg1 | V/curvy grad 10% Fsrg1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cars – private | ‹ 4.5 m | 0.98 | 0.98 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 |
| Cars – commercial | ‹ 4.5 m | 0.97 | 0.98 | 0.99 | 1 | 1 | 0.98 | 0.99 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 |
| Non-Articulated | ‹ 4.5 m | 0.95 | 0.97 | 0.98 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.98 | 0.98 | 0.99 | 0.99 | 1 |
| Buses | ‹ 4.5 m | 0.97 | 0.98 | 0.99 | 1 | 1 | 0.98 | 0.99 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 |
| Articulated | ‹ 4.5 m | 0.95 | 0.97 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| B-double | ‹ 4.5 m | 0.94 | 0.97 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| Road train 1 | ‹ 4.5 m | 0.94 | 0.97 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| Road train 2 | ‹ 4.5 m | 0.94 | 0.97 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| Cars – private | › 4.5 m | 0.96 | 0.96 | 0.98 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 |
| Cars – commercial | › 4.5 m | 0.96 | 0.96 | 0.98 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 |
| Non-Articulated | › 4.5 m | 0.93 | 0.96 | 0.98 | 0.99 | 1 | 0.96 | 0.97 | 0.98 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 |
| Buses | › 4.5 m | 0.95 | 0.98 | 0.99 | 1 | 1 | 0.97 | 0.98 | 0.99 | 1 | 1 | 0.99 | 0.99 | 0.99 | 1 | 1 |
| Articulated | › 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| B-double | › 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| Road train 1 | › 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |
| Road train 2 | › 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1 | 0.97 | 0.98 | 0.99 | 0.99 | 1 | 0.99 | 0.99 | 0.99 | 0.99 | 1 |

*Source: derived by TMR from Austroads (2005) page 18.*

*Table 7: FSRG2 – Pavement speed condition factor at 250 NRM*

| Vehicle type | Road type | Straight flat | Straight grad 4% | Straight grad 6% | Straight grad 8% | Straight grad 10% | Curvy flat | Curvy grad 4% | Curvy grad 6% | Curvy grad 8% | Curvy grad 10% | V/curvy flat | V/curvy grad 4% | V/curvy grad 6% | V/curvy grad 8% | V/curvy grad 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 | Fsrg2 |
| Cars – private | < 4.5 m | 0.76 | 0.77 | 0.8 | 0.87 | 0.92 | 0.79 | 0.8 | 0.83 | 0.88 | 0.92 | 0.84 | 0.85 | 0.87 | 0.9 | 0.94 |
| Cars – commercial | < 4.5 m | 0.75 | 0.77 | 0.81 | 0.88 | 0.93 | 0.79 | 0.8 | 0.83 | 0.89 | 0.93 | 0.84 | 0.85 | 0.87 | 0.9 | 0.94 |
| Non-Articulated | < 4.5 m | 0.68 | 0.76 | 0.84 | 0.91 | 0.95 | 0.74 | 0.79 | 0.86 | 0.91 | 0.95 | 0.79 | 0.83 | 0.87 | 0.92 | 0.95 |
| Buses | < 4.5 m | 0.74 | 0.81 | 0.89 | 0.95 | 0.97 | 0.79 | 0.84 | 0.9 | 0.95 | 0.97 | 0.85 | 0.87 | 0.91 | 0.95 | 0.97 |
| Articulated | < 4.5 m | 0.61 | 0.78 | 0.87 | 0.93 | 0.97 | 0.71 | 0.82 | 0.89 | 0.94 | 0.97 | 0.81 | 0.87 | 0.91 | 0.94 | 0.97 |
| B-double | < 4.5 m | 0.6 | 0.79 | 0.88 | 0.94 | 0.97 | 0.71 | 0.83 | 0.89 | 0.94 | 0.97 | 0.81 | 0.88 | 0.91 | 0.95 | 0.97 |
| Road train 1 | < 4.5 m | 0.6 | 0.79 | 0.88 | 0.94 | 0.97 | 0.71 | 0.83 | 0.89 | 0.94 | 0.97 | 0.81 | 0.88 | 0.91 | 0.95 | 0.97 |
| Road train 2 | < 4.5 m | 0.6 | 0.79 | 0.88 | 0.94 | 0.97 | 0.71 | 0.83 | 0.89 | 0.94 | 0.97 | 0.81 | 0.88 | 0.91 | 0.95 | 0.97 |
| Cars – private | > 4.5 m | 0.63 | 0.65 | 0.73 | 0.83 | 0.9 | 0.71 | 0.72 | 0.77 | 0.85 | 0.91 | 0.81 | 0.81 | 0.84 | 0.88 | 0.93 |
| Cars – commercial | > 4.5 m | 0.64 | 0.67 | 0.75 | 0.85 | 0.91 | 0.72 | 0.74 | 0.79 | 0.86 | 0.92 | 0.81 | 0.82 | 0.85 | 0.89 | 0.93 |
| Non-Articulated | > 4.5 m | 0.62 | 0.71 | 0.83 | 0.9 | 0.95 | 0.7 | 0.77 | 0.85 | 0.91 | 0.95 | 0.77 | 0.82 | 0.87 | 0.92 | 0.95 |
| Buses | > 4.5 m | 0.65 | 0.76 | 0.88 | 0.94 | 0.97 | 0.75 | 0.81 | 0.89 | 0.95 | 0.97 | 0.83 | 0.86 | 0.91 | 0.95 | 0.97 |
| Articulated | > 4.5 m | 0.53 | 0.74 | 0.86 | 0.93 | 0.97 | 0.68 | 0.81 | 0.88 | 0.94 | 0.97 | 0.8 | 0.86 | 0.91 | 0.94 | 0.97 |
| B-double | > 4.5 m | 0.54 | 0.75 | 0.87 | 0.94 | 0.97 | 0.68 | 0.82 | 0.89 | 0.94 | 0.97 | 0.8 | 0.87 | 0.91 | 0.95 | 0.97 |
| Road train 1 | > 4.5 m | 0.54 | 0.75 | 0.87 | 0.94 | 0.97 | 0.68 | 0.82 | 0.89 | 0.94 | 0.97 | 0.8 | 0.87 | 0.91 | 0.95 | 0.97 |
| Road train 2 | > 4.5 m | 0.54 | 0.75 | 0.87 | 0.94 | 0.97 | 0.68 | 0.82 | 0.89 | 0.94 | 0.97 | 0.8 | 0.87 | 0.91 | 0.95 | 0.97 |



*Source: derived by TMR from Austroads (2005) page 18.*

The pavement condition speed factor calculation is shown by Equation 7. The roughness array calculation is made at the 110 and 250 NRM.

*Equation 7: Free speed roughness array*

$$FSRG_i = \sum_i Roughness\ Array\ (VT, Grade_i, HorizAlign, MRS) \times Grade\%$$

Where:

- FSRGi = pavement condition speed factor at either 110 NRM or 250 NRM

*Example: Free speed roughness array*

For a B-double travelling on a curvy flat road of MRS 10:

$$FSRG1 = \sum_i Roughness\ Array(VT, Grade_i, HorizAlign, MRS) \times Grade\%$$

$$FSRG1 = 0.97 \times 0.9 + 0.98 \times 0.1 + 0.99 \times 0 + 0.99 \times 0 + 1 \times 0$$

$$FSRG1 = 0.97$$

$$FSRG2 = \sum_i Roughness\ Array(VT, Grade_i, HorizAlign, MRS) \times Grade\%$$

$$FSRG2 = 0.71 \times 0.9 + 0.83 \times 0.1 + 0.89 \times 0 + 0.94 \times 0 + 0.97 \times 0$$

$$FSRG2 = 0.69$$

Where:

- FSRG1 = pavement condition speed factor at 110 NRM
- FSRG2 = pavement conditino speed factor at 250 NRM

Note: The proportion of section length which falls into each gradient category in CBA6 is illustrated in Table 5.

When current roughness (CNRM) is less than or equal to 110, pavement condition speed factor (pcspdf) is derived by the formula given as Equation 8.

*Equation 8: Pavement condition speed factor at 110NRM*

$$PCSpdF = \begin{cases} CNRM \leq 60 = 1 \\ CNRM \leq 110 = 1 - (1 - FSRG1) \times \dfrac{(CNRM - PAVC)}{(NRMA1 - PAVC)} \end{cases}$$

Where:

- PCSpdF = pavement condition speed factor
- CNRM = current road roughness in NRM counts per kilometre
- FSRG1 = pavement condition speed factor at 110 NRM
- PAVC = minimum roughness following reconstruction (model parameter = 60)
- NRMA1 = roughness value terminating first linear segment of bilinear relationship (model parameter = 110)

Note: The roughness correction should only apply for CNRM › 60, therefore, pcspdf must equal 1 for CNRM 60. When the CNRM is greater than 110 NRM, the pavement condition speed factor is calculated using Equation 9.

*Equation 9: Pavement condition speed factor greater than 110NRM*

$$PCSpdF = Max \begin{cases} FSRG1 - (FSRG1 - FSRG2) \times \dfrac{(CNRM - NRMA1)}{(NRMA - NRMA1)} \\ FSRG2 \end{cases}$$

Where:

- PCSpdF = pavement condition speed factor
- Max = indicates that the larger of the two calculated factors should be selected
- FSRG1 = pavement condition speed factor at 110 NRM
- FSRG2 = pavement condition speed factor at 250 NRM
- CNRM = current road roughness in NRM counts per kilometre
- NRMA = coefficient of the PSR to NRM relationship (model parameter = 250)
- NRMA1 = roughness value terminating first linear segment of bilinear relationship (model parameter = 110)

*Example: Pavement condition speed factor*

A B-double travelling on a curvy flat road at MRS 10 and with a current roughness of 120 NRM.

$$PCSpdF = Max\begin{cases} 0.97 - (0.97 - 0.69) \times \dfrac{(120 - 110)}{(250 - 110)} \\ 0.69 \end{cases}$$

$$PCSpdF = Max\begin{cases} 0.95 \\ 0.69 \end{cases}$$

$$PCSpdF = 0.95$$

As 0.95 is greater than 0.69, the pcspdf used is 0.95.

Corrected free speed is a function of the pavement speed condition factor shown by Equations 8 and 9, and the free speed array calculation shown by Equation 6. The corrected free speed equation for each vehicle type is shown by Equation 10.

*Equation 10: Corrected free speed*

$$Corr\ Free\ Speed(VT) = PCSpdF \times Free\ Speed(VT)$$

Where:

- CorrFreeSpeed(VT) = corrected free speed made for roughness
- PCSpdF = pavement condition speed factor
- FreeSpeed(VT) = free speed per vehicle type adjusted for horizontal and vertical alignment and MRS

*Example: Corrected free speed*

The roughness correction factor is now applied to the average free speed calculated previously for the B-double example.

Where:

$$Corr\ Free\ Speed\ (B - Double) = 0.953 \times 67.67 km/h$$

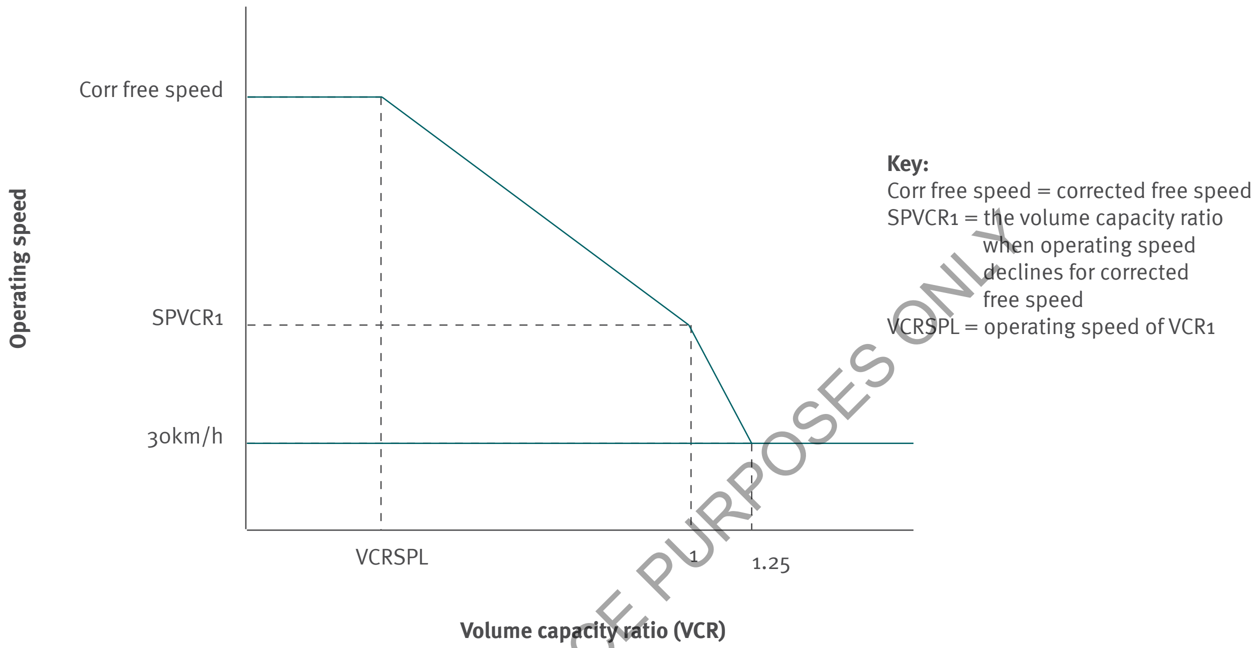
$$Corr\ Free\ Speed\ (B - Double) = 64.4\ km/h$$

Therefore the corrected free speed for a B-double travelling on a curvy flat road at MRS 10 and with roughness of 120 NRM.

## 3.3 Congestion adjustment

Once operating speed has been adjusted for roughness, it is then adjusted for congestion. This function adjusts the speed of the fleet according to the level of congestion on the road, which is described by the VCR. The operating speed is plotted as a function of VCR as shown by Figure 2.

*Figure 2: Operating speed and VCR of private cars*






The vertical axis shown by Figure 2 represents operating speed while the horizontal axis depicts the VCR. The Y-intercept is the corrected free speed which is calculated using Equation 10. When the VCR reaches a value of VCRSPL, the operating speed of the fleet starts to decline to adjust to the growing congestion. The VCRSPL is a parameter value used to represent the VCR level when traffic volume starts to have an effect on the corrected free speed, and vehicle speed declines. As the VCR increases to 1 (the road reaches its theoretical capacity), the speed drops to the corresponding SPVCR1 value. The SPVVCR1 represents the speed at which the fleet can safely travel when capacity is reached. As the VCR increases further to 1.25, the speed drops to the queuing speed of 30km/h. The values of VCRSPL and SPVVCR1 for each MRS are shown by Table 8.

The VCRSPL and SPVVCR1 values are higher for roads with large seal widths and more lanes, than narrow roads with fewer lanes. As the MRS increases, the road is less subject to congestion and speed.

*Table 8: Final operating speed parameters*

| MRS | Road width description | VCRSPL | SPVVCR1 |
|---|---|---|---|
| 1 | Unsealed natural surface | 0.1 | 40 |
| 2 | Unsealed formed road | 0.1 | 40 |
| 3 | Paved ‹ 4.5 m | 0.1 | 40 |
| 4 | Paved ›= 4.5 m | 0.1 | 40 |
| 5 | Narrow seal ‹= 4.5 m | 0.05 | 40 |
| 6 | Narrow seal 4.6 m–5.2 m | 0.05 | 50 |
| 7 | 2 lane seal 5.3 m–5.8 m | 0.05 | 65 |
| 8 | 2 lane seal 5.9 m–6.4 m | 0.08 | 65 |
| 9 | 2 lane seal 6.5 m–7.0 m | 0.11 | 65 |
| 10 | 2 lane seal 7.1 m–7.6 m | 0.12 | 65 |
| 11 | 2 lane plus shoulder seal 7.7 m–8.2 m | 0.12 | 65 |
| 12 | 2 lane plus shoulder seal 8.3 m–9.0 m | 0.12 | 65 |
| 13 | 2 lane plus shoulder seal 9.1 m–9.4 m | 0.12 | 65 |
| 14 | 2 lane plus shoulder seal 9.5 m–10 m | 0.12 | 65 |
| 15 | 2 lane plus shoulder seal 10.1 m–11.6 m | 0.2 | 65 |
| 16 | 3 lane for overtaking | 0.2 | 65 |
| 17 | 4 lane undivided sealed | 0.3 | 70 |
| 18 | 6 lane undivided sealed | 0.3 | 70 |
| 19 | 4 lane divided sealed | 0.3 | 70 |
| 20 | 6 lane divided sealed | 0.3 | 70 |
| 21 | 4 lane divided (limited access) | 0.4 | 70 |
| 22 | 6 lane divided (limited access) | 0.4 | 70 |
| 23 | 8 lane divided (limited access) | 0.4 | 70 |



*Source: Austroads (2005) page 22.*

The operating speed for private vehicle types calculated by CBA6, is illustrated by Equations 11 to 14. The operating speed for commercial vehicles is dependent on the operating speed of private vehicles and corrected free speed as illustrated by Equation 15.

When VCR ‹ VCRSPL, the operating speed is given by Equation 11.

*Equation 11: Operating speed when VCR ‹ VCRSPL*

$$OS(VT) = \ Corr\ Free\ Speed\ (VT)$$

Where:

- OS(VT) = operating speed for each vehicle type

Equation 11 shows that congestion has no effect on the operating speed of the fleet and traffic travels at the corrected free speed. Congestion only starts to affect the operating speed of a private car when the VCR reaches the VCRSPL. The operating speed given by Equation 12 applies when the VCR is less than 1 but greater than VCRSPL.

*Equation 12: Operating speed when VCRSPL VCR 1*

$$OS(VT) = SPVCR1 + (CorrFreeSpeed(VT) - SPVVCR1) \times \left(\frac{(1 - VCR)}{(1 - VCRSPL)}\right)$$

Where:

- SPVCR1 = operating speed at VCR of 1
- VCRSPL = the VCR when operating speed declines from CorrFreeSpeed

Equation 12 shows that as congestion levels increase (VCR approaches 1), operating speed declines to the SPVCR1 operating speed value. When the VCR exceeds this point (1 VCR 1.25), the operating speed is given by Equation 13.

*Equation 13: Operating speed when 1 VCR 1.25*

$$OS\ (VT) = 30\ km/h + (SPVCR1 - 30\ km/h) \times \frac{(1.25 - VCR)}{(1.25 - 1)}$$

In Equation 13, the new operating speed is determined as a function of the SPVCR1 minus a queuing speed of 30 km/h. When the VCR reaches a maximum of 1.25, the operating speed is 30km/h.

Note: Congestion costs per vehicle in CBA6 do not increase once the VCR reaches 1.25. When the VCR is 1.25, operating speed is calculated by the formula given by Equation 14.

*Equation 14: Operating speed when VCR 1.25*

$$OS\ (VT) = 30\ km/h$$

Equations 11 to 14 are used for calculating the operating speed of a private vehicle. The operating speed for a commercial vehicle is calculated by Equation 15.

*Equation 15: Commercial operating speed*

$$OS(Commercial\ VT) = MIN(OS(PrivateCar), Corr\ Free\ Speed(VT))$$

Where:

- MIN = minimum function of equation
- OS (PrivateCar) = operating speed of a private car
- Corr Free Speed (VT) = the corrected free speed of the commercial vehicle

Equation 15 is derived based on the assumption that commercial vehicles should not be able to travel faster than private vehicles.

*Example: Operating speed*

A B-double travelling on a curvy flat road with an MRS 10 and a VCR of 0.058, as calculated in Section 2.4, would have an estimated operating speed calculated as follows:

The calculated VCR ‹ VCRSPL as:

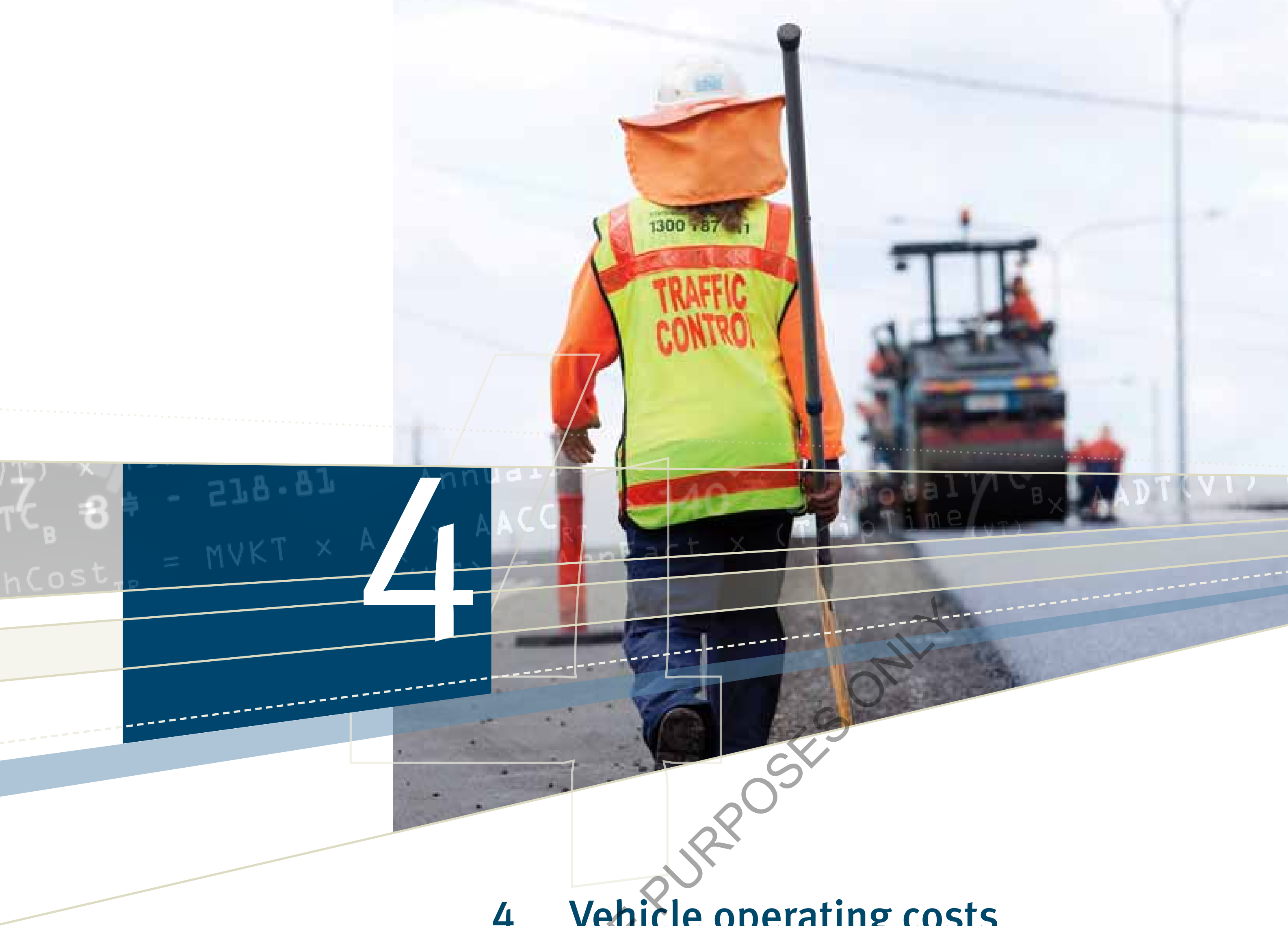
$$VCR = 0.046$$

$$VCRSPL = 0.12$$

Therefore, the operating speed equals the corrected free speed from Equation 11.

$$OS\ (B - Double) = 64.4km/h$$

Assuming that private vehicle operating speed is above this value, the operating speed for the B-double is 64.4 km/h.



# 4 Vehicle operating costs

VOC by definition are the costs associated with operating a motor vehicle. VOC are made up of fuel, oil, tyre, repairs and maintenance and interest and depreciation costs. The calculation of each component of VOC is based on a detailed methodology. The calculation of VOC is impacted by a number of inputs and adjustments are made accordingly.

The inputs and factors that affect VOC calculations in CBA6 are shown by Table 9.

*Table 9: Factors affecting VOC*

| Vehicle operating costs | Operating speed | Vehicle characteristics | | Road infrastructure | | | Traffic volume (pce) |
|---|---|---|---|---|---|---|---|
| | | Type and specs | Fuel type | Gradient | Curvature | Surface type and condition | |
| Fuel | T | T | T | T | T | T | T |
| Oil | T | T | T | | | | |
| Tyres | T | T | | T | T | T | T |
| Repairs and maintenance | | T | | | | T | |
| Depreciation and interest | T | T | | | | T | |

*Source: adapted from Austroads (2005).*

The majority of these algorithms and unit values are derived from Austroads report ap-r264/05 'harmonisation of non-urban road user cost models'.

## 4.1 Fuel

Vehicle fuel cost is calculated based on the fuel consumption of each vehicle. Vehicle operating speed predominantly influences the rate of fuel consumption. Further adjustments to the rate of fuel consumption are made to account for site-specific details such as gradient, curvature, congestion and roughness.

### 4.1.1 Basic fuel consumption

Basic fuel consumption (bfc) and basic fuel cost (fuelcf) are calculated using the parameters given in Table 10. CBA6 applies a unit cost for petrol fuel of 82.49 cents per litre and 81.57 cents per litre for diesel fuel.

Note: Fuel unit values are measured in resources costs and not market/retail prices.

*Table 10: Fuel costs and consumption factors*

| Vehicle type | Square | Reciprocal | Const. | Fcavf | Pdies | Petrol | Diesel | Fcongf |
|---|---|---|---|---|---|---|---|---|
| | Factor 3 | Factor 2 | Factor 1 | State of tune factor | Proportion of diesel vehicles | Petrol price (c/litre) | Diesel fuel price (c/litre) | Fuel cons incr factor-VCR=1 |
| Cars – private | 0.0054 | 1526.2 | 37.3 | 1.071 | 0 | 82.49 | 81.57 | 0.4 |
| Cars – commercial | 0.0114 | 1883 | 38.9 | 1.071 | 0 | 82.49 | 81.57 | 0.4 |
| Non-Articulated | 0.0168 | 3485.1 | 49 | 1.1 | 0.5 | 82.49 | 81.57 | 0.3 |
| Buses | 0.0131 | 5451.1 | 69.4 | 1.1 | 0.7 | 82.49 | 81.57 | 0.3 |
| Articulated | 0.0158 | 9621.1 | 118.6 | 1.1 | 0.9 | 82.49 | 81.57 | 0.3 |
| B-double | 0.016 | 14720.4 | 172.7 | 1.1 | 1 | 0 | 81.57 | 0.3 |
| Road train 1 | 0.0148 | 17201.8 | 223.6 | 1.1 | 1 | 0 | 81.57 | 0.3 |
| Road train 2 | 0.015 | 26646.9 | 312.1 | 1.1 | 1 | 0 | 81.57 | 0.3 |

*Sources: Austroads report 264/5, Austroads report IR-R156/08, CBA4 Technical Manual (1999).*



Basic fuel consumption in litres per 1000 km is calculated using Equation 16. Basic fuel consumption is based on the fuel efficiency of each vehicle type and the operating speed.

*Equation 16: Basic fuel consumption*

$$BFC(VT) = Square(VT) \times OS^2(VT) + \frac{Reciprocal(VT)}{OS(VT)} + Constant(VT)$$

Where:

- BFC(VT) = basic fuel consumption for each vehicle type
- Square(VT) = model parameter
- OS(VT) = operating speed calculation for each vehicle type
- Reciprocal(VT) = model parameter
- Constant(VT) = model parameter

Basic fuel consumption is a function of the default model parameters shown by Table 10. For a graphical representation of the relationship between variables, refer to Figure 12. At this early stage in the fuel consumption calculation, these values will not vary by project location.

*Example: Basic fuel consumption*

Basic fuel consumption in litres per 1000 km for a B-double with an operating speed of 64.4 km/h (as calculated in Section 3) is determined as follows:

$$BFC(VT) = 0.016 \times 64.49^2 + \frac{147,20.40}{64.49} + 172.7$$

$$BFC(VT) = 467.50\ L/1000km$$

This shows that at a constant speed of 64.4 km/h, a B-double will consume 467.5 litres of fuel for every 1000 km travelled.

The basic fuel consumption calculation excludes other project-specific factors that affect vehicle fuel consumption. This calculation merely sets the base level from which the actual fuel consumption rate can be determined. The actual fuel consumption in litres per 1000 km is calculated by applying a series of adjustments for gradient, curvature, congestion and roughness.

### 4.1.2 Fuel consumption gradient correction factors

The gradient adjustment is calculated using the value obtained from the roughness and gradient correction factor values shown by Table 11. The adjustment is made to reflect increased fuel consumption due to a change in gradient. As gradients increase, the adjustment factor also increases, indicating a direct relationship. For example, the gradient adjustment of a private vehicle on a 10% gradient travelling at 40 km/h is 0.30. This indicates that fuel consumption is 30% higher than fuel consumption on a flat road with a grade of less than 4%.

*Table 11: Fuel consumption gradient adjustment array*

| Vehicle type | Gradient | Speed description | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spd_01 | Spd_02 | Spd_03 | Spd_04 | Spd_05 | Spd_06 | Spd_07 | Spd_08 | Spd_09 | Spd_10 | Spd_11 | Spd_12 | Spd_13 |
| | | 8–15km/h | 16–23km/h | 24–31km/h | 32–39km/h | 40–47km/h | 48–55km/h | 56–63km/h | 64–71km/h | 72–79km/h | 80–87km/h | 88–95km/h | 96–103km/h | 104–112km/h |
| Cars – private | <4% | 0.03 | 0.07 | 0.07 | 0.07 | 0.08 | 0.09 | 0.09 | 0.10 | 0.08 | 0.05 | 0.04 | 0.04 | 0.03 |
| Cars – commercial | <4% | 0.02 | 0.06 | 0.06 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
| Non-Articulated | <4% | 0.06 | 0.09 | 0.08 | 0.08 | 0.11 | 0.16 | 0.25 | 0.22 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 |
| Buses | <4% | 0.08 | 0.11 | 0.10 | 0.13 | 0.20 | 0.26 | 0.39 | 0.52 | 0.42 | 0.29 | 0.19 | 0.10 | 0.00 |
| Articulated | <4% | 0.06 | 0.14 | 0.13 | 0.19 | 0.28 | 0.37 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| B-double | <4% | 0.06 | 0.15 | 0.15 | 0.22 | 0.31 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| Road train 1 | <4% | 0.07 | 0.16 | 0.15 | 0.19 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| Road train 2 | <4% | 0.16 | 0.17 | 0.13 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Cars – private | <6% | 0.04 | 0.11 | 0.10 | 0.11 | 0.12 | 0.14 | 0.17 | 0.19 | 0.16 | 0.12 | 0.11 | 0.10 | 0.08 |
| Cars – commercial | <6% | 0.04 | 0.09 | 0.09 | 0.09 | 0.10 | 0.11 | 0.12 | 0.14 | 0.11 | 0.09 | 0.08 | 0.08 | 0.07 |
| Non-Articulated | <6% | 0.10 | 0.18 | 0.22 | 0.28 | 0.34 | 0.43 | 0.52 | 0.47 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| Buses | <6% | 0.15 | 0.24 | 0.32 | 0.42 | 0.54 | 0.65 | 0.83 | 0.98 | 0.84 | 0.70 | 0.57 | 0.45 | 0.32 |
| Articulated | <6% | 0.18 | 0.29 | 0.40 | 0.52 | 0.66 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| B-double | <6% | 0.10 | 0.30 | 0.42 | 0.54 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 |
| Road train 1 | <6% | 0.11 | 0.29 | 0.39 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Road train 2 | <6% | 0.39 | 0.29 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| Cars – private | <8% | 0.05 | 0.19 | 0.17 | 0.17 | 0.18 | 0.21 | 0.26 | 0.30 | 0.25 | 0.21 | 0.18 | 0.15 | 0.12 |
| Cars – commercial | <8% | 0.05 | 0.17 | 0.16 | 0.16 | 0.17 | 0.18 | 0.19 | 0.22 | 0.18 | 0.15 | 0.13 | 0.12 | 0.10 |
| Non-Articulated | <8% | 0.19 | 0.39 | 0.47 | 0.55 | 0.62 | 0.68 | 0.70 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| Buses | <8% | 0.26 | 0.50 | 0.62 | 0.76 | 0.91 | 1.05 | 1.25 | 1.42 | 1.25 | 1.08 | 0.92 | 0.78 | 0.62 |
| Articulated | <8% | 0.33 | 0.60 | 0.75 | 0.90 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| B-double | <8% | 0.18 | 0.62 | 0.76 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 |
| Road train 1 | <8% | 0.21 | 0.61 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| Road train 2 | <8% | 0.60 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| Cars – private | <10% | 0.06 | 0.28 | 0.27 | 0.28 | 0.30 | 0.35 | 0.42 | 0.47 | 0.42 | 0.34 | 0.28 | 0.25 | 0.21 |
| Cars – commercial | <10% | 0.07 | 0.27 | 0.27 | 0.28 | 0.30 | 0.32 | 0.35 | 0.39 | 0.35 | 0.30 | 0.26 | 0.24 | 0.21 |
| Non-Articulated | <10% | 0.30 | 0.61 | 0.72 | 0.83 | 0.89 | 0.93 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| Buses | <10% | 0.39 | 0.76 | 0.93 | 1.11 | 1.28 | 1.45 | 1.69 | 1.90 | 1.69 | 1.49 | 1.31 | 1.13 | 0.95 |
| Articulated | <10% | 0.47 | 0.90 | 1.08 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 |
| B-double | <10% | 0.27 | 0.93 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Road train 1 | <10% | 0.30 | 0.91 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| Road train 2 | <10% | 0.75 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

*Source: adapted from Austroads (2005) pages 28–29.*

The gradient adjustment factor is calculated using Equation 17. This adjustment factor varies by vehicle type, operating speed and the weighted average of the road gradient.

*Equation 17: Fuel consumption gradient adjustment*

$$Grad\ Adjust = \sum_i Gradient\ Adj\ Array(VT, Grade_i, OS) \times Grade\%$$

Where:

- GradAdjust = fuel consumption adjustment factor based on speed and slope
- GradientAdjArray = array table shown by Table 12
- VT = vehicle type
- OS = operating speed (km/h)
- Grade% = slope of the gradient by weighted proportion of road

*Example: Gradient adjustment*

The gradient adjustment for a B-double travelling at the calculated operating speed of 64.4 km/h on flat terrain is calculated as follows:

$$Grad\ Adjust\ = (0\ \times\ 0.9) + (0.43\ \times\ 0.1) + (0.63\ \times\ 0) + (0.85\ \times\ 0) + (1.12\ \times\ 0)$$

$$Grad\ Adjust =\ 0.043$$

Therefore, the fuel consumption example calculated in Section 4.1.1 would be adjusted by an increase in consumption of 4.3%.

### 4.1.3 Curvature adjustment

The horizontal alignment of the road can also affect the fuel consumption of vehicles. It is assumed that vehicles consume more fuel on roads with curvy alignments than on straight alignments. The curvature adjustment is calculated using values obtained from Table 12.

*Table 12: Fuel consumption curvature adjustment*

| Vehicle type | Curve categories | | |
|---|---|---|---|
| | Very curvy | Curvy | Straight |
| Cars – private | 0.2 | 0.1 | 0 |
| Cars – commercial | 0.2 | 0.1 | 0 |
| Non-Articulated | 0.2 | 0.1 | 0 |
| Buses | 0.2 | 0.1 | 0 |
| Articulated | 0.2 | 0.1 | 0 |
| B-double | 0.1 | 0.1 | 0 |
| Road train 1 | 0.1 | 0.1 | 0 |
| Road train 2 | 0.1 | 0.1 | 0 |

*Source: adapted from Austroads (2005) page 32.*

Note: Values in these columns are applied to the default CBA curvature categories, see Table 17.



The fuel consumption curvature adjustment is shown by Equation 18.

*Equation 18: Fuel consumption curvature adjustment*

$$Curve\ Adjust = \sum_i CurveAdjArray(VT, CurveCategory)$$

Where:

- CurveAdjust = fuel consumption adjustment factor based on curvature
- CurveAdjArray = see Table 12 for information
- CurveCategory = very curvy, curvy and straight

*Example: Curvature adjustment*

From Table 12, a B-double travelling on a curvy road will have a curvature adjustment factor of 0.1. A curvy road increases fuel consumption of this vehicle by 10% when compared to a straight road.

### 4.1.4 Congestion adjustment

The congestion adjustment is calculated using values obtained from the fuel consumption (fcongf) parameter in Table 10. Congestion is affected by the rate of fuel consumption of all vehicles, increasing as vehicles remain in congested traffic.

The congestion adjustment is calculated by multiplying the VCR by the fuel consumption factor per vehicle type. The implication of the formula is that some vehicle types consume more fuel in congestion than others. The values in Table 10 indicate that heavy commercial vehicles, which are predominately diesel, use less extra fuel in congested traffic. The congestion adjustment calculation is used in CBA6, if the value calculated is less than 1. If the congestion adjustment calculation is greater than 1, a maximum default value of 1 is used in CBA6. Equation 19 shows the fuel consumption adjustment for congestion.

*Equation 19: Fuel consumption congestion adjustment*

$$Congestion\ adjustment\ =\ MIN(1, VCR\ \times FCONGF)$$

Where:

- Min = minimum value
- VCR = volume capacity ratio
- FCONGF = fuel consumption adjustment parameter

*Example: Congestion adjustment*

If the VCR is 0.046, the congestion adjustment for a B-double would be calculated as follows:

$$Congestion\ adjustment\ =\ 0.046\ \times\ 0.3$$

$$Congestion\ adjustment\ =\ 0.014$$

As the calculated congestion adjustment is less than 1, the calculated congestion adjustment is used. Therefore, fuel consumption of this vehicle increases by 1.4% because of congestion.

### 4.1.5 Roughness adjustment

Adjustments for the effect of road surface condition on fuel consumption are based on road roughness, vehicle type and operating speed.

The first adjustment is the pavement condition cost factor (GCGFAC), which adjusts fuel consumption for the effects of road roughness. This is shown by Equation 20.

*Equation 20: Fuel consumption pavement condition cost factor*

$$GCGFAC = Min\begin{cases} CFSMAX \\ CSENSP \times \dfrac{(CNRM - PAVC)}{(NRMA - PAVC)} \end{cases}$$

Where:

- GCGFAC = pavement condition cost factor
- CFSMAX = maximum cost factor for surfaced roads and equals 1.75
- CSENSP = cost sensitivity for surfaced roads and equals 4
- CNRM = current roughness of the road
- PAVC = minimum roughness of road after (re)construction (equal to 60)
- NRMA = coefficient of the PSR to NRM conversion ratio (equal to 250)

*Example: Pavement condition cost*

The current roughness of a road is 120 NRM.

$$GCGFAC = Min\begin{cases} 1.75 \\ 4 \times \dfrac{(120-60)}{(250-60)} \end{cases} = 1.2631$$

$$GCGFAC = 1.2631$$

The calculated factor is 1.2631 and as the CFSMAX is defaulted to 1.75, the minimum value is applied.

The roughness pavement condition cost factor is adjusted for vehicle type and speed to determine the roughness adjustment factor. The roughness adjustment factor (FCGRVF) is calculated from the roughness correction factors shown by Table 13.

*Table 13: FCGRVF fuel consumption roughness adjustment array*

| Vehicle type | Speed description fcgrvf | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8–15km/h | 16–23km/h | 24–31km/h | 32–39km/h | 40–47km/h | 48–55km/h | 56–63km/h | 64–71km/h | 72–79km/h | 80–87km/h | 88–95km/h | 96–103km/h | 104–112km/h |
| Cars – private | 0.023 | 0.060 | 0.067 | 0.070 | 0.077 | 0.087 | 0.100 | 0.103 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 |
| Cars – commercial | 0.026 | 0.060 | 0.068 | 0.073 | 0.078 | 0.084 | 0.090 | 0.092 | 0.083 | 0.080 | 0.080 | 0.077 | 0.073 |
| Non-Articulated | 0.044 | 0.083 | 0.093 | 0.103 | 0.111 | 0.123 | 0.127 | 0.110 | 0.104 | 0.097 | 0.091 | 0.076 | 0.071 |
| Buses | 0.050 | 0.080 | 0.090 | 0.100 | 0.110 | 0.120 | 0.140 | 0.150 | 0.130 | 0.120 | 0.120 | 0.110 | 0.100 |
| Articulated | 0.033 | 0.097 | 0.113 | 0.127 | 0.143 | 0.160 | 0.177 | 0.193 | 0.187 | 0.170 | 0.160 | 0.147 | 0.133 |
| B-double | 0.050 | 0.100 | 0.120 | 0.140 | 0.160 | 0.170 | 0.190 | 0.200 | 0.200 | 0.220 | 0.190 | 0.180 | 0.170 |
| Road train 1 | 0.060 | 0.110 | 0.130 | 0.150 | 0.170 | 0.190 | 0.210 | 0.220 | 0.240 | 0.240 | 0.200 | 0.200 | 0.200 |
| Road train 2 | 0.060 | 0.120 | 0.140 | 0.150 | 0.170 | 0.200 | 0.230 | 0.270 | 0.220 | 0.260 | 0.230 | 0.230 | 0.210 |



*Source: adapted from Austroads (2005) page 31.*

A B-double travelling at a speed of 64.4 km/h, is subject to a FCGRVF of 0.2. The roughness adjustment consists of both the FCGRVF and the GCGFAC factors. The roughness adjustment equation is shown below by Equation 21.

*Equation 21: Fuel consumption roughness adjustment*

$$Rough\ Adj\ (VT) = \ FCGRVF(VT) \times GCGFAC$$

Where:

- RoughAdj(VT) = fuel consumption roughness adjustment factor
- FCGRVF(VT) = roughness correction factor

*Example: Roughness adjustment*

For a B-double travelling at a speed of 64.49 km/h, on a road with roughness of 120 NRM, the roughness adjustment factor is:

$$Rough\ Adj(B - Double) = \ 0.2 \ \times \ 1.2631$$

$$Rough\ Adj(B - Double) = 0.253$$

This vehicle will incur an increase in fuel consumption of 25.3% due to the impacts of road roughness. This example suggests that road roughness has a significant effect on fuel consumption.

### 4.1.6 Fuel consumption costs

Using data from Table 10, the cost of fuel in cents per litre is shown by Equation 22. This formula incorporates the weighted average of vehicles depending on their fuel type. For example, a rigid (non-articulated) vehicle may use either petrol or diesel fuel.

*Equation 22: Fuel consumption cost*

$$Fuelcf(VT) = Petrol(VT) \times \left(1 - PDies(VT)\right) + Diesel(VT) \times PDies(VT)$$

Where:

- Fuelcf (VT) = fuel cost in cents per litre
- Petrol (VT) = cost of petrol in cents per litre
- PDIES (VT) = proportion of diesel vehicles
- DIESEL(VT) = cost of diesel fuel in cents per litre

*Example: Fuel consumption cost*

The fuel cost of a B-double is given below:

$$Fuelcf(VT) = Petrol(VT) \times \left(1 - PDies(VT)\right) + Diesel(VT) \times PDies(VT)$$

$$Fuelcf(B - Double) = 0 \times 0 + 81.57 \times 1$$

$$Fuelcf(B - Double) = 81.57$$

The fuel cost for this vehicle is 81.57 cents per litre. Therefore, as all B-double vehicles are assumed to use diesel, the fuel cost is unchanged from the diesel cost in Table 10.

Once the fuel consumption cost has been calculated, it can be incorporated into the total fuel cost formula. Total fuel cost is then adjusted for basic fuel consumption, fuel efficiency, gradient, curvature, congestion and roughness. The total fuel cost is given by Equation 23.

*Equation 23: Total fuel cost*

$$Fuel\ Cost(VT) = Fuelcf(VT) \times BFC(VT) \times (1 + FCAVF + Grad\ Adj + Curv\ Adj + Cong\ Adj + Rough\ Adj)VT$$

Where:

- Fuelcf(VT) = fuel cost in cents per litre
- BFC(VT) = basic fuel consumption
- FCAVF = fuel efficiency or state of tune factor
- Grad Adj = adjustment for the road gradient

- Curve Adj = adjustment for the road curvature
- Cong Adj = adjustment for congestion
- Rough Adj = adjustment for the roughness of the road

Total fuel cost example:

The total fuel cost for a B-double is calculated as follows:

$$Fuel\ Cost(B - Double) = 81.57\frac{c}{L} \times 467.50\frac{L}{1000km} \times (1 + 1.1 + 0.043 + 0.1 + 0.014 + 0.253)$$

$$Fuel\ Cost(B - Double) = 95{,}716.277\ c/1000km$$

$$Fuel\ Cost(B - Double) = 95.72\ c/km$$

For every kilometre the B-double travels on this road, it will incur fuel costs of 95.72.

## 4.2 Oil costs

Oil costs are usually a small component of total VOC. Oil consumption is calculated using data in Table 14.

*Table 14: Oil costs and consumption factors*

| Vehicle type | Oil consumption factors (oilcons) | | | | | | | | | | | | | Oil costs | Pdies |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Operating speed | | | | | | | | | | | | | Oils (c/l) | |
| | 8–15km/h | 16–23km/h | 24–31km/h | 32–39km/h | 40–47km/h | 48–55km/h | 56–63km/h | 64–71km/h | 72–79km/h | 80–87km/h | 88–95km/h | 96–103km/h | 104–112km/h | | |
| Cars – private | 0.75 | 0.57 | 0.53 | 0.55 | 0.57 | 0.60 | 0.63 | 0.65 | 0.67 | 0.69 | 0.71 | 0.74 | 0.77 | 522.00 | 0.00 |
| Cars – commercial | 0.75 | 0.57 | 0.53 | 0.55 | 0.57 | 0.60 | 0.63 | 0.65 | 0.67 | 0.69 | 0.71 | 0.74 | 0.77 | 511.00 | 0.00 |
| Non-Articulated | 1.26 | 0.99 | 0.97 | 0.95 | 0.96 | 0.97 | 0.99 | 1.01 | 1.04 | 1.07 | 1.13 | 1.22 | 1.31 | 488.00 | 0.50 |
| Buses | 1.26 | 0.99 | 0.97 | 0.95 | 0.96 | 0.97 | 0.99 | 1.01 | 1.04 | 1.07 | 1.13 | 1.22 | 1.31 | 488.00 | 0.70 |
| Articulated | 1.88 | 1.37 | 1.36 | 1.34 | 1.36 | 1.37 | 1.44 | 1.50 | 1.52 | 1.54 | 1.56 | 1.58 | 1.63 | 488.00 | 0.90 |
| B-double | 2.59 | 2.02 | 1.99 | 1.98 | 1.99 | 2.02 | 2.07 | 2.12 | 2.18 | 2.23 | 2.26 | 2.28 | 2.34 | 488.00 | 1.00 |
| Road train 1 | 2.59 | 2.02 | 1.99 | 1.98 | 1.99 | 2.02 | 2.07 | 2.12 | 2.18 | 2.23 | 2.26 | 2.28 | 2.34 | 488.00 | 1.00 |
| Road train 2 | 2.59 | 2.02 | 1.99 | 1.98 | 1.99 | 2.02 | 2.07 | 2.12 | 2.18 | 2.23 | 2.26 | 2.28 | 2.34 | 488.00 | 1.00 |

*Source: adapted from Austroads (2005) p.35, Austroads (2008) p.16 and pdies*



### 4.2.1 Oil consumption

The average oil consumption per vehicle in litres per 1000 km is given by Equation 24.

*Equation 24: Average oil consumption*

$$Oil(VT) = \left(dtopcf \times Pdies(VT) + \left(1 - Pdies(VT)\right) \times Oilcons(VT, OS) \times gear\right)$$

Where:

- Oil(VT) = oil consumption averaged over diesel and petrol (litres/1000 km)
- dtopcf = petrol to diesel vehicle conversion ratio (model variable = 1.5)
- Pdies = proportion of vehicles which are diesel powered
- Oilcons(VT, OS) = basic engine oil consumption speed relationship per vehicle
- Gear = factor relating total oil consumption to engine oil use (model variable = 1.1)

*Example: Average oil consumption*

The average oil consumption per vehicle in litres per 1000 km for a B-double travelling at 64.4 km/h, is given by:

$$Oil(VT) = \left(dtopcf \times Pdies(VT) + \left(1 - Pdies(VT)\right) \times Oilcon(VT, OS) \times gear\right)$$

$$Oil(B - Double) = (1.5 \times 1 + 1 - 1) \times 2.12 \times 1.1$$

$$Oil(B - Double) = 3.498\ L/1000km$$

On average, a B-double will consume 3.498 litres of oil per 1000 km when travelling at a constant speed of 64.4 km/h.

### 4.2.2 Oil cost

The consumption factor is used to determine the total oil cost for each vehicle, given by Equation 25. The unit oil cost is listed in Table 14 for each vehicle type.

*Equation 25: Total oil cost*

$$OilCost(VT) = Oil(VT) \times Oils(VT)/1000$$

Where:

- OilCost(VT) = the cost of engine oil (c/km)
- Oils(VT) = engine oil price (c/litre)

*Example: Oil cost*

The total cost in cents per kilometre (c/km) for a B-double travelling at 64.4 km/h, with an average oil consumption of 3.498 l/1000 km, is given by:

$$OilCost(B - Double) = 3.498\ L/1000km \times 488/1000$$

$$OilCost(B - Double) = 1.71\ c/km$$

The total cost of oil for this vehicle is 1.71 cents per kilometre travelled. Compared to the fuel cost example presented in Section 4.1.6, oil costs are a relatively small component of VOC.

## 4.3 Tyres

Tyre costs in CBA6 are calculated using the data shown by Table 15. The cost of tread wear in cents per 0.001 mm tread thickness (costtread) is calculated first, followed by basic tyre wear which is calculated as 0.001 mm wear per 1000 km. Adjustments are then made for gradient, curvature, roughness and congestion.

*Table 15: Tyre wear and cost parameters*

| Vehicle type | No.tyre<br>Number of tyres (excl. Spares) | Ctyre#<br>Costs of new tyres ($) | Cretr#<br>Cost of retreads ($) | Retn<br>Average number of retreads per tyre | Treadn<br>Thickness of tread for new tyre | Treadr<br>Thickness of tread for retreaded tyre | Tyre wc1<br>Formula factor 1 | Tyre wc2<br>Formula factor 2 | Tyre k<br>State of tune factor | Tcong^<br>Factor for tyre wear increase at VCR=1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cars – private | 4 | 121 | 66 | 0 | 6.71 | 5.87 | 0.00000 | 0.42780 | 201.9 | 1.7 |
| Cars – commercial | 4 | 136.33 | 84.67 | 0 | 7.22 | 6.32 | 0.00000 | 0.42780 | 201.9 | 1.7 |
| Non-Articulated | 7 | 309.8 | 141.2 | 1.4 | 9.27 | 8.58 | 0.00652 | 0.08556 | 305.54 | 1 |
| Buses | 8 | 309.8 | 141.2 | 1.75 | 9.53 | 8.92 | 0.00815 | 0.00000 | 331.45 | 1 |
| Articulated | 20 | 338.33 | 118.67 | 2.5 | 10.67 | 9.75 | 0.00210 | 0.00000 | 100.23 | 1 |
| B-double | 30 | 331 | 125 | 2.5 | 10.67 | 9.75 | 0.00230 | 0.00000 | 106.3 | 1 |
| Road train 1 | 44 | 331 | 130 | 2.5 | 10.67 | 9.75 | 0.00230 | 0.00000 | 106.3 | 1 |
| Road train 2 | 62 | 327 | 134 | 2.5 | 10.67 | 9.75 | 0.00230 | 0.00000 | 106.3 | 1 |

*Source: adapted from Austroads (2005) p.39, TMR calculations and Austroads (2008) page 16.*

## 4.4 Tread cost

The calculation of the tread cost (VT) per 0.001 mm thickness is given by Equation 26. The tread cost is a function of the cost of new tyres and the cost of the number and thickness of retreaded tyres. Private and commercial cars do not use retread tyres, as opposed to trucks which it is assumed use both retread and new tyres.

*Equation 26: Tread cost*

$$TreadCost = NoTyre \times \frac{((CTYRE + CRETR \times RETN) \times 100)}{((TREADN + TREADR \times RETN) \times 1000)}$$

Where:

- CTYRE = cost of new tyres ($)
- CRETR = cost of retreads ($)
- RETN = average number of retreads per tyre
- TREADN = thickness of tread for new tyre
- TREADR = thickness of tread for retreaded tyre

*Example: Tread cost*

Tread cost for a B-double is given by:

$$Treadcost\ (B - Double) = 30 \times \frac{((331 + 125 \times 2.5) \times 100)}{((10.67 + 9.75 \times 2.5) \times 1000)}$$

$$Treadcost\ (B - Double) = 55.07\ \mathrm{c/0.001mm}$$

Tyre costs for a B-double is 55.07 cents per 0.001 mm of tread. Given the cost of new tyres and the retread costs, heavy vehicles will have the highest tyre costs in the fleet.



### 4.4.1 Tyre wear

The tyre wear formula illustrates the basic speed/tyre wear relationship given by Equation 27. This equation incorporates the operating speed effect, based on the assumption that higher operating speeds increase tyre wear. The example shows that there is a direct relationship between tyre wear and operating speed for private and commercial cars while tyre wear and operating speed for other vehicles exhibit a direct non-linear relationship.

*Equation 27: Basic tyre wear*

$$Tyre\ wear = TyreK(VT) + (OS(VT))^2 \times TyreWC1(VT) + OS(VT) \times TyreWC2(VT))$$

Where:

- Tyrek = state of tune factor
- OS = vehicle operating speed
- TyreWC1 = formula factor 1
- TyreWC2 = formula factor 2

*Example: Basic tyre wear*

Tyre wear for a B-double with operating speed of 64.4 km/h is given by:

$$Tyre\ Wear(B - Double) = 106.30 + 64.49^2 \times 0.0023 + 64.49 \times 0$$

$$Tyre\ Wear(B - Double) = 115.87\ 0.001\text{mm}/1000\text{km}$$

Basic tyre wear for a B-double with a constant operating speed of 64.4 km/h is 115.87 (0.001 mm) per 1000 km travelled.

### 4.4.2 Congestion adjustment

Tyre wear is adjusted for congestion levels on the road to calculate the tyre wear congestion adjustment factor for each vehicle type (TCONG). The congestion adjustment is given by Equation 28. The TCONG factor is sourced from Table 15.

*Equation 28: Congestion adjustment*

$$Cong(VT) = TCONG(VT) \times VCR$$

Where:

- Cong(VT) = congestion adjustment factor per vehicle type
- TCONG(VT) = factor for tyre wear increase where VCR = 1 per vehicle type

*Example: Congestion adjustment*

The congestion adjustment value for a B-double on a road with a VCR of 0.046 is given by:

$$Cong(B - Double) = 1.0 \times 0.046$$

$$Cong(B - Double) = 0.046$$

This result shows that tyre wear increases by 4.6% due to the effect of congestion.

### 4.4.3 Curvature and gradient adjustment

Curvature and gradient adjustments are calculated by the proportion of road sections, which are classified into each curvature and gradient category. These parameter values are shown by Table 16.

*Table 16: Curvature and gradient tyre cost adjustments*

| Vehicle type | Gradient | | | | | Curve design speed (km/h) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | <2% | <4% | <6% | <8% | <10% | 30 | 50 | 65 | 80 |
| Cars – private | 0 | 0.1 | 0.2 | 0.4 | 0.6 | 10 | 15 | 20 | 15 |
| Cars – commercial | 0 | 0.14 | 0.27 | 0.54 | 0.81 | 10 | 15 | 20 | 15 |
| Non-Articulated | 0 | 0.14 | 0.27 | 0.54 | 0.81 | 10 | 15 | 20 | 15 |
| Buses | 0 | 0.15 | 0.3 | 0.6 | 0.9 | 10 | 15 | 20 | 15 |
| Articulated | 0 | 0.15 | 0.3 | 0.6 | 0.9 | 10 | 15 | 20 | 15 |
| B-double | 0 | 0.15 | 0.3 | 0.6 | 0.9 | 10 | 15 | 20 | 15 |
| Road train 1 | 0 | 0.15 | 0.3 | 0.6 | 0.9 | 10 | 15 | 20 | 15 |
| Road train 2 | 0 | 0.15 | 0.3 | 0.6 | 0.9 | 10 | 15 | 20 | 15 |

*Source: TMR calculations and adapted from Austroads (2005) p.41*

Note: For design speeds greater than those specified in Table 16, CBA6 assumed that the adjustment factor of 0 is used.

Gradient and curvature adjustments in CBA6 are weighted to the proportion of road that is classified by each category. Gradient and curvature proportions used in CBA6 are shown by Table 17.

*Table 17: Preset gradient and curvature proportions*

| Preset | Gradient proportion | | | | |
|---|---|---|---|---|---|
| | < 2% | < 4% | < 6% | < 8% | < 10% |
| Level/flat | 90% | 10% | 0% | 0% | 0% |
| Rolling/undulating | 50% | 30% | 20% | 0% | 0% |
| Mountainous | 30% | 30% | 20% | 20% | 0% |

| Preset | Curvature proportion | | | | |
|---|---|---|---|---|---|
| | 30km/h | 50km/h | 65km/h | 80km/h | No curve |
| Straight | 0% | 0% | 0% | 10% | 90% |
| Curvy | 0% | 0% | 10% | 30% | 60% |
| Very curvy | 0% | 0% | 60% | 20% | 20% |

*Source: TMR calculations*

Note: CBA6 default gradient settings can be adjusted.

Sections 4.4.3.1 and 4.4.3.2 outline the calculations used to derive the curvature and gradient adjustment factors in CBA6.

#### 4.4.3.1 Gradient adjustment

Gradient adjustment is calculated using data from Table 16 and is shown by Equation 29. The proportion of the road section that is classified by the gradient category is illustrated by Table 17. Subsequently, these values are multiplied to attain the disaggregated gradient adjustment factors.

*Equation 29: Tyre gradient adjustment factor*

$$Grad(VT) = \sum Gradient\ Adj\ Array(VT, Grade_i) \times Grade\%_i$$

Where:

- Grad(VT) = tyre gradient adjustment factor (vehicle type)
- Gradient Adj Array = gradient adjustment values
- Grade% = percentage of road that falls into each category of gradient

*Example: Gradient adjustment*

Gradient adjustment for a B-double on a flat road is given by:

$$Grad(B - Double) = (90\% \times 0.00) + (10\% \times 0.15) + (0\% \times 0.3) + (0\% \times 0.6) + (0\% \times 0.9)$$

$$Grad(B - Double) = 0.00 + 0.015 + 0.00 + 0.00 + 0.00$$

$$Grad(B - Double) = 0.02$$

A flat road, with 90% of the total section with a grade of less than 2% and 10% of the total section at a grade of 4%, increases tyre wear by 2%.

#### 4.4.3.2 Curvature adjustment

Curvature adjustment is calculated in CBA6 using data from Table 16 and is given by Equation 30.

*Equation 30: Tyre curvature adjustment factor*

$$Curv(VT) = \sum Curvature\ Adj\ Array(VT, Design\ Speed_i) \times Curvature\%_i$$

Where:

- Curv(VT) = curvature adjustment factor for tyre wear
- Curvature Adj Array = curvature parameter values
- $Curvature\%_i$ = percentage of road that falls into each category of curvature

*Example: Curvature adjustment*

The curvature adjustment for a B-double on a curvy road is given by:

$$Curv(B - Double) = (0\% \times 10) + (0\% \times 15) + (10\% \times 20) + (30\% \times 15) + (60\% \times 0)$$

$$Curv(B - Double) = (0.1 \times 20) + (0.3 \times 15) + (0.6 \times 0)$$

$$Curv(B - Double) = 6.5$$

Tyre costs incurred on a curvy road are 6.5 times higher than on a straight road. The curvature adjustment factor accounts for the greatest change in tyre wear.

## 4.4.4 Roughness adjustment

The roughness adjustment for tyre wear is dependent on operating speed and is shown by Table 18.

*Table 18: Tyre roughness adjustment array*

| Vehicle type | Operating speed (km/h) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8–16 | 16–24 | 24–32 | 40–48 | 48–56 | 56–64 | 64–72 | 72–80 | 80–88 | 88–96 | 96–104 |
| Cars – private | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Cars – commercial | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Non-Articulated | 0.32 | 0.32 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.30 | 0.30 |
| Buses | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| Articulated | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| B-double | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Road train 1 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Road train 2 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |

*Source: adapted from Austroads (2005) p.40*

The roughness adjustment value is selected from the tyre roughness adjustment array based on the current operating speed of the vehicle.

*Example: Roughness adjustment example*

The roughness adjustment for a B-double travelling at 64.4 km/h is 0.2, which indicates that the road roughness increases tyre wear by 20%.



## 4.4.5 Total unit tyre cost

The total tyre unit cost represents the total tyre usage cost adjusted for the road characteristics, as shown by Equation 31.

*Equation 31: Tyre cost*

$$Tyres(VT) = TreadCost \times btw(VT) \times (1 + Cong(VT) + Curve(VT) + Rough(VT) + Grad(VT))$$

Where:

- Tyres(VT) = tyre cost
- btw(VT) = basic tyre wear

*Example: Tyre cost*

For a B-double, the total unit cost is shown by the aggregate of the individual calculations as follows:

$$Tyres(B - Double) = 55.07 \times 115.87 \times (1 + 0.046 + 6.5 + 0.2 + 0.02)$$

$$Tyres(B - Double) = 49580.067 \text{ c/1000km}$$

$$Tyres(B - Double) = 49.58\text{c/km}$$

## 4.5 Repairs and maintenance

Repairs and maintenance costs are calculated using the road roughness and basic repairs and servicing costs as shown by Table 19. This table shows the basic repairs and servicing costs for all vehicle types per kilometre travelled. Unlike other operating cost components, speed, road alignment and traffic congestion do not directly affect vehicle repairs and maintenance costs.

*Table 19: Repairs and servicing cost (RMUC)*

| Vehicle type | RMUC |
|---|---|
| | Basic repairs and servicing cost (cents/km) |
| Cars – private | 4.5 |
| Cars – commercial | 4.6 |
| Non-Articulated | 8.6 |
| Buses | 8.6 |
| Articulated | 16.6 |
| B-double | 20.6 |
| Road train 1 | 22.0 |
| Road train 2 | 28.2 |

*Source: adapted from Austroads (2008) page 16.*

*Example: Repairs and service cost*

The basic repairs and servicing cost for a B-double is 20.6 c/km.

The basic servicing and repairs costs are adjusted for pavement condition via the pavement condition index (pavind), in Table 20.

*Table 20: Pavement condition index*

| Surface type | Pavind (NRM) | | | | |
|---|---|---|---|---|---|
| | 50 | 100 | 150 | 200 | 250 |
| Earth/formed | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Gravel | 1.5 | 1.57 | 1.65 | 2 | 2.5 |
| Sealed/concrete | 1 | 1.15 | 1.3 | 1.45 | 1.6 |

*Source: adapted from Austroads (2005) page 47.*

Parameter values are given for 50, 100, 150, 200 and 250 NRM. These pavement condition values need to be interpolated to attain a parameter corresponding to current roughness (CNRM).

Note: The current roughness should lie between 30 and 250 NRM. When the current roughness is less than 50 NRM, the adjustment value or rscmrf factor will be equal to 1 as shown by Equation 32.

*Equation 32: Repairs and maintenance adjustment factor*

$$rscmrf(VT)\begin{cases} 30 \le CNRM < 50 = 1 \\ 50 \le CNRM < 100 = 1 + \left(PAVIND(ST,100) - PAVIND(ST,50)\right)\dfrac{(CNRM-50)}{(100-50)} \\ 100 \le CNRM < 150 = PAVIND(ST,100) + (PAVIND(ST,150) - PAVIND(ST,100))\dfrac{(CNRM-100)}{(150-100)} \\ 150 \le CNRM < 200 = PAVIND(ST,150) + (PAVIND(ST,200) - PAVIND(ST,150))\dfrac{(CNRM-150)}{(200-150)} \\ 200 \le CNRM < 250 = PAVIND(ST,200) + (PAVIND(ST,250) - PAVIND(ST,200))\dfrac{(CNRM-200)}{(250-200)} \end{cases}$$

Where:

- CNRM = current roughness in NRM
- PAVIND(PT) = pavement index value at the current surface type (ST)

*Example: Repairs and maintenance adjustment factor*

For a B-double on a sealed road with a current roughness of 120 NRM, the calculation is as follows:

$$rscmrf(B-Double) = 1.15 + (1.3 - 1.15) \times \frac{(120-100)}{(150-100)}$$

$$rscmrf(B-Double) = 1.21$$

The repairs and maintenance costs for a B-double travelling on a road would increase by 21% if the roughness was increased from below 50 NRM to 120 NRM.

### 4.5.1 Total repairs and maintenance unit cost

The unit repairs and maintenance cost for this VOC component is the sum of the basic repairs and maintenance cost per vehicle type and the roughness adjustment factor shown by Equation 33.

*Equation 33: Repairs and maintenance cost*

$$REPMCS(VT) = RMUC(VT) \times rscmrf(VT)$$

Where:

- REPMCS(VT) = repairs and maintenance cost per vehicle type
- RMUC(VT) = basic repairs and maintenance cost per vehicle type
- rscmrf(VT) = repairs and maintenance adjustment factor per vehicle type

*Example: Repairs and maintenance cost*

The total repairs and maintenance costs for a B-double are given by:

$$REPMCS = RMUC \times rscmrf$$

$$REPMCS = 20.6 \times 1.21$$

$$REPMCS = 24.93\ c/km$$

The repairs and maintenance costs for a B-double travelling on a 120 NRM road surface would incur a repairs and maintenance cost of $24.93$ cents per kilometre travelled.

## 4.6 Depreciation and interest costs

Depreciation and interest costs for all vehicle types are calculated using the data shown by Table 21.

*Table 21: Time and depreciation factors*

| Vehicle type | Tax | Vehicles | Ddpn | Tdi | Fleet | Ahour |
|---|---|---|---|---|---|---|
| | Effective sales tax % on new vehicles | New vehicle price ($) | Basic distance depreciation rate | Basic time depreciation | Proportion of VT susceptible to fleet reduction | No. Of hours/ year vehicle is available on the road |
| Cars – private | 10% | 24,410 | 0.22 | 9.50 | 0.00 | 1000 |
| Cars – commercial | 10% | 29,890 | 0.25 | 9.20 | 0.27 | 1200 |
| Non-Articulated | 10% | 101,450 | 0.28 | 7.40 | 0.80 | 1760 |
| Buses | 10% | 101,450 | 0.15 | 7.00 | 0.80 | 2000 |
| Articulated | 10% | 245,917 | 0.15 | 5.50 | 0.65 | 2833 |
| B-double | 10% | 357,110 | 0.14 | 5.50 | 0.60 | 3000 |
| Road train 1 | 10% | 395,720 | 0.14 | 5.50 | 0.60 | 3000 |
| Road train 2 | 10% | 495,950 | 0.14 | 5.50 | 0.60 | 3000 |

*Source: adapted from Austroads (2008) page 16 and Austroads (2005) page 51.*



The values from Table 22 are used to calculate the net depreciation and interest costs. These values describe the relationship between distance depreciation and road surface type.

*Table 22: Surface type factor*

| Surface type | Depsrf |
|---|---|
| | Factor relating distance depreciation to road surface type |
| Unsurfaced | 2.5 |
| Primerseal | 1.5 |
| Sealed | 1 |
| Concrete | 1 |

*Source: TMR.*

The distance and time depreciation per vehicle type is derived to calculate the net depreciation and interest costs. The economic cost of a new vehicle is calculated and then adjusted to account for distance and time.

### 4.6.1 Economic cost of a new vehicle

A component of the depreciation and interest calculations is the economic cost of a new vehicle. This is defined as the price of the vehicle less the cost of all tyres supplied with the vehicle including any spares. The economic cost of a new vehicle is shown by Equation 34, where price calculations are net of sales tax.

*Equation 34: Economic cost of a new vehicle*

$$ECV(VT) = VEHICLESS(VT) \times \left(\frac{100}{100 + TAX(VT)}\right) - CTYRE(VT) \times (NOTYRE(VT) + 1)$$

Where:

- ECV(VT) = economic cost of the vehicle
- VEHICLESS(VT) = new vehicle price per vehicle type ($)
- TAX = effective sales tax on new vehicles
- NOTYRE(VT) = number of tyres (including spares)
- CTYRE(VT) = cost of new tyres ($)

*Example: Economic cost of a new vehicle*

For a B-double , the economic cost of a new vehicle is:

$$ECV = 357110 \times \left(\frac{100}{100 + 10\%}\right) - 331 \times (30 + 1)$$

$$ECV = \quad \$346{,}492.25$$

The economic cost of a new B-double including sales tax and the number of tyres is $346 492.



### 4.6.2 Basic distance depreciation

Basic distance depreciation (cents/km) is derived from the economic cost of a new vehicle and a distance depreciation rate. Basic distance depreciation is shown by Equation 35.

*Equation 35: Basic distance depreciation*

$$DSTDEP(VT) = 0.001 \times 100 \times ECV(VT) \times \frac{DDPN(VT)}{100}$$

Where:

- DSTDEP = basic distance depreciation (cents/km)
- ECV(VT) = economic cost of new vehicle ($)
- DDPN(VT) = distance depreciation rate %

*Example: Basic distance depreciation*

For a B-double, the distance depreciation is:

$$DSTDEP\ (B - Double) = 0.001 \times 100 \times 346{,}492.25 \times \frac{0.14}{100}$$

$$DSTDEP\ (B - Double) = 48.51 \text{ c/km}$$

The economic value of a new B-double will depreciate by 48.51 cents for every kilometre travelled.

### 4.6.3 Time depreciation

Basic time depreciation is derived as a function of the economic cost of a new vehicle, which is shown by Equation 36.

*Equation 36: Basic time depreciation*

$$TDPINT(VT) = 100 \times ECV(VT) \times \left(\frac{TDI(VT)}{100}\right) \times \frac{FLEET(VT)}{AHOUR(VT)}$$

Where:

- TDPINT(VT) = marginal time depreciation and interest per vehicle type (cents/hour)
- ECV(VT) = economic cost of new vehicle per vehicle type ($)
- TDI(VT) = basic time depreciation and interest rate per vehicle type (%/year)
- FLEET(VT) = proportion of vehicle type susceptible to 'fleet reduction' effects due to travel time reduction per vehicle type
- AHOUR(VT) = number of hours a year for which vehicle type is available 'on the road' per vehicle type

*Example: Basic time depreciation*

For a B-double, time depreciation is:

$$TDPINT(B - Double) = 100 \times 346{,}492.25 \times \left(\frac{5.5}{100}\right) \times \frac{0.6}{3000}$$

$$TDPINT(B - Double) = 381.14\ c/hr$$

This value represents a depreciation rate of 381.14 cents for every hour the vehicle is on the road in addition to the distance depreciation.

### 4.6.4 Net depreciation and interest costs

Net depreciation and interest costs combine both time and distance components, shown by Equation 37.

*Equation 37: Net depreciation and interest*

$$DPINCS(VT) = \left(DSTDEP(VT) \times DEPSRF + \frac{TDPINT(VT)}{OS(VT)}\right)$$

Where:

- DPINCS(VT) = depreciation and interest costs per vehicle type (cents/km)
- DSTDEP(VT) = basic distance depreciation (VT)(cents/km)
- DEPSRF = factor relating distance depreciation to road surface type (VT)
- TDPINT(VT) = marginal time depreciation and interest per vehicle type (cents/hour)
- OS(VT) = operating speed

*Example: Depreciation and interest*

For a B-double travelling at 64.4 km/h on a sealed road, the net depreciation and interest cost is:

$$DPINCS(B - Double) = \left(48.51 \times 1.0 + \frac{381.14}{64.49}\right)$$

$$DPINCS(B - Double) = 54.42\ c/km$$

This figure incorporates both the hourly and distance rates into a single per kilometre depreciation rate.

## 4.7 Total unit vehicle operating cost

The total unit VOC is the sum of the individual VOC components calculated throughout Section 4. This includes fuel, tyres, oil, repairs and maintenance, and interest and depreciation. Total unit VOC are given in Equation 38.

*Equation 38: Total unit VOC*

$$UnitVOC(VT) = Fuel + Oil + Tyres + Repairs + Depreciation$$

Where:

- UnitVOC(VT) = unit vehicle operating cost (cents/km)

*Example: Total unit VOC*

In the B-double, this would be as follows:

$$UnitVOC(B - Double) = 95.72 + 1.71 + 49.58 + 24.93 + 54.42$$

$$UnitVOC(B - Double) = 226.36\, c/km$$

The total unit vehicle operating cost for the B-double is 226.36 cents per kilometre travelled.

The total VOC for the year is then summed across all vehicle types. The VOC formula is shown by Equation 39.

*Equation 39: Total VOC (all vehicle types)*

$$TotalVOC = Seclength \times days \times \sum_i AADT_i \times \frac{VOC_i}{100}$$

The VOC calculation is completed for each year of the evaluation. The VOC value will change as road conditions such as roughness and volume vary each year.

The annual VOC derivation is required for both the base and project cases. The difference between the VOC derived for the base case and project case will be used to estimate the annual and total VOC benefit for the proposed project.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## 5 Travel time costs

TTC are the monetised costs to the road user for the time taken to complete a journey. TTC benefits equal the difference in road user TTC between the base case and the project case. TTC are a function of trip time, average occupancy per vehicle, the monetary value of time per occupant, cost of freight delay per hour and AADT.

The calculation of trip time is shown by Equation 40.

*Equation 40: Trip time*

$$TripTime(VT) = \frac{SecLength}{OS(VT)}$$

Where:

- TripTime(VT) = trip time (hours)
- SecLength = section length (km)
- OS(VT) = operating speed

*Example: Trip time*

For a B-double travelling along a sealed, 5 km road section at 64.4 km/h, the trip time is:

$$TripTime(B - Double) = \frac{5km}{64.4km/h}$$

$$TripTime(B - Double) = 0.0775\ hrs\ (4.65\ minutes)$$

The 5 km journey takes 4.65 minutes to complete when travelling at an average speed of 64.4 km/h.

Note: Trip time will differ for each vehicle type based on operating speed as calculated in Section 3.

Each vehicle type has an associated cost reflecting the value of the occupant's time and the cost of freight delays. These costs differ between urban and rural speed environments as the occupancy rates change between environments. These time costs are shown by Table 23.

*Table 23: Estimated values of travel time – occupant and freight payload values*

| Vehicle type | Environment | Resource prices (June 2007) | | | |
|---|---|---|---|---|---|
| | | Value per occupant (pers/hr) | Freight travel time (value per veh-hour) | Occupancy rate (pers/veh) | Total value of time ($/veh.hr) |
| Cars – private | Rural | 11.49 | 0.00 | 1.70 | 19.53 |
| | Urban | 11.49 | 0.00 | 1.60 | 18.38 |
| Cars – commercial | Rural | 32.01 | 0.00 | 1.30 | 41.62 |
| | Urban | 32.01 | 0.00 | 1.40 | 44.81 |
| Non-Articulated | Rural | 22.86 | 2.67 | 1.17 | 29.35 |
| | Urban | 22.86 | 5.26 | 1.20 | 32.69 |
| Buses | Rural | 11.49 | 0.00 | 12.00 | 137.88 |
| | Urban | 11.62 | 0.00 | 15.00 | 174.30 |
| Articulated | Rural | 23.76 | 15.00 | 1.00 | 38.76 |
| | Urban | 23.76 | 29.54 | 1.00 | 53.30 |
| B-double | Rural | 23.87 | 24.53 | 1.00 | 48.40 |
| | Urban | 24.98 | 48.32 | 1.00 | 73.30 |
| Road train 1 | Rural | 24.98 | 32.79 | 1.00 | 57.77 |
| | Urban | 26.11 | 0.00 | 1.00 | 26.11 |
| Road train 2 | Rural | 25.44 | 48.32 | 1.00 | 73.76 |
| | Urban | 25.44 | 0.00 | 1.00 | 25.44 |

*Source: adapted from Austroads (2008) page 18.*



The final derivation of annual travel time value per vehicle and vehicle type is given by Equation 41.

*Equation 41: Annual travel time*

$$TTC(VT) = AnnFact \times (TripTime(VT) \times AADT_{(VT)} \times VTVEHR(VT))$$

Where:

- TTC(VT) = TTC cost ($)
- AnnFact = annualisation factor (days per year)
- TripTime(VT) = trip time (hrs)
- VTVEHR = value of time per vehicle ($)
- AADT(VT) = annual average daily traffic of vehicles type x

*Example: Travel time cost*

For a B-double travelling 4.65 minutes on a rural road, the annual time cost is:

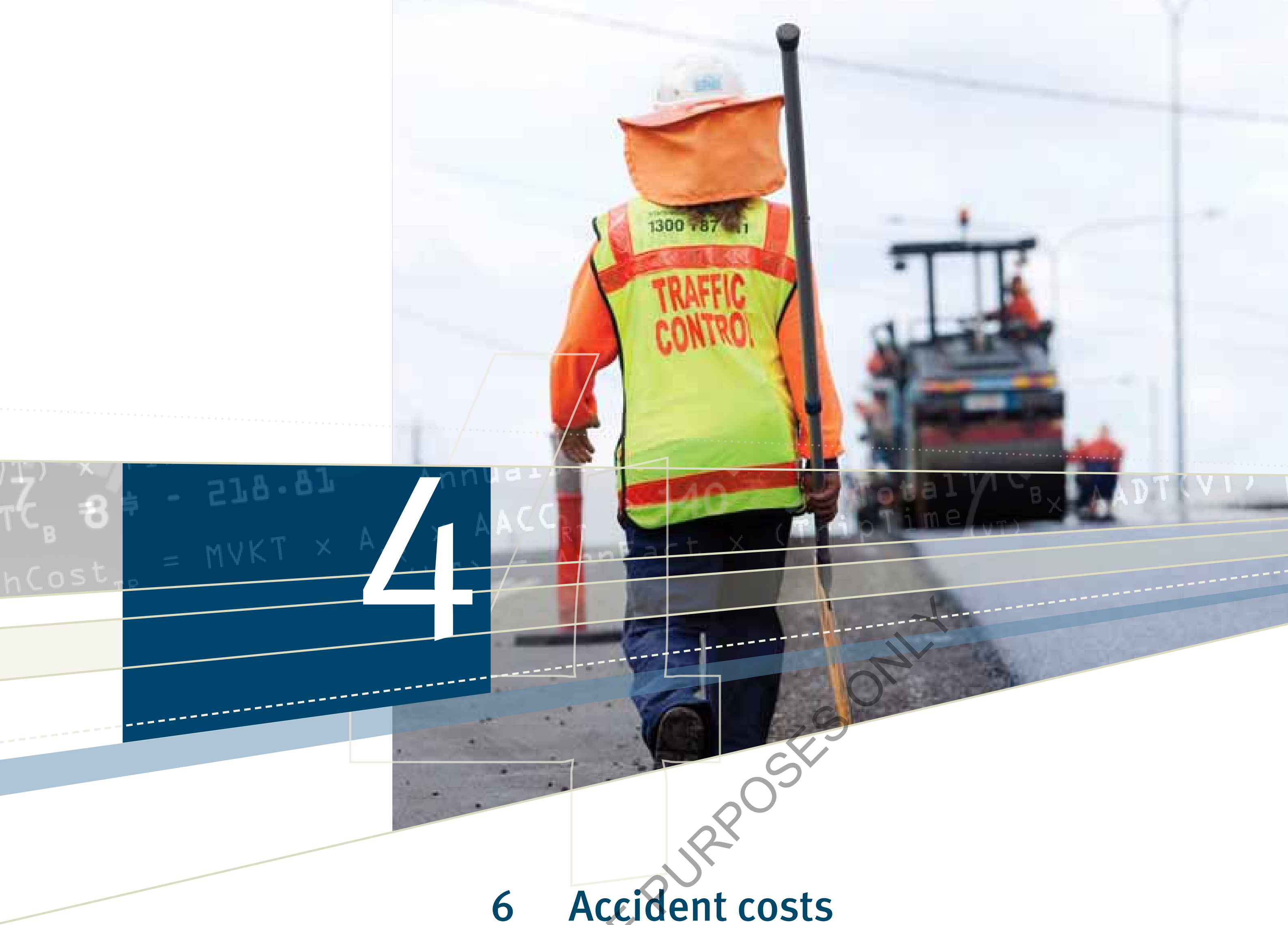
$$TTC(VT) = 365.25 \times (0.0775 \times 1 \times 48.40)$$

$$TTC(VT) = \$1370.05\ per\ year$$

The TTC for a B-double is $1370.05 per year.

This TTC calculation is repeated for each year of the assessment as a number of variables will change with road and traffic conditions, including congestion and trip time.

AADT in this example refers to the number of vehicles for each vehicle type, instead of the aggregate value. In calculating the total TTC, these calculations would be summed for each vehicle type in both base and project cases.




# 6 Accident costs

Accident costs are calculated using a default accident rate based on road type and the average cost of a crash. CBA6 calculates the accident cost from estimations of average crash costs based on the crash severity and historical crash rates determined by the modal road state (MRS).

Accident costs are a Queensland average, based on Austroads unit crash data. Unit costs used in CBA6 are shown by Table 24. Values calculated in this table are derived using the human capital approach rather than willingness to pay. For more detail see Section 2.2.3 of the *Theoretical Guide*.

*Table 24: Unit costs per crash type for Queensland*

| | Fatal injury | Serious injury | Minor injury | Average casualty | Property damage |
|---|---|---|---|---|---|
| Rural | 2 102 000 | 502 000 | 20 200 | 259 000 | 7 500 |
| Urban | 1 958 000 | 471 000 | 20 600 | 183 000 | 7 500 |

*Source: Adapted from Austroads (2008), page 21.*

Unit costs per crash type are weighted according to frequency of occurrence in Queensland. The breakdown of the severity of road crashes in 2005 is shown by Table 25.

*Table 25: Severity of road crashes in Queensland (2005)*

| | | Fatal injury | Serious injury | Other injury | Property damage | Total |
|---|---|---|---|---|---|---|
| Rural | Number of crashes | 153 | 1 051 | 1 193 | 1 462 | 3 859 |
| | Number killed | 174 | | | | |
| | Number serious injuries | 76 | 1 332 | | | |
| | Number other injuries | 22 | 229 | 1 535 | | |
| | Number no injuries | N/A | N/A | N/A | | |
| Urban | Number of crashes | 143 | 4 067 | 7 246 | 7 682 | 19 138 |
| | Number killed | 156 | | | | |
| | Number serious injuries | 37 | 4 842 | | | |
| | Number other injuries | 32 | 739 | 9 059 | | |
| | Number no injuries | N/A | N/A | N/A | | |
| Total | Number of crashes | 296 | 5 118 | 8 439 | 9 144 | 22 997 |
| | Number killed | 330 | | | | |
| | Number serious injuries | 113 | 6 174 | | | |
| | Number other injuries | 54 | 968 | 10 594 | | |
| | Number no injuries | N/A | N/A | N/A | | |

*Source: Table c3, Austroads (2008) page 56.*

Costs per crash are stored in CBA6 as shown by Table 26.

*Table 26: Average crash costs*

| Crash type | Rural | Urban |
|---|---|---|
| Fatal injury | $2 102 000 | $1 958 000 |
| Serious injury | $502 000 | $471 000 |
| Other injury | $20 200 | $20 600 |
| Property damage | $7 500 | $7 500 |
| Average crash cost | $229 145 | $125 532 |

*Source: TMR calculations.*

Table 26 shows that average crash costs calculated for individual casualty crash categories can vary across areas of operation. Severity of crashes tend to increase with vehicle operating speeds as a greater proportion of people are killed or seriously injured in higher speed environments than lower speed environments. As a result, average crash costs in rural areas are higher than for urban areas.

To determine the casualty crash rate for a rural road, the casualty crash rate for a two-lane road with a 7 m seal is used as a base for deriving the casualty crash rate for alternative road types. The rural road crash rate is shown by Equation 42.

*Equation 42: Rural crash rate*

$$A_{CR} = K_{MRS}K_{HA}AB_{CR}$$

Where:

- $A_{CR}$ = predicted casualty crashes per MVKT for a road of given attributes
- $AB_{CR}$ = casualty crash rates for a two-lane road with a 7 m seal and nom curves of speed standard 90 km/h or less is estimated at 0.25 crashes per MVKT
- $K_{MRS}$ = factor to derive crash rates for road standards different from the ABCR value, with no curves of 90 km/h or less
- $K_{HA}$ = factor to modify predicted crash rates for roads with horizontal alignment of speed standard 90 km/h or less

Note: the $K_{HA}$ factor is not currently used in CBA6.

Casualty crashes in CBA6 are factored up to the total crash rate as indicated by Equation 43.

*Equation 43: Crash rate*

$$A_{TR} = \frac{A_{CR}}{P_{CAS}}$$

Where:

- $A_{TR}$ = predicted total crash per MVKT for a given road of given attributes
- $P_{CAS}$ = proportion of casualty crashes in recorded rural crashes (0.568)

(Calculated from TMR databases from 1996–2001.)

The default crash rates applied in CBA6 to each MRS are shown by Table 27.

*Table 27: Crash rate per MRS*

| MRS | Road width description | KMRS * | Acr – rural casualty crash rate/MVKT | Atr – accidents per MVKT |
|---|---|---|---|---|
| 1 | Unsealed natural surface | 1 | 0.25 | 0.440140845 |
| 2 | Unsealed formed road | 1 | 0.25 | 0.440140845 |
| 3 | Paved < 4.5 m | 1.4 | 0.35 | 0.616197183 |
| 4 | Paved >= 4.5 m | 1.4 | 0.35 | 0.616197183 |
| 5 | Narrow seal <= 4.5 m | 1.2 | 0.3 | 0.528169014 |
| 6 | Narrow seal 4.6 m–5.2 m | 1.56 | 0.39 | 0.686619718 |
| 7 | 2 lane seal 5.3 m–5.8 m | 1.6 | 0.4 | 0.704225352 |
| 8 | 2 lane seal 5.9 m–6.4 m | 1.3 | 0.325 | 0.572183099 |
| 9 | 2 lane seal 6.5 m–7.0 m | 1 | 0.25 | 0.440140845 |
| 10 | 2 lane seal 7.1 m–7.6 m | 0.86 | 0.215 | 0.378521127 |
| 11 | 2 lane plus shoulder seal 7.7 m–8.2 m | 0.74 | 0.185 | 0.325704225 |
| 12 | 2 lane plus shoulder seal 8.3 m–9.0 m | 0.64 | 0.16 | 0.281690141 |
| 13 | 2 lane plus shoulder seal 9.1 m–9.4 m | 0.58 | 0.145 | 0.25528169 |
| 14 | 2 lane plus shoulder seal 9.5 m–10 m | 0.52 | 0.13 | 0.228873239 |
| 15 | 2 lane plus shoulder seal 10.1 m–11.6 m | 0.47 | 0.118 | 0.206866197 |
| 16 | 3 lane for overtaking | N/A | N/A | N/A |
| 17 | 4 lane undivided sealed | 0.85 | 0.213 | 0.374119718 |
| 18 | 6 lane undivided sealed | 0.85 | 0.213 | 0.374119718 |
| 19 | 4 lane divided sealed | 0.45 | 0.113 | 0.19806338 |
| 20 | 6 lane divided sealed | 0.45 | 0.113 | 0.19806338 |
| 21 | 4 lane divided (limited access) | 0.275 | 0.069 | 0.121038732 |
| 22 | 6 lane divided (limited access) | 0.275 | 0.069 | 0.121038732 |
| 23 | 8 lane divided (limited access) | 0.275 | 0.069 | 0.121038732 |

*Source: Austroads (2001).*



Note: The accident crash rate is not applicable to MRS 16 as MRS 16 includes an overtaking lane. Accident cost benefits for overtaking lanes can be found in Section 8.

## 6.1 Total crash cost

The total crash cost in monetary terms is given by Equation 44. The total crash cost calculation is determined by the number of vehicles on the road, the accident rate and the average crash cost.

*Equation 44: Total crash cost*

$$CrashCost_{RT} = MVKT \times A_{TR} \times AACC_{RT}$$

$$CrashCost = \frac{AADT \times 365.25 \times SecLength}{1.000.000} \times A_{TR} \times AACC_{RT}$$

Where:

- AADT = annual average daily traffic (vehicles)
- SecLength = section length (km)
- $A_{TR}$ = total crash rate (accident/MVKT)
- $AACC_{RT}$ = average crash cost for road type ($)

*Example: Crash cost*

The crash cost for a thousand vehicles travelling along a 10 km, rural two-lane road with a shoulder seal (MRS 11) is:

$$CrashCost_{RT} = \frac{1000 \times 365.25 \times 10}{1,000,000} \times 0.325704225 \times \$229,145$$

$$CrashCost_{RT} = 3.6525 \times 0.325704225 \times 229,145$$

$$CrashCost_{RT} = \$272,598.84/\text{year}$$

## Percentage reduction in accidents for intersection treatments, low speed environment — two vehicle accidents

| | Two vehicle accidents | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Accident Group Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| DCA Codes | 101-109 | 201,501 | 202-206 | 207,304 | 301-303 | 305-307 | 308-309 | 401-409 | 503-506 | 601 | 903 |
| Accident Costs (2007 prices) | $78 100 | $178 300 | $77 300 | $38 800 | $60 600 | $54 200 | $74 100 | $54 900 | $73 400 | $55 000 | $216 700 |
| Roundabout - 1 lane | 70 | 70 | 60 | 50 | 30 | | | 20 | | | |
| Roundabout - 2 lane | 70 | 70 | 60 | 50 | 30 | | | 20 | | | |
| New traffic signals - filter turns allowed | 60 | | -30 | | -40 | | | | | | |
| New traffic signals - no filter turns allowed | 60 | | 90 | | -40 | | | | | | |
| Street closure - cross intersection | 70 | 50 | 70 | | 50 | | | | | | |
| Street closure - T intersection | 100 | 50 | 100 | | 50 | | | | | | |
| Grade separation of intersection | 100 | | 100 | | | | 50 | | | | |
| Median closure | 100 | | 100 | 100 | 50 | | | | | | |
| Stagger cross intersection | 50 | 50 | 50 | | | | | | | | |
| Seagull island without acceleration lane - raised island | 10 | 40 | 40 | 15 | 60 | 40 | 40 | | 70 | | |
| Seagull island without acceleration lane - painted island | 20 | 40 | 40 | 15 | 60 | 40 | 40 | | 70 | | |
| Seagull island without acceleration lane - painted island | 10 | 40 | 40 | 15 | 60 | 40 | 40 | | 70 | | |
| Seagull island without acceleration lane - painted island | 20 | 40 | 40 | 15 | 60 | 40 | 40 | | 70 | | |
| New signing stop | 50 | | | | -50 | | | | | | |
| New signing give way | 10 | | | | | | | | | | |
| New signing prohibit turns | 70 | | 70 | | 70 | | 70 | | | | |
| Fully control right turn with arrows | | | 80 | | | | | | | | |
| Introduce right turn phase while leaving filter | | | -10 | | | | | | | | |
| Red light camera at existing traffic signals | 30 | | 25 | | -30 | | | | | | |
| Upgrade signal display (mast arm/additional lanterns) | 20 | | 10 | | 25 | | | | | | |
| Protected right turn lane | 15 | | 40 | | 60 | 40 | 40 | | 70 | | |
| Protected right turn lane | 15 | | 40 | | 60 | 40 | 40 | | 70 | | |
| Left turn acceleration lane | | | 25 | | 60 | 40 | 40 | | | | |
| Separate left turn acceleration lane | 10 | | 15 | | 60 | 40 | 40 | | | | |
| Install additional priority signals | 30 | | | | | | | | | | |
| Move limit lines forward using paint markings | 10 | | | | | | | | | | |
| New signing - intersection warning | 15 | | | | 25 | 10 | | | | | |
| Move limit lines forward using curb extensions | 25 | | | | | | | | | | |



**Accident Group Description**

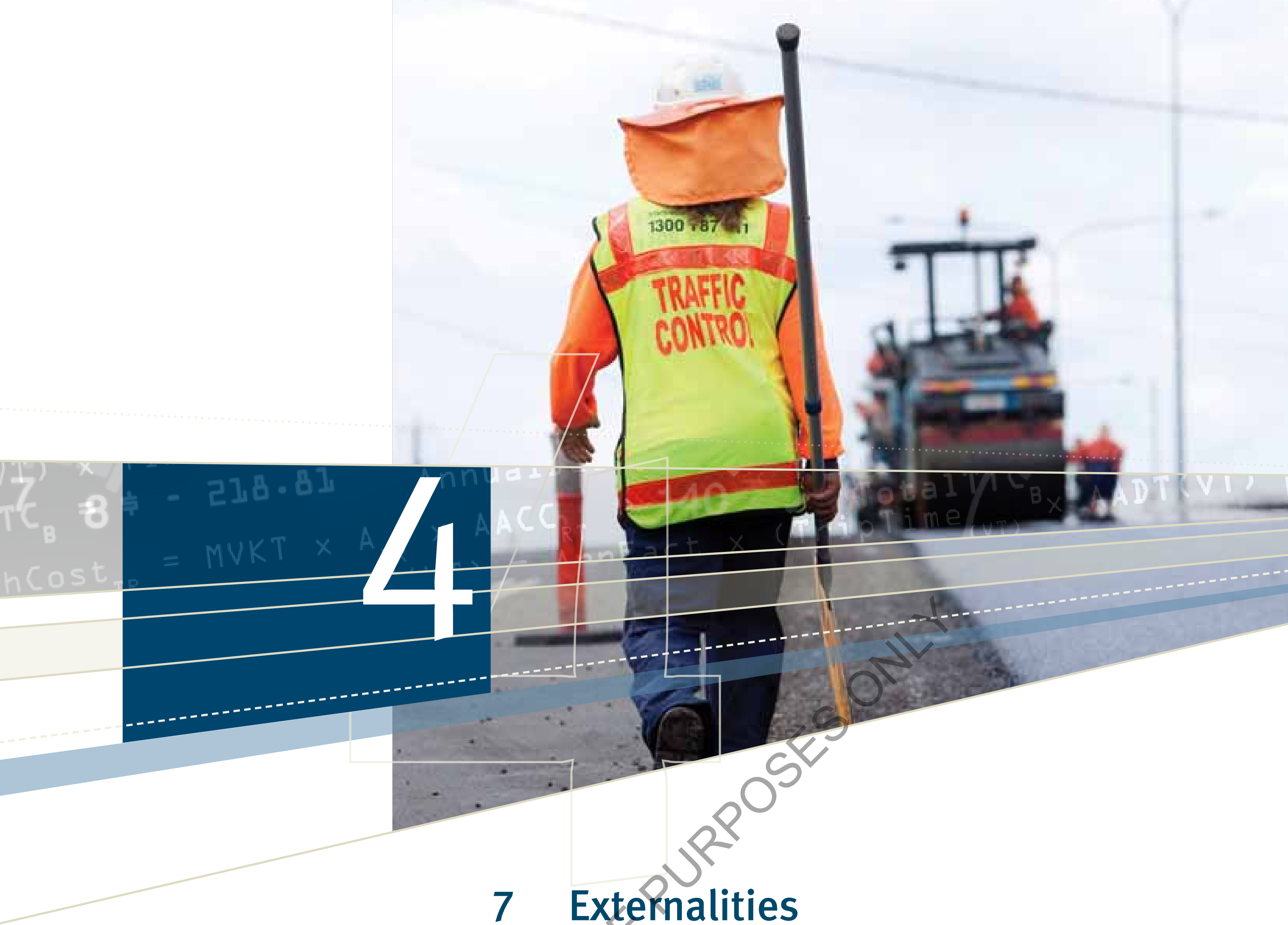
1 Intersection - adjacent approaches
2 Head-on
3 Opposing vehicles
4 U-turn
5 Rear-end
6 Lane change
7 Parallel lanes - turning
8 Manouvering
9 Overtaking - same direction
10 Hit parked vehicle
11 Hit railway train
12 Hit pedestrian
13 Permanent obstruction
14 Hit animal
15 Off carriageway - hit object
16 Off straight - hit object
17 Out of control straight
18 Off carriageway - curve
19 Off curve - hit object
20 Out of control - curve

### Percentage reduction in accidents for intersection treatments, low speed environment —one vehicle accidents

| | Single vehicle accidents | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Accident Group Number | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| DCA Codes | 001-008, 901-902 | 605 | 609 | 701-702,502, 706-709 | 703-704 | 705,502 | 801-802 | 803-804 | 805 |
| Accident Costs (2007 prices) | $164 600 | $74 900 | $40 300 | $60 600 | $116 200 | $84 400 | $102 700 | $102 700 | $87 700 |
| Roundabout - 1 lane | 10 | | | | | | | | |
| Roundabout - 2 lane | -20 | | | | | | | | |
| New traffic signals - filter turns allowed | 0 | | | | | | | | |
| New traffic signals - no filter turns allowed | 10 | | | | | | | | |
| Street closure - cross intersection | 30 | | | | | | | | |
| Street closure - T intersection | 40 | | | | | | | | |
| Grade separation of intersection | 70 | | | | | | | | |
| Median closure | | | | | | | | | |
| Stagger cross intersection | 50 | | | | | | | | |
| Seagull island without acceleration lane - raised island | 25 | | | | | | | | |
| Seagull island without acceleration lane - painted island | 25 | | | | | | | | |
| Seagull island without acceleration lane - painted island | 25 | | | | | | | | |
| Seagull island without acceleration lane - painted island | 25 | | | | | | | | |
| New signing stop | 10 | | | | | | | | |
| New signing give way | | | | | | | | | |
| New signing prohibit turns | | | | | | | | | |
| Fully control right turn with arrows | | | | | | | | | |
| Introduce right turn phase while leaving filter | | | | | | | | | |
| Red light camera at existing traffic signals | | | | | | | | | |
| Upgrade signal display (mast arm/additional lanterns) | | | | | | | | | |
| Protected right turn lane | | | | | | | | | |
| Protected right turn lane | | | | | | | | | |
| Left turn acceleration lane | | | | | | | | | |
| Separate left turn acceleration lane | | | | | | | | | |
| Install additional priority signals | | | | | | | | | |
| Move limit lines forward using paint markings | | | | | | | | | |
| New signing - intersection warning | | | | | | | | | |
| Move limit lines forward using curb extensions | | | | | | | | | |



Note: Costs are based on the costs contained in “Crash costs 2001: cost by accident type” produced by Dr David Andreassen of Data Capture and Analysis, factored up by 2.393% for 6 years and rounded to the nearest $100.DCA codes, in TMR, are predominantly limited to the evaluation of accident cost savings at intersections. The columns in the table represent the percentage reduction in accidents of a particular nature from a prescribed treatment. For example, introducing a stop sign will reduce accidents from intersection, adjacent approaches by 50% and accidents involving pedestrians by 10% but increase rear-end accidents by 50%. If we assume an annual average of 4 accidents from intersection, adjacent approaches, 6 accidents from rear-end collisions and 1 accident involving a pedestrian at a particular intersection, the annual undiscounted accident cost savings from implementing the stop sign at this intersection = 4×0.5×$78,100+6×(-0.5)×$38,800+1×0.1×$164,600 = $56 260 in Year 1. The following years’ savings can be calculated by multiplying the Year 1 savings by the traffic growth rate.




# 7 Externalities

This section of the *Technical Guide* explains the calculation of externality costs for transport infrastructure projects. Externality costs are calculated outside CBA6. The manual calculation is entered as a dollar value per year in the 'accident and other costs' screen, see Section 3.7 of the *User Guide*. The theories supporting the calculation of externalities are covered extensively in Chapter 3 of the *Theoretical Guide*.

Externality costs are calculated based on VKT for passenger and bus vehicle types and 1000 tonne kilometres (1000 t/km) for light and heavy freight vehicles. This applies to both rural and urban environments.

The equation for calculating externalities costs for passenger and bus movements is Equation 45.

*Equation 45: Externality cost*

$$Externality_i = UnitCost_{exty} \times VKT$$

Where:

- $Externality_i$ = externality cost per year per vehicle type ($)
- $UnitCost_{exty}$ = externality unit cost per vehicle type and environment (c/km)
- VKT = vehicle kilometres travelled (AADT × SecLength × 365.25)

The unit externality costs are derived for both rural and urban environments for both passenger cars and buses. The unit costs are provided by Austroads in 2007 values as shown by Table 28.

*Table 28: Externality unit costs for passenger vehicles and buses (c/vkt)*

| Vehicle/units | Urban | | Rural | |
|---|---|---|---|---|
| | Passengers cars | Buses | Passengers cars | Buses |
| Air pollution | 2.54<br>(2.48–2.60) | 28.61<br>(20.24–31.82) | 0.03<br>(0.02–0.03) | 0.00<br>(0.00–0.32) |
| Greenhouse | 2.00<br>(1.77–2.24) | 11.79<br>(n/a) | 2.00<br>(1.77–2.24) | 11.79<br>(n/a) |
| Noise | 0.82<br>(0.59–1.06) | 2.00<br>(1.18–2.83) | 0.00<br>(0.00) | 0.00<br>(0.00) |
| Water | 0.38<br>(0.37–0.39) | 4.29<br>(3.04–4.77) | 0.04<br>(0.04–0.04) | 0.04<br>(0.03–0.05) |
| Nature and landscape | 0.05<br>(0.05–0.17) | 0.13<br>(0.13–0.6) | 0.47<br>(0.47–1.65) | 1.3<br>(1.3–6.01) |
| Urban separation | 0.59<br>(0.35–0.82) | 1.89<br>(1.18–2.6) | 0.00<br>(0.00) | 0.00<br>(0.00) |
| Upstream and downstream costs | 3.42<br>(2.95–3.89) | 17.68<br>(14.14–21.21) | 3.42<br>(2.95–3.89) | 17.68<br>(14.14–21.21) |

*Source: Austroads (2008) pages 25–29.*

Note: Austroads provides unit cost ranges (in brackets). The non-bracketed values are an average of the supplied range.

*Example: Air pollution*

The externality cost for 100 passenger cars over a 5 km section of urban highway is:

$$Externality_i = UnitCost_{exty} \times 182{,}625$$

Air pollution externality costs are therefore given by:

$$Air\ Pollution_i = 2.54 \times 182{,}625$$

$$Air\ Pollution_i = 463{,}867.5\ cents$$

$$Air\ Pollution_i = \$4638.68\ p.a.$$

The air pollution cost to the environment from 100 cars travelling 5 km is $4638 per annum.

The unit externality costs for light and heavy freight vehicles in both rural and urban environments are shown by Table 29.

*Table 29: Externality unit costs for freight vehicles ($ per 1000 tonne-km)*



| Vehicle/units | Urban | | Rural | |
|---|---|---|---|---|
| | Light vehicles | Heavy vehicles | Light vehicles | Heavy vehicles |
| Air pollution range | 158.93<br>(117.85–261.60) | 21.19<br>(10.28–25.93) | 0.00<br>(0.00) | 0.21<br>(0.11–0.26) |
| Greenhouse range | 49.50<br>(45.96–51.85) | 4.71<br>(2.36–8.25) | 49.50<br>(45.96–51.85) | 4.71<br>(2.36–8.25) |
| Noise ranges | 27.10<br>(18.86–37.71) | 3.54<br>(2.36–4.71) | 0.0<br>(0.00) | 0.35<br>(0.24–0.49) |
| Water | 23.84<br>(17.68–39.20) | 3.18<br>(1.06–3.89) | 0.24<br>(0.18–0.42) | 1.27<br>(0.64–1.56) |
| Nature and landscape | 17.68<br>(17.68–34.18) | 0.35<br>(0.35–0.71) | 0.18<br>(0.18–0.34) | 3.54<br>(3.54–7.07) |
| Urban separation | 25.93<br>(15.32–36.53) | 2.36<br>(1.18–3.54) | 0.00<br>(0.00) | 0.00<br>(0.00) |
| Upstream and downstream costs | 164.99<br>(117.85–212.13) | 18.86<br>(16.5–21.21) | 164.99<br>(117.85–212.13) | 18.86<br>(16.5–21.21) |

*Source: Austroads (2008) pages 25–29.*

To calculate the externality costs for freight vehicles, the unit externality costs per VKT are calculated using the gross combination mass (GCM) as detailed by Table 30.

*Table 30: Gross combination mass (Queensland freight vehicles)*

| Vehicle type | Maximal length (m) | GCM (t) | Weight of freight (t) |
|---|---|---|---|
| Semi-trailer | 19.00 | 42.50 | 36.5 |
| Quad axle semi-trailer | 19.00 | 46.50 | 40.5 |
| B-double | 26.00 | 62.50 | 46.5 |
| Road train 1 | 36.50 | 79.00 | 73.0 |
| B-triple | 36.50 | 82.50 | 76.5 |
| AB-triple | 36.50 | 99.00 | 93.0 |
| Road train 2 | 53.50 | 115.50 | 109.5 |
| AAB-quad | 53.50 | 142.50 | 136.5 |
| BAB-quad | 53.50 | 119.00 | 113 |
| ABB-quad | 53.50 | 119.00 | 113 |

*Source: TMR.*

The unit externality costs per VKT per vehicle are calculated as shown by Equation 46.

*Equation 46: Heavy vehicle externality costs per VKT*

$$UnitCost_{exty} = \frac{ExternalityCost_{per1000tkm} \text{ x } WeightofFreight(VT)}{10}$$

Where:

- $UnitCost_{exty}$ = externality unit cost per vehicle type and environment (c/km)
- WeightofFreight(VT) = GCM – weight of prime mover

The unit externality costs per VKT for freight vehicles are given by Table 31.

*Table 31: Externality unit costs for CBA6 heavy vehicles (c/VKT)*

| Vehicle/units | Urban | | | | Rural | | | |
|---|---|---|---|---|---|---|---|---|
| | Articulated | B-double | Road train 1 | Road train 2 | Articulated | B-double | Road train 1 | Road train 2 |
| Air pollution | 77.34 | 119.72 | 154.69 | 232.03 | 0.77 | 1.19 | 1.53 | 2.30 |
| Greenhouse | 17.19 | 26.61 | 34.38 | 51.57 | 17.19 | 26.61 | 34.38 | 51.57 |
| Noise | 12.92 | 20.00 | 25.84 | 38.76 | 1.28 | 1.98 | 2.56 | 3.83 |
| Water | 11.61 | 17.97 | 23.21 | 34.82 | 4.64 | 7.18 | 9.27 | 13.91 |
| Nature and landscape | 1.28 | 1.978 | 2.56 | 3.83 | 12.92 | 20.00 | 25.84 | 38.76 |
| Urban separation | 8.61 | 13.33 | 17.23 | 25.84 | 0 | 0 | 0 | 0 |
| Upstream and downstream | 68.84 | 106.56 | 137.68 | 206.52 | 68.84 | 106.56 | 137.68 | 206.52 |

*Equation 47: Freight externality cost*

$$FreightExternality_i = \frac{UnitCost_{Fexty} \text{ x } VKT_i}{100}$$

Where:

- $FreightExternality_i$ = Freight externality cost per year per vehicle type ($)
- $VKT_i = AADT_i \times$ section length × 365.25

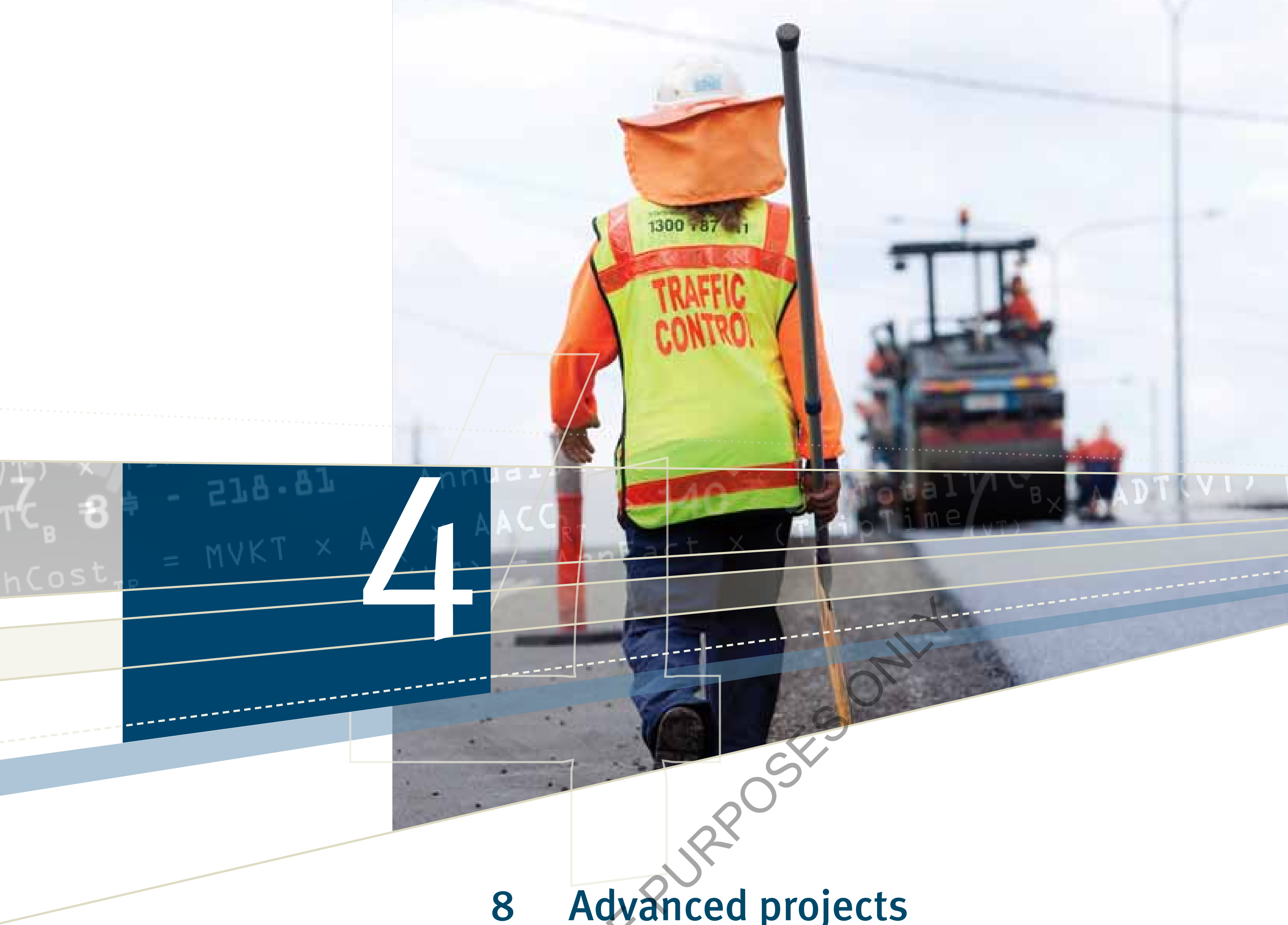
*Example: Freight externality cost*

The air pollution externality cost for 100 B-doubles over a 5 km section of urban highway per year is:

$VKT_i = 100 \times 5 \times 365.25 = 182\,625$

$$AirPollutionExternalityCost = \frac{119.72 \text{ x } 182{,}625}{100} = 218{,}639$$

The air pollution cost to the environment from 100 B-doubles travelling 5 km is $218 639 per annum.




# 8 Advanced projects

This section provides the methodologies and algorithms contained in CBA6 for the advanced modules. This section builds on the previous explanations of road user costs such as VOC, TTC and accident costs and applies those calculations to advanced projects. It outlines the methodologies applied to derive the following benefits/costs:

- flooding/diversions (diversions with a road closure)
- road closures (road closure with no diversion)
- generated traffic
- livestock damage
- intersections
- overtaking lanes.

All examples in this chapter are consecutive quantifications of a single year's user cost for the B-double vehicle type.

## 8.1 Road closure with diverting route

Flood immunity projects require a detailed understanding of both the road network and road user behaviour. As in Section 5.4.5 of the *User Guide*, road user responses to flooding can vary depending on the frequency, severity and extent of flooding. Flood warning times and the availability of alternative routes will also affect the decisions made by motorists. The following three options exist for motorists affected by flooded roads:

- Wait – remain at the flood site for waters to subside.
- Divert – use an alternative route around the flood affected area.
- Do not travel – choose not to travel at all.

*Example: Flooded road*

In this example for a flooded road, the following assumptions apply:

- 10% – wait at the flooding site (wait for the flood to subside).
- 20% – divert to another route.
- 70% – choose not to travel during the flooding event at all.

Note: Proportions of road user behaviour must equal 100%.

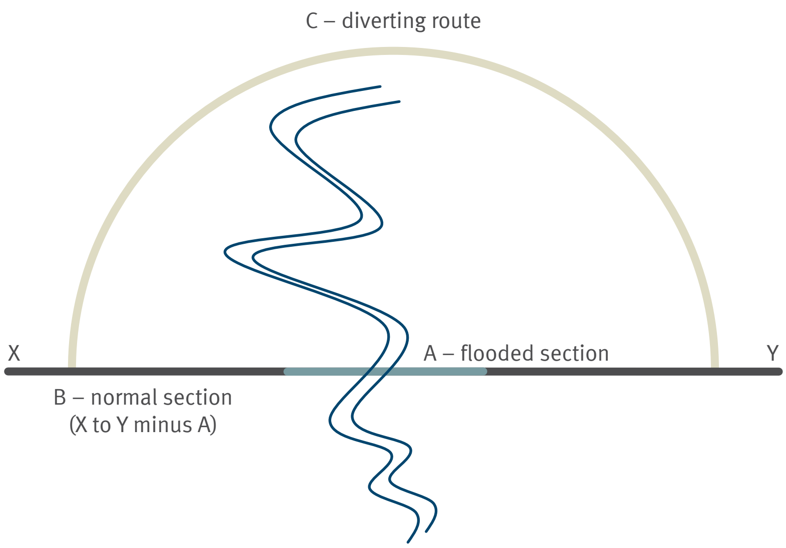
For all road closure projects CBA6 requires road closure information associated with local flooding and data on the AATOC and the ADC for the base and project cases.

Note: For further details on the costs of not travelling see Section 2.4.1.3 of the *Theoretical Guide*. CBA6 does not calculate road user costs for existing traffic.

Figure 3 illustrates the relevant sections of a flooding diversion which are identified as:

- Section A is the flood affected section, which is to be upgraded.
- Section B is the normal full length of the road, and is assumed to have the same road configuration as section A in the base case (prior to the upgrade). The length of B is the distance between X and Y minus the length of A.
- Section C is the diverting route, which can be substantially longer than section B and should be measured as the length along the diversion route between X and Y.

*Figure 3: Flooding closure*




## 8.1.1 Flooding data

The AATOC and ADC values are used in CBA6 to determine the waiting time during a flood event. These calculations are then used to estimate road user costs associated with the flood event. An example of flood data is shown by Table 32, and formulae for AATOC are given by Equation 48.

*Table 32: Example base case flood data*

| Base case flood data | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Number of floods | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Total time closed (hours) | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | 0 | 0 | 48 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 80 | 0 |

### 8.1.1.1 Average annual time of closure

*Equation 48: Average annual time of closure*

$$AATOC = \frac{\left(\sum HoursClosed_i\right)}{Years_i}$$

Where:

- AATOC = average annual time of closure
- $HoursClosed_i$ = total hours closed per flooding event
- $Years_i$ = number of years of flood data evaluated

The AATOC is the average number of hours a road is closed per year. The AATOC calculation is used throughout CBA6's flooding diversion module to estimate the proportion of the year that the given road is closed to traffic. It is important to note that averages are based on the range of time series flood data used. An appropriate number of observations should be obtained in the sample to represent accurate closure averages.

*Example: Average annual time of closure*

The average annual time of closure is calculated as follows:

$$AATOC = \frac{280}{20}$$

$$AATOC = 14$$

Using the data in Table 32, the road has been closed due to flooding for 280 hours over the last 20 years, which equates to an annual average closure time of 14 hours per year.

#### 8.1.1.2 Average duration of closure

The ADC represents the average duration of each road closure per flood and is used in CBA6 to calculate costs incurred by the road users who opted to wait. The ADC calculation is given by Equation 49.

*Equation 49: Average duration of closure*

The average annual time of closure is calculated as follows:

$$ADC = \frac{\left(\sum Hours\ Closed_i\right)}{\left(\sum NoFloods_i\right)}$$

Where:

- ADC = average duration of closure
- $NoFloods_i$ = total number of floods over evaluation period

*Example: Average duration of closure*

The ADC is calculated as:

$$ADC = \frac{280}{5}$$

$$ADC = 56$$

Based on the data in Table 32, the road is closed for an average of 56 hours per flooding event. This derivation of AATOC and ADC is used by CBA6 to calculate road user costs based on the average number of days of the year that road users are affected by a flooding event.

### 8.1.2 CBA6 road user cost methodology

The CBA6 road user cost methodology is founded on the average period of closure during a flooding event and the traffic behaviour during this period. Road users have three choices when confronted with a flood event. The consequence and calculated costs of these choices are described by Table 33.

*Table 33: Flood/diversion road user costs calculation*

| Section | During flood | No flood |
|---|---|---|
| A | Waiting costs calculated for % waiting | Road user costs calculated as normal |
| B | Road user costs forgone for % diverting and % no travel | No road user costs calculated (net zero) |
| C | Road user costs for % diverting only | No road user costs calculated |

For the flood affected section (A), road user costs are calculated during the periods where there is no flood event (% of year). During a flood event, some road users will divert and some will choose not to travel. Waiting costs are calculated for those vehicles that choose to wait at the flood affected site.

For the improved route (B) and diversion route (C), road user costs are only calculated during periods of a flood event as the road user costs are assumed not to change from the base case to the project case when there is no flood event.

During a flood event, user costs are calculated for the improved route, as it is assumed to represent user costs forgone as road users divert. For the diversion route during a flood event, road user costs are calculated based on the percentage of vehicles which choose to divert (% AADT).[1]

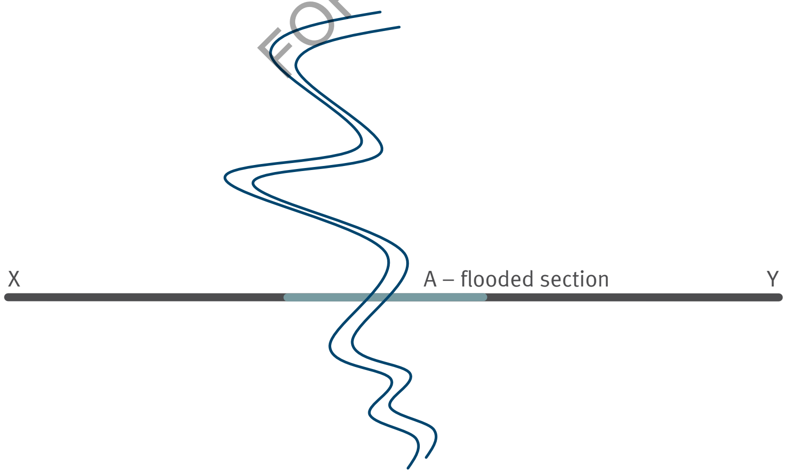
This methodology is highlighted in detailed road user cost algorithms.

- 8.1.3 Section A - project area
- 8.1.4 Section B - improved route
- 8.1.5 Section C - diversion route

### 8.1.3 Section A – project area

Section A refers to the flood prone section requiring the upgrade, see Figure 4. During periods when there are no flooding events, road users will not incur any additional road user costs by travelling through the section. During a flood event, the waiting costs associated with those vehicles that choose to wait at the flood site are calculated in CBA6.

*Figure 4: Project area*






[1] For mathematical proof of improved route methodology, see Appendix C.

#### 8.1.3.1 Vehicle operating costs – Section A

VOC for Section A are shown by Equation 50. This equation shows that for the base and project cases VOCs are calculated for vehicles that travel on Section A for the proportion of the year that the road is open.

*Equation 50: Vehicle operating costs – Section A*

$$TOTVOC_A = SecLength_{BC/PC} \times \left(365.25 - \left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times \frac{VOC_i}{100}\right)$$

Where:

- $SecLength_{BC/PV}$ = section length as given in the base and project case
- %D = percentage of vehicles diverting during closure (%)
- $VOC_i$ = vehicle operating unit cost

Note: When %D is equal to 0, no vehicles divert and VOC is calculated as per equations outlined in Section 4.

*Example: Vehicle operating costs – Section A*

Assume that there are 100 B-doubles travelling along a 5 km stretch of highway. The traffic behaviour during a flood event is anticipated to be 50% diverting, 30% waiting and 20% choosing not to travel at all. VOCs are assumed to be 255.42 c/km. It is also assumed that the length for the upgraded Section A is 5 km, the improved route is 10 km and the diverting route is 50 km. Other road characteristics are representative of examples illustrated in Sections 2 to 4. VOC are given below:

$$TOTVOC = 5 \times \left(365.25 - \left(\frac{14}{24} \times 0.50\right)\right) \times \sum_i \left(100 \times \frac{255.42}{100}\right)$$

$$TOTVOC = \$\ 466{,}088.29$$

The total VOC incurred over the year when flooding occurs is $466 088.29.



#### 8.1.3.2 Travel time cost – Section A

The TTC for Section A is given by Equation 51. This equation shows the base case and project case TTC.

*Equation 51: Travel time cost – Section A*

$$Total\ TTC_A = TripTime_{BC/PC} \times \left(365.25 - \left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times VTVEHR(VT)\right)$$

*Example: Travel time cost – Section A*

Using the data from the previous example, trip time and VTVEHR from Table 23, the total TTC for Section A is equal to:

$$Total\ TTC = 0.07753 \times \left(365.25 - \left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i (100 \times 48.40)$$

$$Total\ TTC = 0.07753 \times 364.96 \times 484.0$$

$$Total\ TTC = \$13{,}694.95$$

The total TTC incurred over the year as a result of the flood is $13 694.95.

#### 8.1.3.3 Waiting costs – Section A

Road users who choose to wait at the flood affected site and continue their journey once the flood subsides, incur a waiting cost representative of the value of their personal and business time. The time spent waiting for the road to reopen is valued based on the number of vehicles which choose to wait at the flood affected site and the duration of the flooding event per year. The waiting time calculation is shown by Equation 52.

*Equation 52: Waiting time – Section A*

$$Waiting\ Time = \frac{1}{2}\left(AATOC - \frac{AATOC}{ADC} \times \left(Trunc\left(\frac{ADC}{24}\right) \times 12\right)\right)$$

Where:

- Trunc = truncates a number to an integer by removing the fractional part of the number

The ½ shown by the waiting time equation represents an even distribution of vehicles while the truncation assumes a smaller proportion of vehicles will wait the entire length of the closure once the road has been closed for more than 24 hours. The waiting time is given in hours per year which is then used to calculate the costs associated with those vehicles which choose to wait.

*Example: Waiting time – Section A*

Waiting cost is based on the total waiting time of the closure. The waiting time is calculated as follows:

$$Waiting\ Time = \frac{1}{2} \times \left(14 - \frac{14}{56} \times \left(Trunc\left(\frac{14}{24}\right) \times 12\right)\right)$$

$$Waiting\ Time = 7\ hrs$$

*Equation 53: Waiting costs – Section A*

$$CW = WaitingTime \times \frac{ADC}{24} \times AADT(VT) \times \%VehWaiting \times VTVEHR(VT)$$

Where:

- CW = costs of waiting ($)
- %VehWaiting = the proportion of vehicles waiting per vehicle type (%)

*Example: Waiting costs – Section A*

Waiting costs are then calculated as follows:

$$CW = 7 \text{ x } \frac{58}{24} \text{ x } 100 \text{ x } 30\% \text{ x } 48.40$$

$$CW = \$23{,}716$$

#### 8.1.3.4 Crash costs

The crash costs for Section A are shown by Equation 54.

*Equation 54: Crash costs – Section A*

$$TOTACC_A = SecLength \times \left(365.25 - \left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(\frac{AADT_i}{1{,}000{,}000}\right) \times A_{TR} \times AACC_{RT}$$

Where:

- $A_{TR}$ = total crash rate (Accidents/MVKT)
- $AACC_{RT}$ = average crash cost for road type ($)

*Example: Crash costs – Section A*

Total crash costs for Section A are calculated as follows:

$$TOTACC_A = 5 \times \left(365.25 - \left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i \left(\frac{100}{1{,}000{,}000}\right) \times 0.325704225 \times 229{,}145$$

$$TOTACC_A = \$\ 13{,}619.06$$

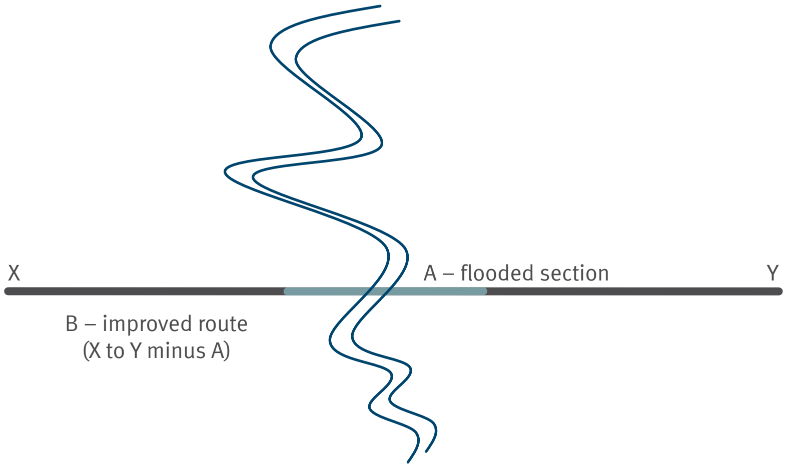
### 8.1.4 Section B – improved route

The improved route is assumed to be the section of road which vehicles are able to traverse during periods when the road is not closed. This route spans from the origin of the diversion route to the end of the diversion route (where the diverting traffic rejoins) minus the flooded section, see Figure 5. The assumption is made that under normal circumstances, road user costs for Section B are the same in the base and project cases and thus, the net difference would be 0.

The difference in costs that occur on the improved route when there is a flood due to road users not travelling or diverting is calculated. Based on this assumption the road user costs calculated are negative, i.e. road user costs not incurred.

For the mathematical proof of improved route methodology, see Appendix C – Mathematical proof of improved route calculation.

*Figure 5: Improved route*




### 8.1.4.1 Vehicle operating costs – Section B

VOC for Section B are shown by Equation 55.

*Equation 55: Vehicle operating costs – Section B*

$$TOTVOC_B = SecLength_{IR} \times \left(-\left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times \frac{VOC_i}{100}\right)$$

*Example: Vehicle operating costs – Section B*

Calculation of VOC for the improved route is:

$$TOTVOC_B = 10 \times \left(-\left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i \left(100 \times \frac{255.42}{100}\right)$$

$$TOTVOC_B = -\$744.98$$



### 8.1.4.2 Travel time costs – Section B

TTC for Section B are shown by Equation 56.

*Equation 56: Travel time costs – Section B*

$$Total\ TTC_B = TripTime_{IR} \times \left(-\left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i (AADT_i \times VTVEHR(VT))$$

*Example: Travel time costs – Section B*

Calculation of TTC for the improved route is:

$$Total\ TTC_B = 0.155 \times \left(-\left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i (100 \times 48.40)$$

$$Total\ TTC_B = -\$218.81$$

#### 8.1.4.3 Crash costs – Section B

Crash costs for section B are shown by Equation 57.

*Equation 57: Section B crash costs*

$$TOTACC_B = SecLength \times \left(-\left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(\frac{AADT_i}{1{,}000{,}000}\right) \times A_{TR} \times AACC_{RT}$$

*Example: Crash costs – Section B*

Total crash costs for Section B are:

$$TOTACC_B = 10 \times \left(-\left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i \left(\frac{100}{1{,}000{,}000}\right) \times 0.325704225 \times 229{,}145$$

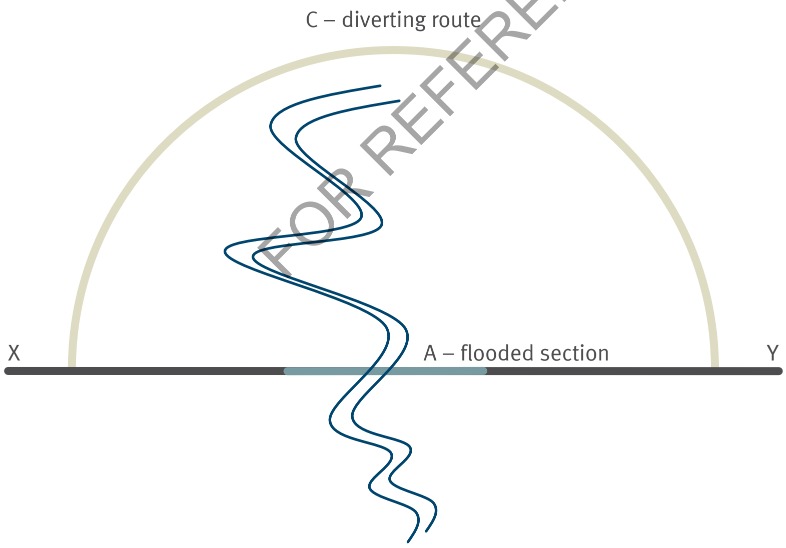
$$TOTACC_B = -\ \$21.77$$



### 8.1.5 Section C – diversion route

The diverting route road user costs are only calculated during a flooding event. When a road closure occurs at Section A, some vehicles that would normally traverse the flood affected site, will now divert to an alternative route to complete their journey. The traffic diverting from Section A will join the existing traffic travelling along the diverting route.[2]

*Figure 6: Diversion route*




#### 8.1.5.1 AADT – Section C

AADT on the diverting route during closure periods is determined by Equation 58. This equation incorporates the proportion of vehicles that choose to divert and the number of existing road users on the diversion route.

[2] Previous versions of the tool assumed that the road user costs of existing road users would be included in the diversion calculation during a flooding event. Old versions however, did not fully capture the road user costs incurred by existing traffic in the project case. CBA6 now omits existing traffic on the diverting route.

*Equation 58: AADT – Section C*

$$\%BD_{DR} = \frac{\%BD_D \times AADT_D + \%BD_E \times AADT_E}{AADT_D + AADT_E}$$

Where:

- $\%BD_{DR}$ = percentage breakdown of traffic on the diverting route
- $\%BD_D$ = percentage breakdown of diverting traffic
- $\%BD_E$ = percentage breakdown of existing traffic on the diversion route
- $AADT_D$ = traffic volume of diverting traffic
- $AADT_E$ = traffic volume of existing traffic

*Example: AADT – Section C*

If the diverting route consists of 5000 diverting vehicles and 2000 existing vehicles, and if 10% of diverting vehicles are B-doubles while 17% of existing vehicles are B-doubles, the percentage breakdown of B-doubles along the diverting route during a closure is:

$$\%BD_{DR} = \frac{17\% \text{ x } 2000 + 10\% \text{ x } 5000}{2000 + 5000} = 12\%$$



### 8.1.5.2 Traffic growth rate

Growth rate of AADT on the diversion route is made up of the increase in traffic on the normal route and the diversion route. The growth rate formula is shown by Equation 59.

*Equation 59: AADT growth – Section C*

$$G_{DR} = \frac{G_D \times AADT_D + G_E \times AADT_E}{AADT_D + AADT_E}$$

Where:

- $G_{DR}$ = growth rate on diverting route (%)
- $G_D$ = growth rate of diverting traffic (%)
- $G_E$ = growth rate of existing traffic (%)

*Example: AADT growth – Section C*

If the growth rate of the diverting traffic is 5.1%, while the growth rate of the existing traffic is 3%, the growth rate of the traffic along the diverting route is:

$$G_{DR} = \frac{5.1\% \text{ x } 2000 + 3\% \text{ x } 5000}{2000 + 5000} = 3.6\%$$

#### 8.1.5.3 Vehicle operating costs – Section C

VOC for Section C are shown by Equation 60.

Note: The traffic component is incorporated in the diversion route.

*Equation 60: Vehicle operating costs – Section C*

$$TOTVOC_C = SecLength_{DR} \times \frac{AATOC}{24} \times \sum_i \left( (AADT_{di}) \times \frac{VOC_i}{100} \right)$$

Where:

- $AADT_{di}$ = average annual daily traffic of diverting traffic

*Example: Vehicle operating costs – Section C*

For the B-double example on a 50 km diverting route with similar characteristics of the upgraded section where there is no existing traffic.

$$TOTVOC_C = 50 \times \frac{14}{24} \times \sum_i \left( 50 \times \frac{255.42}{100} \right)$$

$$TOTVOC_C = \$3{,}724.875$$



#### 8.1.5.4 Travel time cost – Section C

TTC for Section C are shown by Equation 61.

Note: The traffic component is incorporated in the diversion route TTC.

*Equation 61: Travel time costs – Section C*

$$Total\ TTC_C = TripTime_{DR} \times \frac{AATOC}{24} \times \sum_i (AADT_{di} \times VTVEHR\,(VT))$$

*Example: Travel time costs – Section C*

TTC for the B-double example is calculated as follows:

$$Total\ TTC_C = 0.77531 \times \frac{14}{24} \times \sum_i 50 \times 48.40$$

$$Total\ TTC_C = \$1{,}094.48$$

Note: Trip time in this example is based on the B-double travelling at 80 km/h for the 50 km diversion route.

#### 8.1.5.5 Crash costs – Section C

Crash costs for Section C are shown by Equation 62.

Note: The traffic component is incorporated in the diversion route.

*Equation 62: Crash costs – Section C*

$$TOTACC_C = SecLength \times \frac{AATOC}{24} \times \sum_i \frac{AADT_{di}}{1{,}000{,}000} \times A_{TR} \times AACC_{RT}$$

*Example: Crash costs – Section C*

Crash costs for the diverting route are:

$$TOTACC_C = 50 \times \frac{14}{24} \times \sum_i \left(\frac{50}{1{,}000{,}000}\right) \times 0.325704225 \times 229{,}145$$

$$TOTACC_C = \$108.84$$

### 8.1.6 Total road user cost – flooding diversion

Total road user costs and benefits in a flooding diversion are calculated by Equation 63.

*Equation 63: Total road user costs*

$$TotalRUC_{BC/PC} = RUC_A + Wait_A + RUC_B + RUC_C$$

Where:

- Road user costs = total road user costs for the relevant section (VOC + TTC + ACC)
- $Wait_A$ = waiting costs (Section A)

*Example: Total road user costs*

The annual net cost from the examples above is as follows:

$$Total\ Cost_{BC} = (466{,}088.29 + 13{,}694.95 + 13{,}619.06) + 23{,}716 + (-744.98 - 218.81 - 21.77) + (3724.88 + 1094.48 + 108.84)$$

$$Total\ Cost_{BC} = 493{,}402.30 + 23{,}716 - 985.56 + 4928.20$$

$$Total\ Cost_{BC} = \$521{,}060.94$$

The net benefits of a flooding/diversion are derived from road user costs calculated for all years in the evaluation for both base and project cases. The total road user costs are also discounted, see Section 9.1. Benefits are the total discounted base case costs minus the project case equivalents.

## 8.2 Road closures

With the exception of the diversion and improved route calculations, the road closure module in CBA6 follows the same methodology as the flooding diversion module. In road closure scenarios, such as rock falls and flooding, road users are not provided with a viable alternate route and have only two options:

- Wait at the closure site.
- Choose not to travel at all.

Based on the percentage of road users who choose to wait at the project site, CBA6 calculates the average duration of the road closure per year and waiting costs associated with the closure. Road user costs defined in Section 4 are calculated during periods where the road is not closed. Similar to the flooding diversion, those road users who choose not to travel at all during the road closure do not incur any additional road user costs for the duration of the closure.

Note: For further details on the costs of not travelling see Section 2.4.1.3 of the *Theoretical Guide*.

## 8.3 Intersections

The intersection module is dependent on SIDRA outputs, see Table 34. Consequently, the accuracy of the CBA6 results is dependent on the accuracy of the SIDRA modelling. Information is required for two or more years of the evaluation period, for both base and project cases. This requires at least four runs of the SIDRA intersection analysis tool depending on the number of time periods to be modelled. For this reason, generally only the peak periods are evaluated. For a more detailed discussion on the intersection module, see Section 5.5 of the *User Guide*. Data from alternative modelling tools could be used if converted to SIDRA output format.

*Table 34: CBA6 intersection inputs*

| Period description | Period duration (hours) | Flow (veh/hour) | Average delay (seconds) | Fuel consumption (l/hour) |
|---|---|---|---|---|
| Morning peak | 1 | 1000 | 20 | 100 |
| Afternoon peak | 1 | 2000 | 30 | 75 |
| Non-peak | 10 | 0 | 0 | 0 |
| Night | 12 | 0 | 0 | 0 |
| Weekend day | 12 | 0 | 0 | 0 |
| Weekend night | 12 | 0 | 0 | 0 |

One year is assumed to consist of 260.9 weekdays and 104.4 weekend days (i.e. 365.25 x 5/7 and 365.25 x 2/7). Hence, there are 260.9 morning peak periods and 104.4 weekend periods in a year.

Note: The flow rate (veh/hour) is representative of all vehicles in the fleet.

### 8.3.1 Delay cost calculation

The average delay in seconds is converted into hours per year per vehicle type. This calculation is shown by Equation 64.

*Equation 64: Annual delay (hours)*

$$Delay(VT) = \frac{averagedelay}{3600} \times flow(VT) \times duration(period) \times periods\ per\ year$$

*Example: Annual delay (hours)*

Using inputs from Table 34, the average delay in hours in the morning peak for a B-double at a rural intersection is calculated by the following:

$$Delay(B - Double) = \frac{20}{3600} \times 35 \times 1 \times 260.9 = 50.73\ hrs$$

The average delay of 20 seconds in the morning peak impedes the B-double fleet by 50.73 hours each year.

Note: It is assumed that there are 3.5% B-doubles out of the total vehicle flow deriving an am peak flow of 35 B-doubles.

Vehicle delay time is multiplied by the unit cost of time. The annual delay cost per vehicle type is shown by Equation 65.

*Equation 65: Annual delay cost*

$$Annual\ Delay\ Cost(VT) = Delay(VT) \times VTVEHR(VT)$$

Where:

- Time cost VTVEHR(VT) = TTC per vehicle ($)

*Example: Annual delay cost*

Following the previous example, the annual delay cost is calculated as follows:

$$Annual\ Delay\ Cost(B - Double) = 50.73hrs \times 48.40/h$$

$$Annual\ Delay\ Cost(B - Double) = \$2455.38\ p.a$$

Delays in the morning peak cost the B-double fleet $2455 each year.

### 8.3.2 Fuel cost calculation

In the intersection module, only VOC incurred by road users are fuel consumption costs. The basic fuel consumption is calculated by Equation 66.

*Equation 66: Basic fuel consumption*

$$BFC(VT) = \left(Square(VT) \times OS^2 + \frac{Reciprocal(VT)}{OS} + Constant(VT)\right) \times FCAVF$$

Where:

- BFC(VT) = basic fuel consumption per vehicle type (L/1000 km)
- Square(VT) = model parameter
- OS(VT) = operating speed calculation for each vehicle type (30 km/h)
- Reciprocal(VT) = model parameter
- Constant(VT) = model parameter

Note: The intersection module operating speed is assumed to equal 30 km/h.

The variables in the formula are sourced from Table 10, Section 4 and are reproduced in Table 35.

*Table 35: Intersection BFC variables*

| Vehicle type | FCAVF | Constant | Reciprocal | Square | BFC |
|---|---|---|---|---|---|
| Cars – private | 1.07 | 37.30 | 1 526.20 | 0.01 | 96.40 |
| Cars – commercial | 1.07 | 38.90 | 1 883.00 | 0.01 | 140.92 |
| Non-Articulated | 1.10 | 49.00 | 3 485.10 | 0.02 | 239.97 |
| Buses | 1.10 | 69.40 | 5 451.10 | 0.01 | 239.97 |
| Articulated | 1.10 | 118.60 | 9 621.10 | 0.02 | 445.52 |
| B-double | 1.10 | 172.70 | 14 720.40 | 0.02 | 745.56 |
| Road train 1 | 1.10 | 223.60 | 17 201.80 | 0.01 | 891.34 |
| Road train 2 | 1.10 | 312.10 | 26 646.90 | 0.02 | 1 335.21 |

*Source: Austroads (2005) and TMR calculations.*

*Example: Basic fuel consumption*

Using the same B-double example at an operating speed of 30 km/h, the basic fuel consumption is calculated as follows:

$$BFC(B - Double) = 745.56\ L/1000km$$

The fuel proportion weighting for each vehicle type, based on the volume and BFC of each vehicle type, relative to the BFC of a private car is shown by Equation 67.

*Equation 67: Fuel proportion*

$$Fuel\ Proportion(VT) = \frac{Veh/hr(VT) \times BFC(VT)}{\sum(Veh/hr \times BCF(VT)}$$

Where:

- Veh/hr(VT) = vehicles per hour for a specific vehicle type (Flow)
- BFC(VT) = basic fuel consumption for the target vehicle, see Table 35

*Example: Fuel proportion example*

In the B-double example, the total fuel consumption for all vehicles is 164 052.6; this figure can be verified in Table 36. The fuel proportion is calculated as:

$$Fuel\ Proportion\ (B - Double) = \frac{35 \times 745.56}{164{,}052.60}$$

$$Fuel\ Proportion\ (B - Double) = 15.91\%$$

The fuel consumption for each vehicle type, using the total fuel consumption value output by SIDRA, is shown by Equation 68.

*Equation 68: Fuel consumption*

$$Fuel\ Consumption(VT) = fuelcons(SIDRA) \times Fuel\ Proportion\ (VT)$$

Where:

- Fuelcons(SIDRA) = fuel consumption (L/hr) as per SIDRA output

*Example: Fuel consumption*

Fuel consumption for a B-double is:

$$Fuel\ Consumption(B - Double) = 100 \times 15.91\%$$

$$Fuel\ Consumption(B - Double) = 15.91\ L/hr$$

Morning peak fleet fuel consumption of 100 litres per hour equates to 15.91 litres per hour for a B-double.

Annual fuel cost for each vehicle type, using the weighted average fuel price (fuelcf) is shown by Equation 69.

*Equation 69: Annual fuel cost*

$$AnnualFuelCost(VT) = FuelCons(VT) \times \frac{Fuelcf}{100} \times PeriodPerYear \times HrsPerPeriod$$

Where:

- AnnualFuelCost(VT) = annual fuel cost per vehicle type
- FuelCons (VT) = fuel consumption per vehicle type (L/hr)
- Fuelcf = weighted fuel cost per vehicle type

*Example: Annual fuel cost*

In the B-double example, the annual fuel cost is calculated, assuming the weighted fuel cost for a B-double equals 81.57 cents per litre:

$$AnnualFuelCost(B - Double) = 15.91 \times \frac{81.57}{100} \times 260.90 \times 1$$

$$AnnualFuelCost(B - Double) = \$3385.10\ p.a$$

Table 36 shows the complete calculation of fuel costs in the morning peak using the previous intersection calculations.

*Table 36: Intersection fuel cost example*

| Morning peak fuel cost | | | | | | |
|---|---|---|---|---|---|---|
| **Vehicle type** | **Flow (veh/hr)** | **BFC (l/1000km)** | **Flow fuel consumption** | **Fuel proportion (%)** | **Fuel consumption (l/hr)** | **Annual fuel cost ($)** |
| Cars – private | 700.00 | 96.40 | 67 480.50 | 41.13 | 41.13 | 8 852.59 |
| Cars – commercial | 100.00 | 140.92 | 14 091.50 | 8.59 | 8.59 | 1 848.63 |
| Non-Articulated | 100.00 | 239.97 | 23 996.87 | 14.63 | 14.63 | 3 130.53 |
| Buses | 5.00 | 239.97 | 1 199.84 | 0.73 | 0.73 | 156.18 |
| Articulated | 50.00 | 445.52 | 22 275.92 | 13.58 | 13.58 | 2 892.99 |
| B-double | 35.00 | 745.56 | 26 094.53 | 15.91 | 15.91 | 3 385.10 |
| Road train 1 | 10.00 | 891.34 | 8 913.45 | 5.43 | 5.43 | 1 156.29 |
| Road train 2 | - | 1 335.21 | - | 0.00 | 0.00 | 0.00 |
| Total | 1 000.00 | 4 134.89 | 164 052.60 | 100.00 | 100.00 | 21 422.30 |



## 8.3.3 Accident cost calculation

Accident costs for intersection evaluations are manually entered by the system user on a yearly basis. The manual calculation of accident costs can be derived using the formulae provided in Section 6.

Note: Average intersection crash costs per million vehicles entering an inter (MVE) are provided in Appendix F as per Austroads (2001) AP-R/184.

*Example: Intersection accident*

The crash cost for 1000 vehicles using the intersection with an average accident cost of $229 145 as per Section 6 is derived by the following:

$$CrashCost_{RT} = MVE \times A_{TR} \times AAcc_{RT}$$

$$CrashCost_{RT} = \frac{1000 \times 365.25 \times 1}{1.000.000} \times 0.25 \times \$229{,}145$$

$$CrashCost_{RT} = 0.36525 \times 0.25 \times 229{,}145$$

$$CrashCost_{RT} = \$20{,}924/\text{year}$$

In this example a project specific crash rate has been adopted based on the accident history of the intersection.

### 8.3.4 Benefit calculation

Calculation of benefits derived from an intersection evaluation using the outputs from SIDRA in CBA6 is shown by Equation 70.

*Equation 70: Total benefit*

$$TotalBenefit = (TotalBaseCosts) - (TotalProjectCosts)$$

Where:

- TotalBaseCosts = Base delay costs + base fuel costs + base accident costs
- Total project Costs = Project delay costs + project fuel costs + project accident costs

Calculations of benefits are completed for each year of the evaluation in both the base and project cases. Where SIDRA data is only provided in the first and last year of the evaluation, intermittent data sets are interpolated through Equation 71.

*Equation 71: Linear intersection interpolation*

$$Value_{YrZ} = Value_{YrX} + (YrZ - YrX) \times \left(\frac{Value_{YrY} - Value_{YrX}}{YrY - YrX}\right)$$

Where:

- $Value_{YrZ}$ = value of the interpolated variable in a year for which data has not been provided
- $Value_{YrX}$ = value of the first variable provided by the data
- $Value_{YrY}$ = value of the second variable provided by the data

Note: Data can be entered for each individual year, although this will first require multiple runs of SIDRA.

## 8.4 Overtaking lanes

Overtaking lane methodology takes into account recent research on accident reductions from the Austroads report AP-R184. Reduction in crashes depends on the type of overtaking lane constroad user coststed. The methodology applied to the calculation of the reduction of crashes is different than the methodology applied to the calculation of the reduction of crashes of a standard road evaluation.

### 8.4.1 Travel time costs and vehicle operating costs calculation

The capacity of the downstream section is assumed to increase by 20% because of the constroad user coststion of the overtaking lane. Length of the downstream and upstream areas is assumed to be 5 km and 3 km respectively. For more information on the downstream and upstream areas, see Section 2.4.5 of the *Theoretical Guide*.

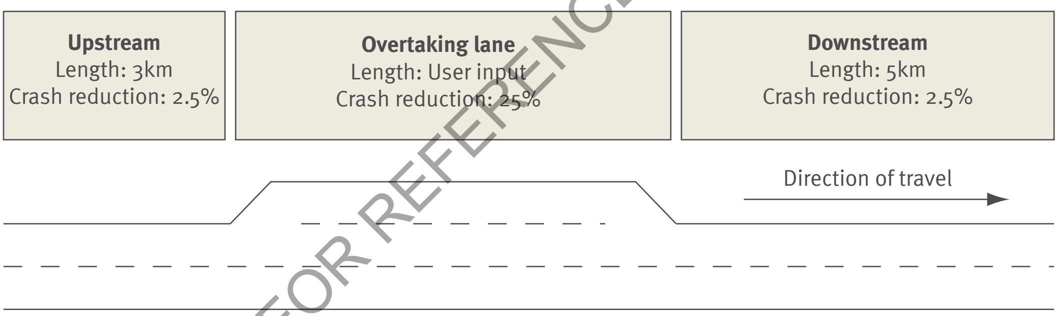
### 8.4.2 Crash costs

Provision of an overtaking lane will reduce the frequency of crashes for the road sections immediately before, during and after the overtaking lane location (Austroads 2001). Crash cost reduction for the three types of overtaking lanes is shown by Sections 8.4.2.1 to 8.4.2.3 of the *Theoretical Guide*.

#### 8.4.2.1 Single overtaking lane

The crash cost reduction for a single overtaking lane is illustrated by Figure 7.

*Figure 7: Single overtaking lane*






Calculations for crash reductions are specified in monetary terms for a single overtaking lane by Equation 72. Accidents are reduced by 25% in the section where the overtaking lane is constroad user coststed, 2.5% in the 3 km upstream section and 2.5% in the 5 km downstream area. These reductions are applied to Equations 72 to 74.

*Equation 72: Single overtaking lane crash reduction*

$$ReductionOTL_{Single} = [(0.25 \times SecLength)A_R \times AADT \times 365.2 \times 10^{-6}] \times Av.Crash\ Cost$$

$$ReductionUP_{Single} = [(0.025 \times 3)A_R \times AADT \times 365.25 \times 10^{-6}] \times Av.Crash\ Cost$$

$$ReductionDN_{Single} = [(0.025 \times 5)A_R \times AADT \times 365.25 \times 10^{-6}] \times Av.Crash\ Cost$$

Where:

- $ReductionOTL_{Single}$ = reduction in crashes for the overtaking section

- $ReductionUP_{Single}$ = reduction in crashes for the upstream section
- $ReductionDN_{Single}$ = reduction in crashes for the downstream section
- $A_R$ = base case crash rate for the relevant section (crashes per MVKT)
- SecLength = length of the relevant section (km)

*Example: Single overtaking lane crash reduction*

The reduction in crashes for a 2 km overtaking lane on a highway with MRS of 12 and 1000 vehicles is calculated by:

$$ReductionOTL_{Single} = [(0.25 \times 2)0.281690141 \times 1000 \times 365.25 \times 10^{-6}] \times 229{,}145$$

$$ReductionOTL_{Single} = \$11{,}788.06$$

$$ReductionUP_{Single} = [(0.025 \times 3)0.281690141 \times 1000 \times 365.25 \times 10^{-6}] \times 229{,}145$$

$$ReductionUP_{Single} = \$1768.21$$

$$ReductionDN_{Single} = [(0.025 \times 5)0.281690141 \times 1000 \times 365.25 \times 10^{-6}] \times 229{,}145$$

$$ReductionDN_{Single} = \$2947.01$$

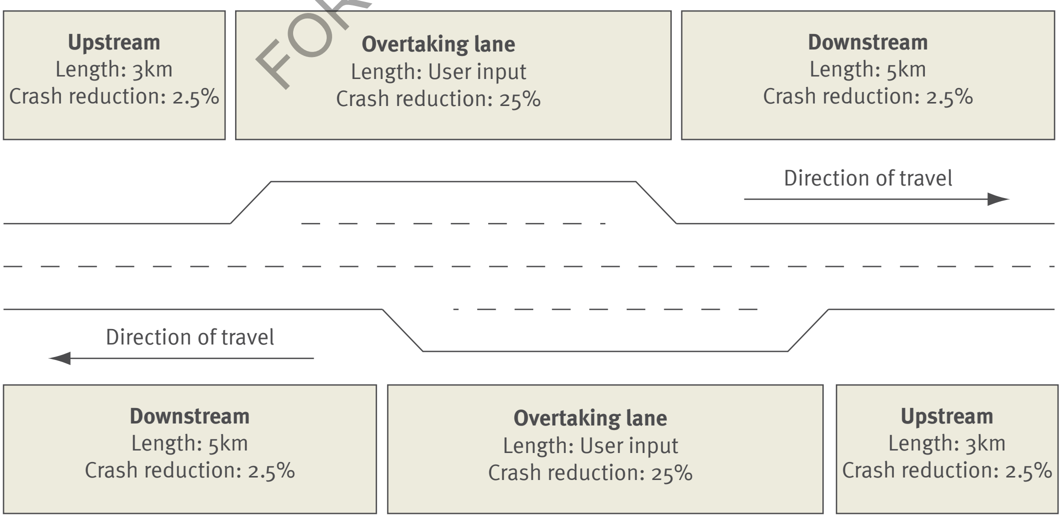
Crash cost reduction is the sum of the single, upstream and downstream overtaking lane sections. The total crash cost reduction as a result of the overtaking lane above is equal to $16 503.28.

Note: The difference between the upstream and downstream benefits is a factor of the section length.

### 8.4.2.2 Head-to-head overtaking lane

The crash reduction of a head-to-head overtaking lane is illustrated by Figure 8.

*Figure 8: Head-to-head overtaking lane*




Equations for calculating the crash cost reduction for a head-to-head overtaking are shown by Equation 73.

*Equation 73: Head-to-head overtaking lane accident reduction*

$$ReductionOTL_{hth} = [0.25(2 \text{ x SecLength - SS})A_R \text{ x AADT x } 365.25 \text{ x } 10^{-6}] \text{ x AvCrashCost}$$

$$ReductionUP_{hth} = [(2 \text{ x } 0.025 \text{ x } 3)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

$$ReductionDN_{hth} = [(2 \text{ x } 0.025 \text{ x } 5)\ A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

Where:

- $\text{ReductionOTL}_{hth}$ = reduction in crashes for the overtaking section
- $\text{ReductionUP}_{hth}$ = reduction in crashes for the upstream section
- $\text{ReductionDN}_{hth}$ = reduction in crashes for the downstream section
- $A_R$ = base case crash rate for the relevant section (crashes per MVKT)
- SecLength = length of the relevant section (km)
- SS = section length of the overtaking lane that runs side-by-side

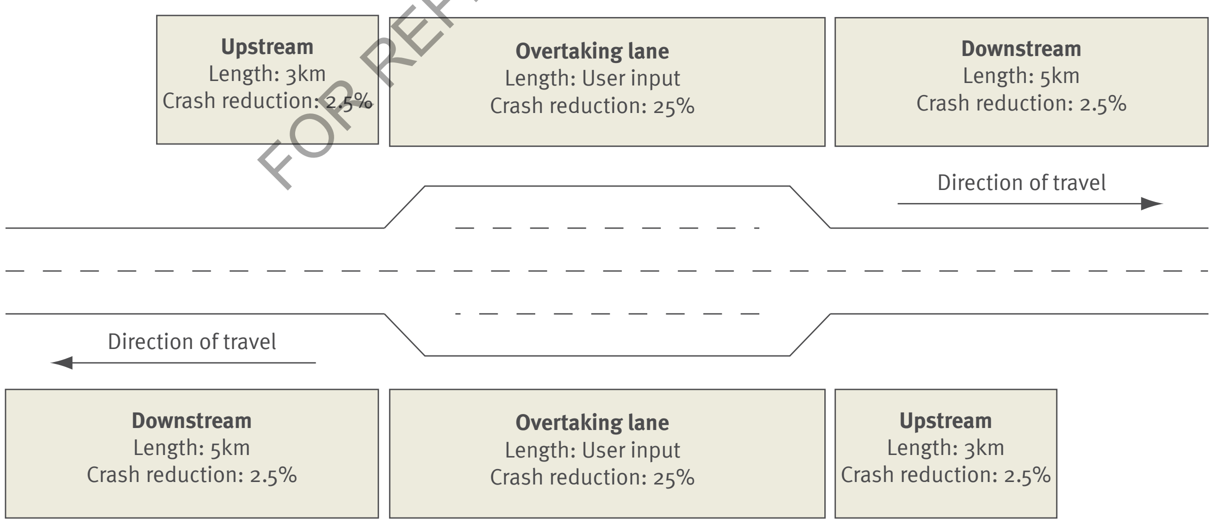
Note: Unlike single overtaking lanes, accident reductions for head-to-head overtaking lanes are derived from two upstream and downstream areas.



### 8.4.2.3 Side-by-side overtaking lane

Equations for calculating the crash cost reduction for a side-by-side overtaking lane are shown by Equation 74. Figure 9 illustrates the crash reduction of a side-by-side overtaking lane.

*Figure 9: Side-by-side overtaking lane*




*Equation 74: Side-by-side overtaking lane accident reduction*

$$ReductionOTL_{sbs} = [(0.25 \text{ x } SecLength)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

$$ReductionUP_{sbs} = [(2 \text{ x } 0.025 \text{ x } 3)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

$$ReductionDN_{sbs} = [(2 \text{ x } 0.025 \text{ x } 3)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

Where:

- $ReductionOTL_{sbs}$ = reduction in crashes for the overtaking section
- $ReductionUP_{sbs}$ = reduction in crashes for the upstream section
- $ReductionDN_{sbs}$ = reduction in crashes for the downstream section
- AR = base case crash rate for the relevant section (crashes per MVKT)
- SecLength = length of the relevant section (km)

Note: The side-by-side overtaking lane is not expected to provide the same amount of safety benefits when compared to the head-to-head overtaking lane. The side-by-side configuration is usually constroad user coststed over a shorter 'net' distance. For example, the head-to-head overtaking lane can be constroad user coststed as two separate overtaking lanes at 3 km each, which equates to 6 km in total, whereas two side-by-side overtaking lanes, 3 km each, only accounts for 3 km in total road section.

## 8.5 Generated traffic

As discussed in Section 2.4.2 of the *Theoretical Guide*, generated traffic is the number of additional road users making trips in the project case. The benefits of generated traffic can be illustrated by the increase in consumer surplus in Figure 10.

*Figure 10: Generated traffic*

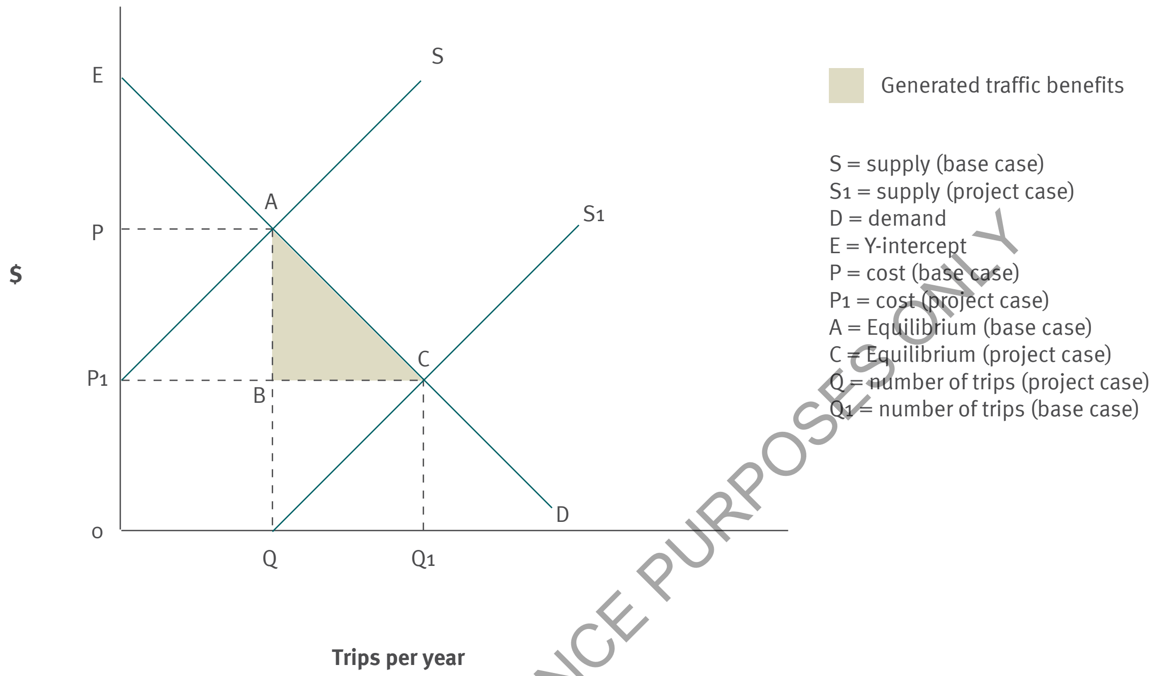



Figure 10 shows that when road user costs decline from p to p1, the declining perceived cost per trip entices more trips to be made by transport and generates additional road users. The declined perceived cost per trip is a result of an improvement in the quality of the road. The benefit accruing to those generated road users is measured by the triangle, ACB. The generated traffic module in CBA6 measures the benefit represented by this triangle by applying 'the rule of half'.

Note: The theory of generated traffic benefits should not be applied to an evaluation with a capacity constraint issue.

The generated traffic benefit calculation is given by Equation 74. This equation applies the 'rule of half' to calculate the benefits of increased road use by incorporating the benefits of lower TTC and VOC.

*Equation 75: Generated traffic*

$$Benefits_{GENTRAF} = \frac{\left(\left((TTC_{BC} + VOC_{BC}) - (TTC_{PC} + VOC_{PC})\right) \times GenTraffic\right)}{2}$$

Where:

- $Benefits_{GENTRAF}$ = the total value of generated traffic benefits derived in CBA6 ($)
- GenTraffic = the number of vehicles generated from a project (vehicles)
- $TTC_{BC}$ and $VOC_{BC}$ = base case annual total road user cost per vehicle
- $TTC_{PC}$ and $VOC_{PC}$ = project case annual total road user cost per vehicle

Note: Total road user costs (TTC and VOC) are calculated as follows:

$$RUC = \frac{Sec\ Length \times Unit\ RUC \times 365.25}{100}$$

*Example: Generated traffic*

Table 37 outlines a generated traffic example which shows that an upgrade of a 5 km section of road offers a significant reduction in travel cost which in turn is expected to generate 50 extra trips made by private vehicles. Using the data in Table 37 and Equation 75, the benefit from generated traffic is:

$$Benefit_{GENTRAF} = \frac{\big((253.85 + 279.42) - (228.25 + 255.68)\big) \times 50)}{2}$$

$$Benefit_{GENTRAF} = \$1232.72\ p.a$$

The above calculations show that the economic benefit of an increase in the number of private vehicles is $1233 where the benefit to existing road users is $4930.

*Table 37: Generated traffic (private vehicle)*

| Case | Section length (km) | TTC (c/km) | VOC (c/km) | TTC per vehicle ($ p.a) | VOC per vehicle ($ p.a) | AADT | Generated vehicles | Annual existing benefit | Annual generated benefit ($) |
|---|---|---|---|---|---|---|---|---|---|
| Base | 5 | 13.9 | 15.3 | 253.85 | 279.42 | 100 | 50 | 4 930.88 | 1 232.72 |
| Project | 5 | 12.5 | 14.0 | 228.28 | 255.68 | 150 | | | |

## 8.6 Livestock damage

Damage to livestock occurs as a result of dust inhalation and jarring on unpaved or unsealed roads. Livestock damage benefits are calculated using default values from Table 38. This table shows that the default livestock benefit is based on the change in MRS between the base and project cases. For example, if the base case road has an MRS of 1 (unsealed natural surface) and the road is upgraded to an MRS of 3 (paved ‹ 4.5 m), the benefit per kilometer for a B-double is $0.605.

The largest livestock benefit accrues when an unsealed/formed road is upgraded to a sealed surface in the project case. The lowest benefits occur when a paved road is sealed.

*Table 38: Damage to livestock benefits*

| Heavy vehicle type | Benefits ($/km) | | |
|---|---|---|---|
| | Unsealed/formed road to sealed road | Unsealed/formed road to gravel/paved road | Paved road to sealed road |
| | MRS 1, 2 to MRS 5+ | MRS 1, 2 to MRS 3,4 | MRS 3,4 to MRS 5+ |
| Articulated | 0.304 | 0.202 | 0.104 |
| B-double | 0.909 | 0.605 | 0.304 |
| Road train 1 | 0.909 | 0.605 | 0.304 |
| Road train 2 | 0.909 | 0.605 | 0.304 |

*Source: TMR, see Appendix I – model road state.*



The proportion of heavy vehicles carrying livestock requires specification in order for CBA6 to calculate the livestock damage benefits. Equation 76 can be used to determine the proportion of total vehicles carrying livestock.

*Equation 76: Vehicles carrying livestock*

$$\%Livestock(VT) = \frac{VT_{Livestock}}{VT_{Total}}$$

*Example: Vehicles carrying livestock*

The AADT along an unsealed paved road is 200 and there are approximately 20 B-doubles, with only five of the 20 B-doubles carrying livestock.

$$\%Livestock(B - Double) = \frac{5}{20} = 25\%$$

25% would be entered in the livestock column for B-doubles.

After the proportion of vehicles carrying livestock has been determined, the benefits that are attributable to these vehicles can be calculated using Equation 77. This shows the annual livestock damage benefit for those heavy vehicles carrying livestock based on the road upgrade benefit from Table 38.

*Equation 77: Annual livestock benefits*

$$Benefits_a = \sum_{VT} Benefit_{i(VT)} \times AADT(VT) \times Livestock_c\%(VT) \times 365.25 \times SecLength$$

*Example: Annual livestock benefits*

Table 39 illustrates the calculation of livestock benefits for a 10 km upgrade from an unsealed road with an MRS 4, to a sealed road with an MRS 7. By inputting the assumed data presented in Table 39 into Equation 77, the benefits per year by vehicle type can be calculated. The results of these calculations are shown in the 'benefits/year' column of Table 39.

Table 39 shows that a benefit of $0.304 per kilometre per vehicle, for 35 B-double vehicles, travelling 10 km, on a road upgraded from an unsealed road with an MRS of 4 to a sealed road with an MRS of 7, is equivalent to a benefit of $31 724.

*Table 39: Damage to livestock benefits example*

| Vehicle type | Benefits ($/km) | Section length (km) | Number of vehicles | Breakdown (%) | Number carrying livestock | Livestock (%) | Benefits/year ($) |
|---|---|---|---|---|---|---|---|
| Cars – private | - | 10 | 700 | 70.0 | - | - | - |
| Cars – commercial | - | 10 | 100 | 10.0 | - | - | - |
| Non-Articulated | - | 10 | 100 | 10.0 | - | - | - |
| Buses | - | 10 | 5 | 0.5 | - | - | - |
| Articulated | 0.104 | 10 | 50 | 5.0 | 20 | 40.0% | 15 194.40 |
| B-double | 0.304 | 10 | 35 | 3.5 | 10 | 28.6% | 31 724.57 |
| Road train 1 | 0.304 | 10 | 10 | 1.0 | 2 | 20.0% | 22 207.20 |
| Road train 2 | 0.304 | 10 | 0 | 0.0 | 0 | - | - |
| Total | - | 10 | 1000 | 100 | 32 | - | 69 126.17 |

## 8.7 Bypass

A bypass is a new road which provides an alternative route for traffic around a town or built-up area. In a bypass, the total costs of all individual links are compared with a proposed bypass. Evaluations of bypasses tend to be data intensive depending on the magnitude of the bypass. For an example of a bypass, see Section 5.7 of the *User Guide*.

In terms of methodology, CBA6 compares total road user costs on all individual links and the proposed bypass. The bypass benefit calculation is shown by Equation 78.

*Equation 78: Bypass*

$$BypassBenefits = (RUC1_{BC} + RUC2_{BC} + \ldots RUCB_{BC}) - (RUC1_{PC} + RUC2_{PC} + \ldots RUCB_{PC})$$

Where:

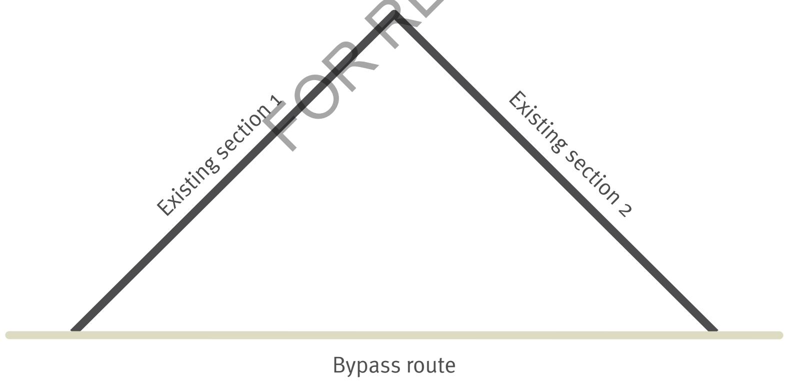
- Road user costs$1_{BC}$ = base case road user costs for existing section 1
- Road user costs$1_{PC}$ = project case road user costs for existing section 1
- Road user costs$B_{BC}$ = base case road user costs for the bypass section

Note: Road user costs$1_{BC}$ = ($TTC_{BC}$ + $VOC_{BC}$ + $Acc_{BC}$).

Road user costs are calculated based on road conditions and traffic volume for each individual road link and bypass section for both base and project cases. The calculation of road user costs for each existing road section and bypass section is consistent with the TTC, VOC and accident costs shown previously in Sections 4 to 6.

An example of a bypass project is shown by Figure 11 and Table 40. This example shows that without the bypass, road users only have the option of travelling along the existing sections. Once the bypass route is in place, some motorists who travel through the town will opt not to travel along the existing sections but alternatively choose to travel on the bypass route.

*Figure 11: Bypass*




To calculate the traffic breakdown of a bypass, attention is given to the amount of vehicles which divert from the existing sections to the bypass in a project case. For example, in the bypass case study shown in the *User Guide*, the breakdown is shown by Table 40.

*Table 40: Bypass traffic breakdown example*

| | Existing 1 | | Existing 2 | | Existing 3 | | Existing 4 | | Bypass | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Base** | **Project** | **Base** | **Project** | **Base** | **Project** | **Base** | **Project** | **Base** | **Project** |
| AADT | 4 000 | 2 000 | 8 000 | 6 000 | 8 000 | 6 000 | 4 000 | 2 000 | 0 | 2 000 |
| Cars – private | 82.0% | 88.0% | 82.0% | 84.0% | 82.0% | 84.0% | 82.0% | 84.0% | 0.0% | 76.0% |
| Cars – commercial | 11.0% | 9.0% | 11.0% | 10.3% | 11.0% | 10.3% | 11.0% | 10.3% | 0.0% | 13.0% |
| Non-Articulated | 3.3% | 1.6% | 3.3% | 2.7% | 3.3% | 2.7% | 3.3% | 2.7% | 0.0% | 5.0% |
| Buses | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 1.0% | 0.0% | 1.0% |
| Articulated | 1.1% | 0.2% | 1.1% | 0.8% | 1.1% | 0.8% | 1.1% | 0.8% | 0.0% | 2.0% |
| B-double | 1.6% | 0.2% | 1.6% | 1.1% | 1.6% | 1.1% | 1.6% | 1.1% | 0.0% | 3.0% |
| Road train 1 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Road train 2 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Growth rate (%pa linear) | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | 3.0% | N/A | 3.0% |

To estimate the project case vehicle breakdown, the number of vehicles that enter the bypass in the project case is derived from each existing section's breakdown, and is shown by Table 41.

*Table 41: Bypass example – average annual daily traffic*

| | Existing 1 | | Existing 2 | | Existing 3 | | Existing 4 | | Bypass | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Base** | **Project** | **Base** | **Project** | **Base** | **Project** | **Base** | **Project** | **Base** | **Project** |
| AADT | 4 000 | 2 000 | 8 000 | 6 000 | 8 000 | 6 000 | 4 000 | 2 000 | - | 2 000 |
| Cars – private | 3 280 | 1 760 | 6 560 | 5 040 | 6 560 | 5 040 | 3 280 | 1 680 | - | 1 520 |
| Cars – commercial | 440 | 180 | 880 | 620 | 880 | 620 | 440 | 207 | - | 260 |
| Non-Articulated | 132 | 32 | 264 | 164 | 264 | 164 | 132 | 55 | - | 100 |
| Buses | 40 | 20 | 80 | 60 | 80 | 60 | 40 | 20 | - | 20 |
| Articulated | 44 | 4 | 88 | 48 | 88 | 48 | 44 | 16 | - | 40 |
| B-double | 64 | 4 | 128 | 68 | 128 | 68 | 64 | 23 | - | 60 |
| Road train 1 | - | - | - | - | - | - | - | - | - | - |
| Road train 2 | - | - | - | - | - | - | - | - | - | - |

The number of vehicles which will divert to the bypass is the difference between the bypass project case and each existing section base case, as given by Equation 79.

*Equation 79: Existing project case AADT*

$$Existing_x\ AADT_{PC}(VT) = Existing_x\ AADT_{BC}(VT) - Bypass_{PC}AADT(VT)$$

*Example: Existing project case AADT*

In the bypass case study, AADT for the existing 1 for private cars is calculated as follows:

$$Existing\ 1\ AADT_{PC}(Private) = 3280 - 1520 = 1760$$

Existing private car AADT is converted to a percentage of total AADT.

$$Existing\ 1\ AADT_{PC}\%\ (Private) = \frac{1760}{2000} * 100 = 88\%$$

*Example: Bypass*

Referring to Figure 11, a single B-double is currently travelling along two individual 10 km links (existing Sections 1 and 2), which will be bypassed under a new project. The single B-double is assumed to divert to the 7 km new bypass route. The aggregate discounted road user costs for the individual links are assumed to be $525 000 and $650 000 for existing Sections 1 and 2 respectively. When the bypass road is completed, the B-double is assumed to incur net discounted road user costs equal to $750 000 for travelling along the bypass route. The total benefit of the bypass project is:

$$BypassBenefits = (525{,}000 + 650{,}000 + 0) - (0 + 0 + 750{,}000)$$

$$BypassBenefits = \$425{,}000$$

The above calculation shows that in the base case, the B-double only incurs road user costs for the existing Sections 1 and 2 as there are no road user costs for the bypass route in the base case, because the bypass route is assumed to be a new road (i.e. there is no bypass route in the base case).

However, in some instances the bypass route could be an existing road. This example also shows that in the project case the B-double only travels on the bypass route.


# 9 Decision criteria

The decision criteria provide an indication of the economic performance of the proposal. This section provides the formula used to calculate the decision criteria employed in CBA6. The key decision criteria used in CBA6 include:

- BCR
- NPV
- FYRR
- NPVI
- IBCR

The BCR is the economic measure which is used to prioritise the selection of road projects. The BCR provides a single measure that can be used to support the decision to either accept or reject a project. In a budget constrained environment, the BCR can be used as a tool to rank and prioritise all projects in the budget pool. For this reason, the BCR is the preferred decision criterion for project economic justification.

The other decision criterion that provides decision makers with additional information is the NPV. Other indicators such as payback period and internal rate of return are not addressed in CBA6 or in this section. For further detail on why some indicators are used over others, see Section 1.7 of the *Theoretical Guide*.

Note: The principal of discounting is applied within each of these measures and is covered in Section 9.1. The residual value calculation used to calculate the value of the remaining life of the asset is discussed in Section 9.7, and is incorporated in the final year of the evaluation as a benefit.

## 9.1 Discounting

Future flows of benefits and costs are discounted to reflect the time value of money, as discussed in Section 1.4 of the *Theoretical Guide*. The discounting formula is applied to both benefits and cost streams. Equation 80 shows the discounting formula used in CBA6.

*Equation 80: Discounting benefits*

$$Present\ Value = \frac{B_1}{1+r} + \frac{B_2}{(1+r)^2} + \frac{B_3}{(1+r)^3} +..+ \frac{B_n}{(1+r)^n}$$

$$Present\ Value = \sum_{i=1}^{n} \frac{B_i}{(1+r)^i}$$

Where:

- $B_i$ = benefit or cost in year i
- n = number of years in the evaluation period
- r = real discount rate

Table 42 shows a benefit flow of $1000 in Year 1 followed by benefits of $500 per annum until Year 5.

*Table 42: Discounting benefits*

| Year | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| Benefit ($) | 1000 | 500 | 500 | 500 | 500 | 3000 |
| Discounted benefit (present value $) | 943 | 445 | 419 | 396 | 373 | 2577 |

*Example: Discounting benefits*

Assuming a 6% discount rate, the discounted total benefit is equal to:

$$Total\ Benefit = \frac{1000}{1.06^1} + \frac{500}{1.06^2} + \ldots + \frac{500}{1.06^5}$$

$$Total\ Benefit = 2577.88$$

The results shown by Table 42 show that the benefit of $500 earned in Year 2 is higher than the $500 earned in Year 5 when compared to the present value. $500 in Year 2 is equivalent to $445 in present value while benefits of $500 in Year 5 are only worth $373 in present value.

## 9.2 Benefit-cost ratio

BCR is the discounted benefits divided by the discounted capital costs and the discounted net operating costs. The BCR is shown by Equation 81. The BCR will be greater than 1 whenever discounted benefits exceed discounted costs. A project with a BCR above 1 provides a net economic gain and can be considered economically justified. In a budget constrained environment, projects should be prioritised according to their BCRs. A project with a higher BCR provides a greater benefit per dollar invested and should receive priority in the allocation of funding. This will ensure the efficient allocation of scarce resources.

*Equation 81: Benefit-cost ratio*

$$BCR = \sum_{i=1}^{n} \frac{B}{(1+r)^i} \Bigg/ \sum_{i=1}^{n} \frac{K_i + OC_i}{(1+r)^i}$$

Where:

- $K_i$ = capital costs
- $OC_i$ = operating costs
- R = discount rate
- B = net benefits

*Example: Benefit-cost ratio*

If the sum of the discounted capital and operating costs is assumed to be $50 million over the evaluation period and the discounted benefits are assumed to be $70 million, then the BCR is given as follows:

$$BCR = \$70m/\$50m$$

$$BCR = 1.4$$

This example indicates that the present value of the benefits exceeds the present value of the costs required to build a project by 1.4 times.

## 9.3 Net present value

NPV measures the actual or real net economic benefit of a project. While the BCR provides a ratio of benefits to costs, NPV measures the absolute net economic gain. NPV is calculated by subtracting the discounted costs from the discounted benefits. All projects with a positive NPV provide a net economic benefit. NPV should be used when comparing mutually exclusive project options. The option with the highest NPV is the preferred option.

*Equation 82: Net present value*

$$NPV = \sum_{i=1}^{n} \frac{(B_i - C_i}{(1+r)^i}$$

Where:

- $B_i$ = net annual benefits
- R = discount rate
- $C_i$ = net annual costs

*Example: Net present value*

If the discounted total benefits are assumed to be \$70 million and the discounted total costs are assumed to be \$50 million, the NPV is:

$$NPV = \$70m - \$50m$$

$$NPV = \$20m$$

This result indicates that there has been a welfare improvement of \$20 million in net terms as a result of this project.

## 9.4 First year rate of return

FYRR measures the economic return of a project in the first year of operation. FYRR is defined as the ratio of benefits in the first year divided by the capital costs of a project (including operating costs). If the FYRR is below the project discount rate, deferral of the project may be warranted to maximise the net economic gain.

*Equation 83: First year rate of return*

$$FYRR = \frac{B_{t_f}}{(1+r)^{t_f}} \Big/ \sum_{t=1}^{t_f-1} \frac{C_i}{(1+r)^t}$$

Where:

- $B_{tf}$ = net benefits in the first year of operation
- $C_i$ = net capital costs

*Example: First year rate of return*

Using the 6% discount rate, if the first year net benefits of a project are $2 million and the discounted total cost is $50 million, then the FYRR is:

$$FYRR = \$2m/\$50m$$

$$FYRR = 4\%$$

## 9.5 Incremental benefit-cost ratio

IBCR is generally used in options analysis.

*Equation 84: Incremental benefit-cost ratio*

$$IBCR = \frac{\sum_{i=1}^{n} \frac{Ba_i}{(1+r)^i} - \sum_{i=1}^{n} \frac{Bb_i}{(1+r)^i}}{\sum_{i=1}^{n} \frac{Ka_i + ICa_i}{(1+r)^i} - \sum_{i=1}^{n} \frac{Kb_i + ICb_i}{(1+r)^i}}$$

Where:

- $Ka_i$ and $Kb_i$ = capital costs for option A and option B respectively
- $ICa_i$ and $ICb_i$ = investment costs for option A and option B respectively

*Example: Incremental benefit-cost ratio*

IBCR compares the incremental benefits and costs of project option A to those of option B.

Discounted net benefits are assumed to be $70 million and $30 million for options A and B respectively, while the discounted net costs are assumed to be $50 million and $25 million for options A and B respectively. The IBCR is given by:

$$IBCR = (70 - 30)/(50 - 25)$$

$$IBCR = \frac{40}{25}$$

$$IBCR = 1.6$$

In this example project option A is preferred over option B. Every additional dollar spent on option A increases the net benefits of a project by $1.60.

## 9.6 Net present value per dollar investment

The NPVI, also known as the capital efficiency ratio, is the NPV of a project divided by the net capital cost of a project.

*Equation 85: Net present value per dollar investment*

$$NPVperDollarInvestment = \sum_{i=1}^{n} \frac{(B_i - C_i)}{(1+r)^i} \Big/ \sum_{i=1}^{n} \frac{C_i}{(1+r)^i}$$

Where:

- Bi = net annual benefits
- Ci = net annual cost

*Example: Net present value per dollar investment*

If the discounted net benefit of a project is $70 million and the discounted net cost is $50 million, the NPVI is:

$$NPVperDollarInvestment = (\$70m - \$50m)/\$50m$$

$$NPVperDollarInvestment = 0.4$$

The NPVI of 0.4 means that for each dollar invested, a contribution of $0.4 is made to a project's NPV.

## 9.7 Residual value

As mentioned in Section 2.3.3 of the *Theoretical Guide*, there are occasions where capital assets have a useful life beyond the life of the evaluation. To account for the benefit that the asset returns beyond the evaluation period, a residual value is calculated and applied in the last year of the evaluation as a negative cost.

The remaining life of the asset/project at the end of the analysis period should be expressed as a proportion of the total asset life. Multiplying the capital cost of a project by the proportion of remaining asset life to total asset life is one method of calculating the residual value of the asset. This value is then discounted in the final year of the evaluation.

*Equation 86: Residual value*

$$ResidualValue = \frac{YearsRemain}{UsefulLife} \times K$$

Where:

- YearsRemain = useful remaining life of the project (years)

*Example: Residual value*

The residual value of a $100 million project with a useful life of 50 years over a 30-year analysis period is:

$$ResidualValue = \frac{20}{50} \times \$100m$$
$$ResidualValue = \$40m$$

The result implies that additional benefits to the value of $40 million will accrue to a project beyond the evaluation.


## 10 Sensitivity testing

This section outlines the calculations used in sensitivity testing presented in the ‘road case report’ within CBA6. For further information on the ‘road case report’ see Section 4.6 of the *User Guide*. For further detail on the assumptions of sensitivity analysis, see Section 1.8.3 of the *Theoretical Guide*.

The standard sensitivity analysis in CBA6 recalculates BCR, NPV and FYRR subject to the following changes in inputs:

- capital costs ± 20%
- TTC ± 40%
- VOC ± 20%
- accident costs ±20%
- exclude private travel time costs.

Sensitivity testing shown in these sections is based on the following 'best estimate' assumptions:

- cost = $50 million
- capital costs = $40 million
- operating costs = $10 million
- benefits = $70 million
- TTC savings = $40 million
- private TTC savings = $1 million
- VOC savings = $20 million
- accident savings = $10 million
- first year benefits = $2 million
- discount rate = 4%.

Under these assumptions of benefits and costs the BCR is 1.4, the NPV is $20 million and the FYRR is 4%.

## 10.1 Net present value

There are a number of key project inputs that can influence the NPV when they are subjected to some variability. These inputs have been described in Section 10.1.1.

### 10.1.1 Changes in capital cost

*Equation 87: Changes in capital cost (NPV)*

$$NPV = \sum_{i=1}^{n} \frac{B_i - C_i \times (1 \pm \Delta B)}{(1+r)^i}$$

Where:

- NPV = net present value
- $B_i$ = total discounted benefits
- $C_i$ = total discounted costs
- ΔB = the percentage change in capital cost determined in the sensitivity analysis

*Example: Changes in capital cost (NPV)*

When the capital cost of a project, with discounted net benefits of $70 million and discounted net costs of $50 million, increases by 20%, the NPV is calculated as follows:

$$NPV = 70 - (40 \times 1.2) - 10$$

$$NPV = 70 - 58$$

$$NPV = \$12$$

Positive NPV indicates that despite the capital cost increase of 20% the project is still viable.



### 10.1.2 Changes in road user cost savings

The impact that changes in TTC, VOC and accident cost savings have on the NPV is shown by Equation 88.

*Equation 88: Changes in benefits (NPV)*

$$NPV = \sum_{i=1}^{n} \frac{(B_{ru} \times (1 \pm \Delta A) + B_{oi} - C_i}{(1+r)^i}$$

Where:

- $B_{ru}$ = road user cost savings (TTC, VOC or Acc)
- ΔA = the percentage change in $B_{ru}$ determined in the sensitivity analysis
- $B_{oi}$ = benefits other than $B_{ru}$

*Example: Changes in benefits (NPV)*

If TTC increase by 40%, all other benefits and costs remain unchanged at $20 million for VOC benefits, $10 million for accident cost savings and $50 million for costs. The resulting NPV is:

$$NPV = (40 * 1.40) + (20 + 10) - 50$$

$$NPV = \$36\ million$$

The NPV has increased from $20 million under the normal scenario to $36 million when TTC savings are increased by 40%. This is an increase in NPV of 80% compared to the best estimate. In this example, the NPV is very sensitive to changes in TTC savings.

### 10.1.3 Excluding private travel time costs

The impact that removal of private TTC savings has on NPV is calculated by Equation 89.

*Equation 89: Excluding private TTC (NPV)*

$$NPV = \sum_{i=1}^{n} \frac{(B_i - PTTC_i - C_i)}{(1+r)^i}$$

Where:

- $PTTC_i$ = private travel time costs

*Example: Excluding private TTC (NPV)*

If a project has discounted net benefits of $70 million, the private TTC component of that net benefit is $1 million, and the net cost of the project is $50 million, then the NPV excluding private travel time is:

$$NPV = 70 - 1 - 50$$

$$NPV = \$19\ million$$

Given the small amount of private TTC savings as a proportion of total benefits in this case, the change in NPV is not very sensitive to percentage changes in private TTC savings.

## 10.2 Benefit-cost ratio

The derivation of BCR throughout the sensitivity analysis is shown in Sections 10.2.1 to 10.2.3.

### 10.2.1 Changes in capital cost

The impact of a change in capital cost on the BCR is given by Equation 90.

*Equation 90: Changes in capital cost (BCR)*

$$BCR = \sum_{i=1}^{n} \frac{B_i}{(1+r)^i} \Bigg/ \sum_{i=1}^{n} \frac{K_i \times (1 \pm \Delta B) + OC_i}{(1+r)^i}$$

Where:

- $K_i$ = capital costs
- $OC_i$ = net operating costs

*Example: Changes in capital cost (BCR)*

With a 20% increase in capital cost with discounted net benefits of $70 million, discounted net capital cost of $40 million, and a discounted net operating cost of $10 million, the BCR is:

$$BCR = 70/(40 \times 1.20) + 10$$

$$BCR = \frac{70}{58}$$

$$BCR = 1.21$$

In this example, the BCR has decreased from 1.4 to 1.21 demonstrating that the project is not economically viable if capital cost was to increase by 20%.

Note: The BCR must be greater than 1 to justify the investment.



### 10.2.2 Changes in road user cost savings

The impact of a change in road user cost savings on the BCR is given by Equation 91.

*Equation 91: Changes in road user cost savings (BCR)*

$$BCR = \sum_{i=1}^{n} \frac{B_{ru} \times (1 \pm \Delta A) + B_{oi}}{(1+r)^i} \Bigg/ \sum_{i=1}^{n} \frac{K_i + OC_i}{(1+r)^i}$$

Where:

- $B_{ru}$ = road user cost savings (TTC, VOC or Acc)
- $B_{oi}$ = benefits other than $B_{ru}$
- $\Delta A$ = percentage change in $B_{ru}$ determined in the sensitivity analysis
- $K_i$ = capital costs

- $OC_i$ = operating costs

*Example: Changes in road user cost savings (BCR)*

Where TTC savings increase by 40%, discounted net investment costs are $50 million, VOC benefits are $20 million and crash costs are $10 million, the BCR is:

$$BCR = \big((40 \times 1.4) + (20 + 10)\big)/50$$

$$BCR = 1.72$$

The BCR of the project has changed from 1.4 to 1.72, an increase of 22% from the 'best estimate' as a result of a 40% increase in TTC savings.

### 10.2.3 Excluding private travel time costs

The removal of private TTC on the BCR is given by Equation 91.

*Equation 92: Excluding private travel time costs (BCR)*

$$BCR = \sum_{i=1}^{n} \frac{B_i - PTTC_i}{(1+r)^i} \Bigg/ \sum_{i=1}^{n} \frac{K_i + OC_i}{(1+r)^i}$$

Where:

- $PTTC_i$ = private travel time costs

*Example: Excluding private travel time costs (BCR)*

A project has discounted net benefits of $70 million, the private TTC component of that net benefit is $1 million, and the net cost of the project is $50 million. The BCR excluding private TTC is:

$$BCR = (70 - 1)/50$$

$$BCR = 1.38$$

The BCR is reduced by 0.02 as a result of the escalating private TTC.

Note: The change in BCR is relatively small given the low proportion of private TTC savings.

## 10.3 First year rate of return

The derivation of FYRR sensitivity analysis is calculated through Sections 10.3.1 to 10.3.3.

### 10.3.1 Changes in capital cost

A change in capital cost on FYRR is shown by Equation 93.

*Equation 93: Changes in capital cost (FYRR)*

$$FYRR = \frac{B_{t\,f}}{(1+r)^{t_f}} \Bigg/ \sum_{t=1}^{t_{f-1}} \frac{C_i \times (1 \pm \Delta B)}{(1+r)^t}$$

Where:

- $B_{tf}$ = total first year benefits
- $\Delta$B = the percentage change in capital cost determined in the sensitivity analysis

*Example: Changes in capital cost (FYRR)*

A 20% increase in the capital costs of a project with discounted first year benefits of $2 million, discounted net capital cost of $40 million, and a discounted net operating cost of $10 million, produces an FYRR of:

$$FYRR = 2/(40 \times 1.2) + 10$$

$$FYRR = \frac{2}{58}$$

$$FYRR = 3.45\%$$

The 20% increase in capital cost lowers the FYRR from 4% to 3.45%.



### 10.3.2 Changes in road user cost savings

The impact that a change in road user cost savings has on FYRR is given by Equation 94.

*Equation 94: Changes in benefits (FYRR)*

$$FYRR = \frac{B_{RU\,f} \times (1 \pm \Delta A) + B_{t0\,f}}{(1+r)^{t_f}} \Bigg/ \sum_{t=1}^{t_{f-1}} \frac{C_i}{(1+r)^t}$$

Where:

- $B_{ruf}$ = first year of road user cost savings
- $\Delta$A = the percentage change in $B_{ruf}$ determined in the sensitivity analysis
- $B_{t0f}$ = benefits other than $B_{ruf}$

If first year TTC benefits increase by 40%, the FYRR becomes:

$$FYRR = (1 * 1.40) + (0.5 + 0.5)/50$$

$FYRR = 4.8\%$

A 40% increase in road user cost savings in the first year increases the FYRR from 4% to 4.8%.

### 10.3.3 Excluding private travel time costs

The impact that removal of private TTC has on the FYRR is given by Equation 95.

*Equation 95: Excluding private travel time costs (FYRR)*

$$FYRR = \frac{B_{t_f} - PTTC_{t_f}}{(1+r)^{t_f}} \Big/ \sum_{t=1}^{t_{f-1}} \frac{C_i}{(1+r)^t}$$

Where:

$PTTC_{tf}$ = first year private TTC savings

*Example: Excluding private travel time costs (FYRR)*

A given project has discounted first year net benefits of $2 million, a private TTC component of that net benefit of $0.1 million, and a net cost of $50 million. If private TTC savings are excluded the FYRR is:

$FYRR = (2 - 0.1)/50$

$FYRR = 3.8\%$

The removal of private TTC savings in the first year decreases the FYRR from 4% to 3.8%; this is below the cut off level at 4%.


## 11 Effects of intermediate outputs

This section outlines the key relationships between intermediate outputs such as road roughness and speed, and the outputs of VOC and TTC.

*Table 43: Input and output relationships*

| Input | Intermediary output | Output |
|---|---|---|
| Speed/roughness | Fuel | VOC |
| | Tyres | VOC |
| | Oil | VOC |
| | Interest and depreciation | VOC |
| | Repairs and maintenance | VOC |
| | Travel time | TTC |

This analysis will examine the effects of changes in the intermediate outputs such as speed and roughness on the final outputs.

## 11.1 Vehicle operating costs

Table 44 shows the effects of a change in operating speed and current roughness on the outputs. This comparison differs with vehicle types, however it provides a general guide as to trends of output change, holding all other inputs constant.

Importantly, this example compares changes to a 'base case' as described in the examples throughout Section 4 i.e. a single B-Double travelling at 64.49 km/h on a curvy flat road with a VCR of 0.049.

As illustrated by Table 44, changes made in the intermediate outputs of speed and roughness have a significant effect on VOC in CBA6. When these costs are combined over multiple vehicle types and lengthy sections of motorway, their impacts become large in monetary terms.

*Table 44: Sensitivity testing of VOC components in respect to changes in intermediate outputs (B-doubles)*

| Outputs (c/km) | Base case | Intermediate output change | | | |
|---|---|---|---|---|---|
| | | Change in speed | | Change in roughness | |
| | 64.49km/h/ 120NRM | 40km/h | 85km/h | 30NRM | 200NRM |
| Fuel | 95.72 | 113.04 | 95.42 | 81.26 | 99.42 |
| Oil | 1.71 | 1.60 | 1.80 | 1.71 | 1.71 |
| Tyres | 49.58 | 47.00 | 52.60 | 49.58 | 49.58 |
| Repairs and maintenance | 24.93 | 24.93 | 24.93 | 20.60 | 29.87 |
| Interest and depreciation | 54.42 | 58.04 | 52.99 | 54.42 | 54.42 |
| Total VOC unit cost | 226.36 | 244.61 | 227.74 | 207.57 | 235.00 |

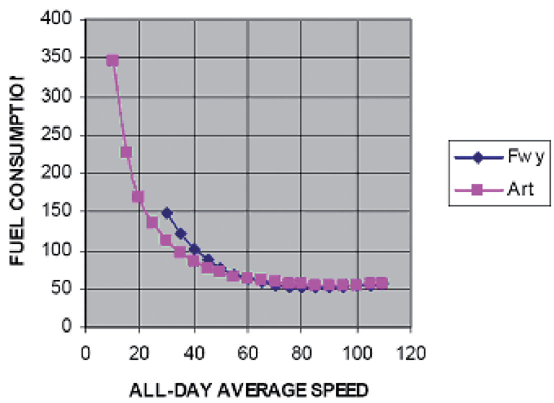
There are two important points to be noted from this comparison.

1 Table 44 illustrates trends in the calculation of fuel costs with regard to changes in roughness and speed. Fuel consumption and speed do not have a linear relationship. Moreover, fuel consumption reaches an efficiency frontier, when a marginal increase in speed produces an increase in fuel consumption. This trend is illustrated by Figure 12.

2 Fuel costs are sensitive to changes in road roughness. This point is based on the fuel consumption roughness adjustment (Equation 21) which becomes a proportionately larger adjustment as roughness increases (all other things being equal). Oil costs however, are only affected by speed and not by roughness. This is a result of Equation 25, which is derived solely on changes in speed. Similarly, the results in Table 44 show that interest and depreciation and tyre costs are based solely on changes in speed. This is a result of the net interest and depreciation equation (Equation 37), which includes operating speed to derive the final cost. However, changes in operating speed in the interest and depreciation calculation have a relatively small influence on the final unit VOC. The impact of changes in speed on tyre costs are greater and are a result of the roughness adjustment and the basic tyre wear equation (Equation 27).

It is important to note that changes in roughness do not affect tyre wear or tyre costs. The inclusion of a ‘roughness adjustment’ based on speed is the result of the assumption that lower operating speeds should reflect rough surface conditions.

*Figure 12: Fuel consumption (B-Double)*



## 11.2 Travel time

The impact of speed on travel time is intuitive. The following calculation shows TTC for the road user.

*Equation 96: Trip time*

$$TripTime(VT) = \frac{SecLength}{OS(VT)}$$

As calculated in Section 5, trip time (hours) is then applied to vehicle cost per hour, which is reflective of the driver's time (for private vehicles), business costs and freight carried (commercial vehicles where appropriate).

Changes in road roughness have no effect on TTC, unless the vehicle's operating speed is also affected by the change in roughness. TTC are based purely on changes in operating speed.

*Example: Trip time*

A section length of a rural road remains constant at 5 km and a B-Double is travelling at 85 km/h. The time it takes for the B-Double to complete its journey is:

$$TripTime(VT) = \frac{5}{85} = 0.059hrs$$

Applying this trip time to the hourly time unit rate for a B-Double ($48.40 from Table 23) yields TTC of $2.86. Assuming that the B-Double travels the same section length at a speed of 45 km/h, TTC increase to $5.38. When operating speed decreases by 53%, TTC increase by 88%. There is an inverse relationship between the change in speed and the change in TTC.


# Appendices

5

# Appendix A: Case study input data

## Maintenance

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | State strategic | State strategic |
| | Region | Darling Downs | Darling Downs |
| | Zone | Dry non-reactive | Dry non-reactive |
| | Evaluation period | 30 | 30 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 8 | 8 |
| | Section length | 2 km | 2 km |
| | Initial roughness | 80 NRM | 80 NRM |
| | Safe operating speed | 80 km/h | 80 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 2500 | 2500 |
| | Traffic growth rate | 2% linear | 2% linear |
| | Cars – private | 73% | 73% |
| | Cars – commercial | 5% | 5% |
| | Non-articulated | 5% | 5% |
| | Buses | 0% | 0% |
| | Articulated | 5% | 5% |
| | B-double | 8% | 8% |
| | Road train 1 | 3% | 3% |
| | Road train 2 | 1% | 1% |
| Capital and maintenance costs | Capital | 0 | 0 |
| | Routine maintenance costs | $10 000 yearly | $10 000 yearly |
| | Periodic maintenance costs | $500 000 in years 5, 10, 15, 20, 25 and 29 | $500 000 in years 6 and 28 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | 0 | $2 000 000 in year 12 |
| | Roughness after rehabilitation | NA | 50 NRM |
| | Residual value | 0 | 0 |

## Road widening without shoulder seal

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | North Coast | North Coast |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 7 | 10 |
| | Section length | 2 km | 2 km |
| | Initial roughness | 100 NRM | 50 NRM |
| | Safe operating speed | 80 km/h | 80 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Curvy | Curvy |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 3000 | 3000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 84% | 84% |
| | Cars – commercial | 10% | 10% |
| | Non-articulated | 2% | 2% |
| | Buses | 0% | 0% |
| | Articulated | 2% | 2% |
| | B-double | 2% | 2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $2 500 000 |
| | Routine maintenance costs | $10 000 yearly | $10 000 yearly excluding year 1 |
| | Periodic maintenance costs | $500 000 in years 7, 21 and 28 | $500 000 in years 10, 17 and 24 |
| | Reduction in toughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | $1 000 000 in year 14 | 0 |
| | Roughness after rehabilitation | 80 NRM | NA |
| | Residual value | 0 | 0 |

## Road widening with shoulder seal

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | North Coast | North Coast |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 7 | 11 |
| | Section length | 2 km | 2 km |
| | Initial roughness | 100 NRM | 50 NRM |
| | Safe operating speed | 80 km/h | 80 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Curvy | Curvy |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 3000 | 3000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 84% | 84% |
| | Cars – commercial | 10% | 10% |
| | Non-articulated | 2% | 2% |
| | Buses | 0% | 0% |
| | Articulated | 2% | 2% |
| | B-double | 2% | 2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $2 800 000 |
| | Routine maintenance costs | $10 000 yearly | $10 000 yearly excluding year 1 |
| | Periodic maintenance costs | $500 000 in years 7, 21 and 28 | $500 000 in years 10, 17 and 24 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | $1 000 000 in year 14 | 0 |
| | Roughness after rehabilitation | 80 NRM | NA |
| | Residual value | 0 | 0 |

## Realignment

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | Central West | Central West |
| | Zone | Dry reactive | Dry reactive |
| | Evaluation period | 32 | 32 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 12 | 12 |
| | Section length | 2.5 km | 2.3 km |
| | Initial roughness | 100 NRM | 60 NRM |
| | Safe operating speed | 80 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Curvy | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT Year 1 | 5000 | 5000 |
| | Traffic growth rate | 4% compound | 4% compound |
| | Cars – private | 85% | 85% |
| | Cars – commercial | 5% | 5% |
| | Non-articulated | 4% | 4% |
| | Buses | 2% | 2% |
| | Articulated | 2% | 2% |
| | B-double | 2% | 2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $2 000 000 year 1 and $6 000 000 year 2 |
| | Routine maintenance costs | $50 000 yearly | $45 000 yearly |
| | Periodic maintenance costs | $550 000 in years 7, 21 and 28 | $545 000 in years 9, 23 and 30 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | $2 000 000 in year 14 | $1 950 000 in year 16 |
| | Roughness after rehabilitation | 50 NRM | 50 NRM |
| | Residual value | 0 | 0 |

## Single overtaking lane

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | National network | National network |
| | Region | Northern | Northern |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 7% | 7% |
| | Speed environment | Rural | Rural |
| | Advanced option selected | Overtaking lane (single) | Overtaking lane (single) |
| Road details | MRS | 12 | 16 |
| | Section length | 2 km | 2 km |
| | Initial roughness | 80 NRM | 60 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 4545 | 4545 |
| | Traffic growth rate | 2% compound | 2% compound |
| | Cars – private | 80% | 80% |
| | Cars – commercial | 5% | 5% |
| | Non-articulated | 4% | 4% |
| | Buses | 2% | 2% |
| | Articulated | 2% | 2% |
| | B-double | 7% | 7% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | | $3 000 000 |
| | Routine maintenance costs | $2000 yearly | $3000 yearly |
| | Periodic maintenance costs | $20 000 in years 7, 12, 17, 22 and 27 | $30 000 in years 7, 12, 17, 22 and 27 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | 0 | 0 |
| | Roughness after rehabilitation | NA | NA |
| | Residual value | 0 | 0 |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Downstream area details | MRS | 12 | 12 |
| | Section length | 5 km | 5 km |
| | Initial roughness | 80 NRM | 80 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |

## Head-to-head overtaking lanes

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | National network | National network |
| | Region | Northern | Northern |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 7% | 7% |
| | Speed environment | Rural | Rural |
| | Advanced option selected | Overtaking lane (head to head) | Overtaking lane (head to head) |
| Road details | MRS | 12 | 16 |
| | Section length | 4 km | 4 km |
| | Initial roughness | 80 NRM | 60 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 4545 | 4545 |
| | Traffic growth rate | 2% compound | 2% compound |
| | Cars – private | 80% | 80% |
| | Cars – commercial | 5% | 5% |
| | Non-articulated | 4% | 4% |
| | Buses | 2% | 2% |
| | Articulated | 2% | 2% |
| | B-double | 7% | 7% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | | $6 000 000 |
| | Routine maintenance costs | $4000 yearly | $6000 yearly excluding year 1 |
| | Periodic maintenance costs | $40 000 in years 7, 12, 17, 22 and 27 | $60 000 in years 7, 12, 17, 22 and 27 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | 0 | 0 |
| | Roughness after rehabilitation | NA | NA |
| | Residual value | 0 | 0 |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Downstream area details | MRS | 12 | 12 |
| | Section length | 10 km | 10 km |
| | Initial roughness | 80 NRM | 80 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |

## Side-by-side overtaking lanes

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | National network | National network |
| | Region | Northern | Northern |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 7% | 7% |
| | Speed environment | Rural | Rural |
| | Advanced option selected | Overtaking lane (side by side) | Overtaking lane (side by side) |
| Road details | MRS | 12 | 17 |
| | Section length | 2 km | 2 km |
| | Initial roughness | 80 NRM | 60 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 4545 | 4545 |
| | Traffic growth rate | 2% compound | 2% compound |
| | Cars – private | 80% | 80% |
| | Cars – commercial | 5% | 5% |
| | Non-articulated | 4% | 4% |
| | Buses | 2% | 2% |
| | Articulated | 2% | 2% |
| | B-double | 7% | 7% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | | $5 500 000 |
| | Routine maintenance costs | $4000 yearly | $6000 yearly excluding year 1 |
| | Periodic maintenance costs | $40 000 in years 7, 12, 17, 22 and 27 | $60 000 in years 7, 12, 17, 22 and 27 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | 0 | 0 |
| | Roughness after rehabilitation | NA | NA |
| | Residual value | 0 | 0 |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Downstream area details | MRS | 12 | 12 |
| | Section length | 10 km | 10 km |
| | Initial roughness | 80 NRM | 80 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |

## Flood immunity

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | State strategic | State strategic |
| | Region | Fitzroy | Fitzroy |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 33 | 33 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| | Advanced option selected | Road closure and diverting route | Road closure and diverting route |
| Road details | MRS | 10 | 15 |
| | Section length | 1 km | 1 km |
| | Initial roughness | 80 NRM | 50 NRM |
| | Safe operating speed | 80 km/h | 80 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Very curvy | Straight |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| Road traffic data | AADT year 1 | 8000 | 8000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 67% | 67% |
| | Cars – commercial | 20% | 20% |
| | Non-articulated | 0% | 0% |
| | Buses | 1% | 1% |
| | Articulated | 3% | 3% |
| | B-double | 9% | 9% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| | Average annual time of closure (AATOC) | 14 hours | 0 hours |
| Road closure details | Average duration of closure (ADC) | 56 hours | 10 |
| | % of traffic not travelling | 0% | 0% |
| | % of traffic waiting | 10% | 20% |
| | % of traffic diverting | 90% | 80% |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Capital and maintenance costs | Capital | | \$3 000 000 in year 1 and<br>\$7 000 000 in year 2 |
| | Routine maintenance costs | \$13 000 yearly | \$15 000 yearly excluding years 1 and 2 |
| | Periodic maintenance costs | \$300 000 in years 7, 21 and 28 | \$320 000 in years 10, 15, 20 and 30 |
| | Reduction in roughness from periodic maintenance | 10 NRM each time | 10 NRM each time |
| | Rehabilitation | \$5 000 000 in year 14 | \$0 |
| | Roughness after rehabilitation | 60 NRM | NA |
| | Residual value | | \$7 000 000 |
| | **Diverting route details** | **Base case** | **Project case** |
| | MRS | 9 | 9 |
| | Road class | Regional | Regional |
| | Roughness | 60 NRM | 60 NRM |
| | Safe operating speed | 60 km/h | 60 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Curvy | Curvy |
| | Vertical alignment | Rolling or undulating | Rolling or undulating |
| | Existing traffic on route | 1200 | 1200 |
| | Length of alternate route (C) | 15 km | 15 km |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road traffic data | AADT year 1 | 8400 | 8400 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 67% | 67% |
| | Cars – commercial | 20% | 20% |
| | Non-articulated | 0% | 0% |
| | Buses | 1% | 1% |
| | Articulated | 3% | 3% |
| | B-double | 9% | 9% |
| | Road train type 1 | 0% | 0% |
| | Road train type 2 | 0% | 0% |
| | Improved route case | | |
| | Improved route details | | |
| | MRS | 10 | 10 |
| | Road class | State strategic | State strategic |
| | Roughness | 60 NRM | 60 NRM |
| | Safe operating speed | 80 km/h | 80 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Curvy | Curvy |
| | Vertical alignment | Level or flat | Level or flat |
| | Length of improved route (B) | 10 km | 10 km |

## Road closure

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | Central West | Central West |
| | Zone | Dry non-reactive | Dry non-reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| | Advance option selected | Road closure | Road closure |
| Road details | MRS | 10 | 10 |
| | Section length | 1 | 1 |
| | Initial roughness | 110 NRM | 60 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 500 | 500 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 42% | 42% |
| | Cars – commercial | 10% | 10% |
| | Non-articulated | 5% | 5% |
| | Buses | 0% | 0% |
| | Articulated | 3% | 3% |
| | B-double | 12% | 12% |
| | Road train 1 | 8% | 8% |
| | Road train 2 | 20% | 20% |
| | Road closure details | | |
| | Average annual time of closure (AATOC) | 12 | 0 |
| | Average duration of closure (ADC) | 12 | 0 |
| | % of traffic not travelling | 0% | 0% |
| | % of traffic waiting | 100% | 0% |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Capital and maintenance costs | Capital | | $800 000 |
| | Routine maintenance costs | | |
| | Periodic maintenance costs | | |
| | Reduction in roughness from periodic maintenance | | |
| | Rehabilitation | $1000 yearly excluding years 1 and 31 | $1000 yearly excluding years 1 and 31 |
| | Roughness after rehabilitation | 110 NRM | 60 NRM |
| | Residual value | 0 | 0 |

## Intersection

| Screen | Inputs | Base int case | | Project int case | |
|---|---|---|---|---|---|
| Create new evaluation | Road class | Regional | | Regional | |
| | Region | South Coast | | South Coast | |
| | Zone | Wet non-reactive | | Wet non-reactive | |
| | Evaluation period | 11 | | 11 | |
| | Discount rate | 6% | | 6% | |
| | Speed environment | Urban | | Urban | |
| | Advance option selected | New intersection evaluation | | New intersection evaluation | |
| Intersection data (include at least 2 years data for each case) | Morning peak | Year 1 | Year 11 | Year 1 | Year 11 |
| | Duration of period (hours) | 1 | 1 | 1 | 1 |
| | Number of vehicles (per hour) | 2203 | 2646 | 2203 | 2646 |
| | Average delay (in seconds/period) | 28.2 | 181.1 | 4.4 | 56.9 |
| | Fuel consumption (litres/hour) | 152.7 | 335.3 | 122.5 | 235.5 |
| | Afternoon peak | Year 1 | Year 11 | Year 1 | Year 11 |
| | Duration of period (hours) | 1 | 1 | 1 | 1 |
| | Number of vehicles (per hour) | 2361 | 2835 | 2361 | 2835 |
| | Average delay (in seconds/period) | 36.3 | 327 | 3.7 | 6.7 |
| | Fuel consumption (litres/hour) | 161.8 | 503.4 | 126.7 | 172.2 |
| | Cars – private | 93% | 93% | 93% | 93% |
| | Cars – commercial | 5% | 5% | 5% | 5% |
| | Non-articulated | 1% | 1% | 1% | 1% |
| | Buses | 1% | 1% | 1% | 1% |
| | Articulated | 0% | 0% | 0% | 0% |
| | B-double | 0% | 0% | 0% | 0% |
| | Road train 1 | 0% | 0% | 0% | 0% |
| | Road train 2 | 0% | 0% | 0% | 0% |
| Intersection capital and maintenance costs | Capital | | $1 500 000 | | |
| | Maintenance and operations | $2000 yearly | $15 000 yearly excluding year 1 | | |
| | Residual value | | | | |
| Accident and other costs | Accident costs | $50 000 yearly | $25 000 yearly | | |

## Duplication

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | National network | National network |
| | Region | Far North | Far North |
| | Zone | Wet reactive | Wet reactive |
| | Evaluation period | 32 | 32 |
| | Discount rate | 7% | 7% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 13 | 19 |
| | Section length | 3 km | 3 km |
| | Initial roughness | 75 NRM | 50 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Rigid |
| | Surface type | Sprayed surface seal | Asphaltic concrete |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 12 000 | 12 000 |
| | Traffic growth rate | 5% linear | 5% linear |
| | Cars – private | 77% | 77% |
| | Cars – commercial | 12% | 12% |
| | Non-articulated | 5% | 5% |
| | Buses | 1% | 1% |
| | Articulated | 3% | 3% |
| | B-double | 2% | 2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $2 000 000 year 1 and $49 000 000 year 2 |
| | Routine maintenance costs | $30 000 yearly | $75 000 yearly excluding years 1 and 2 |
| | Periodic maintenance costs | $500 000 in years 5, 10, 20, 25 and 30 | $1 200 000 in years 10, 17, 24 and 31 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | $2 000 000 in year 15 | 0 |
| | Roughness after rehabilitation | 75 NRM | NA |
| | Residual value | 0 | 0 |

## Bypass

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | State strategic | State strategic |
| | Region | Fitzroy | Fitzroy |
| | Zone | Dry non-reactive | Dry non-reactive |
| | Evaluation period | 32 | 32 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| | Advance option selected | Bypass | Bypass |
| Road details | MRS | 1 | 15 |
| | Section length | 7 km | 7 km |
| | Initial roughness | 200 NRM | 50 NRM |
| | Safe operating speed | 0 km/h | 100 km/h |
| | Pavement type | Unpaved | Flexible |
| | Surface type | Unsurfaced | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 0 | 2000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 100% | 76% |
| | Cars – commercial | 0% | 13% |
| | Non-articulated | 0% | 5% |
| | Buses | 0% | 1% |
| | Articulated | 0% | 2% |
| | B-double | 0% | 3% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $10 000 000 year 1 and $50 000 000 year 2 |
| | Routine maintenance costs | $50 000 yearly | $20 000 yearly excluding years 1 and 2 |
| | Periodic maintenance costs | $0 | $1 000 000 in years 8, 15 and 29 |
| | Reduction in roughness from periodic maintenance | NA | 5 NRM each time |
| | Rehabilitation | $0 | $3 000 000 in year 22 |
| | Roughness after rehabilitation | NA | 50 NRM |
| | Residual value | 0 | 0 |

## Existing section 1

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 1 km | 1 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 4000 | 2000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 88.0% |
| | Cars – commercial | 11.0% | 9.0% |
| | Non-articulated | 3.3% | 1.6% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.2% |
| | B-double | 1.6% | 0.2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Existing section 2

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 4 km | 4 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 8000 | 6000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 84.1% |
| | Cars – commercial | 11.0% | 10.3% |
| | Non-articulated | 3.3% | 2.7% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.8% |
| | B-double | 1.6% | 1.1% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Existing section 3

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 4 km | 4 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 8000 | 6000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 84.1% |
| | Cars – commercial | 11.0% | 10.3% |
| | Non-articulated | 3.3% | 2.7% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.8% |
| | B-double | 1.6% | 1.1% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Existing section 4

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 1 km | 1 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 4000 | 2000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 88.0% |
| | Cars – commercial | 11.0% | 9.0% |
| | Non-articulated | 3.3% | 1.6% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.2% |
| | B-double | 1.6% | 0.2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Unsealed road

| Screen | Inputs | Base case | | Project case | |
|---|---|---|---|---|---|
| Create new evaluation | Road class | District | | District | |
| | Region | Far North | | Far North | |
| | Zone | Dry non-reactive | | Dry non-reactive | |
| | Evaluation period | 31 | | 31 | |
| | Discount rate | 6% | | 6% | |
| | Speed environment | Rural | | Rural | |
| | Advance option selected | Livestock | | Livestock | |
| Road details | MRS | 1 | | 7 | |
| | Section length | 12 km | | 12 km | |
| | Initial roughness | 200 NRM | | 75 NRM | |
| | Safe operating speed | 70 km/h | | 100 km/h | |
| | Pavement type | Unpaved | | Flexible | |
| | Surface type | Unsurfaced | | Sprayed surface seal | |
| | Horizontal alignment | Straight | | Straight | |
| | Vertical alignment | Level or flat | | Level or flat | |
| Road traffic data | AADT year 1 | 125 | | 125 | |
| | Traffic growth rate | 1% linear | | 1% linear | |
| | Cars – private | 55% | | 55% | |
| | Cars – commercial | 5% | | 5% | |
| | Non-articulated | 3% | | 3% | |
| | Buses | 0% | | 0% | |
| | Articulated/ livestock | 6% | 50% | 6% | 50% |
| | B-double/livestock | 14% | 50% | 14% | 50% |
| | Road train 1/ livestock | 0% | 0% | 0% | 0% |
| | Road train 2/ livestock | 17% | 100% | 17% | 100% |

| Screen | Inputs | Base case | Project case |
| --- | --- | --- | --- |
| Capital and maintenance costs | Capital | | $6 000 000 |
| | Routine maintenance costs | $20 000 yearly | $25 000 yearly excluding year 1 |
| | Periodic maintenance costs | 0 | $250 000 in years 7, 14, 21 and 28 |
| | Reduction in roughness from periodic maintenance | NA | 5 NRM each time |
| | Rehabilitation | 0 | 0 |
| | Roughness after rehabilitation | NA | NA |
| | Residual value | 0 | 0 |

## Generated traffic

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | Mackay/Whitsunday | Mackay/Whitsunday |
| | Zone | Wet reactive | Wet reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | Advanced option selected | Generated traffic | Generated traffic |
| | MRS | 6 | 15 |
| | Section length | 25 km | 20 km |
| | Initial roughness | 100 NRM | 65 NRM |
| | Safe operating speed | 60 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Curvy | Straight |
| | Vertical alignment | Mountainous | Rolling or undulating |
| Road traffic data | AADT year 1 | 1750 | 1750 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 95% | 95% |
| | Cars – commercial | 0% | 0% |
| | Non-articulated | 5% | 5% |
| | Buses | 0% | 0% |
| | Articulated | 0% | 0% |
| | B-double | 0% | 0% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $120 000 000 |
| | Routine maintenance costs | $50 000 yearly | $40 000 yearly |
| | Periodic maintenance costs | $600 000 in years 5, 10, 20, 25 and 30 | $400 000 in years 7 and 14 and $500 000 in year 27 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | $7 000 000 in year 15 | $5 000 000 in year 21 |
| | Roughness after rehabilitation | 70 NRM | 70 NRM |
| | Residual value | 0 | 0 |

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Generated traffic – road traffic data | AADT year 2 | 150 | 150 |
| | Traffic growth rate | 6% compound | 6% compound |
| | Cars – private | 100% | 100% |
| | Cars – commercial | 0% | 0% |
| | Non-articulated | 0% | 0% |
| | Buses | 0% | 0% |
| | Articulated | 0% | 0% |
| | B-double | 0% | 0% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Changes in multi-combination vehicle

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | Wide Bay/Burnett | Wide Bay/Burnett |
| | Zone | Wet reactive | Wet reactive |
| | Evaluation period | 31 | 31 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 8 | 13 |
| | Section length | 2 km | 2 km |
| | Initial roughness | 110 NRM | 60 NRM |
| | Safe operating speed | 100 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 515 | 491 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 48.9% | 51.4% |
| | Cars – commercial | 21.0% | 22.0% |
| | Non-articulated | 6.0% | 6.3% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 10.1% | 5.6% |
| | B-double | 1.0% | 1.2% |
| | Road train 1 | 12.0% | 7.5% |
| | Road train 2 | 0.0% | 5.0% |
| Capital and maintenance costs | Capital | 0 | $1 000 000 |
| | Routine maintenance costs | $5000 yearly | $10 000 yearly |
| | Periodic maintenance costs | $100 000 in years 7, 21 and 28 | $110 000 in years 7, 14 and 28 |
| | Reduction in roughness from periodic maintenance | 5 NRM each time | 5 NRM each time |
| | Rehabilitation | $700 000 in year 14 | $500 000 in year 21 |
| | Roughness after rehabilitation | 80 NRM | 60 NRM |
| | Residual value | 0 | 0 |

## Multiple project cases

| Screen | Inputs | Base case | Project case 1 | Project case 2 | Project case 3 |
|---|---|---|---|---|---|
| Create new evaluation | Road class | State strategic | State strategic | State strategic | State strategic |
| | Region | Metropolitan | Metropolitan | Metropolitan | Metropolitan |
| | Zone | Wet non-reactive | Wet non-reactive | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 32 | 32 | 32 | 32 |
| | Discount rate | 6% | 6% | 6% | 6% |
| | Speed environment | Rural | Rural | Rural | Rural |
| | Advanced option selected | Multiple project case | Multiple project case | Multiple project case | Multiple project case |
| Road details | MRS | 7 | 10 | 15 | 17 |
| | Section length | 5 km | 5 km | 5 km | 5 km |
| | Initial roughness | 120 NRM | 60 NRM | 60 NRM | 60 NRM |
| | Safe operating speed | 80 km/h | 80 km/h | 80 km/h | 100 km/h |
| | Pavement type | Flexible | Flexible | Flexible | Rigid |
| | Surface type | Sprayed surface seal | Sprayed surface seal | Sprayed surface seal | Asphaltic concrete |
| | Horizontal alignment | Straight | Straight | Straight | Straight |
| | Vertical alignment | Rolling undulating | Rolling undulating | Rolling undulating | Rolling undulating |
| Road traffic data | AADT year 1 | 10 000 | 10 000 | 10 000 | 10 000 |
| | Traffic growth rate | 3% linear | 3% linear | 3% linear | 3% linear |
| | Cars – private | 81% | 81% | 81% | 81% |
| | Cars – commercial | 8% | 8% | 8% | 8% |
| | Non-articulated | 5% | 5% | 5% | 5% |
| | Buses | 1% | 1% | 1% | 1% |
| | Articulated | 3% | 3% | 3% | 3% |
| | B-double | 2% | 2% | 2% | 2% |
| | Road train 1 | 0% | 0% | 0% | 0% |
| | Road train 2 | 0% | 0% | 0% | 0% |
| Capital and maintenance costs | Capital | | $2 000 000 year 1<br>$3 000 000 year 2 | $4 000 000 year 1<br>$6 000 000 year 2 | $8 000 000 year 1<br>$10 000 000 year2 |
| | Routine maintenance costs | $20 000 yearly | $22 000 yearly | $27 000 yearly | $35 000 yearly |
| | Periodic maintenance costs | $100 000 years 14, 21 and 28 | $125 000 years 9, 16 and 30 | $130 000 years 9, 16 and 30 | $200 000 years 9, 16 and 30 |
| | Reduction in Roughness | 5 NRM | 5 NRM | 5 NRM | 5 NRM |
| | Rehabilitation | $1 000 000 year 7 | $1 200 000 year 23 | $1 300 000 year 23 | $5 000 000 year 23 |
| | Roughness after rehabilitation | 80 NRM | 60 NRM | 60 NRM | 60 NRM |
| | Residual value | 0 | 0 | 0 | 0 |

# Incremental analysis (town bypass 2)

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | State strategic | State strategic |
| | Region | Fitzroy | Fitzroy |
| | Zone | Dry non-reactive | Dry non-reactive |
| | Evaluation period | 32 | 32 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| | Advance option selected | Bypass | Bypass |
| Road details | MRS | 1 | 17 |
| | Section length | 7 km | 7 km |
| | Initial roughness | 200 NRM | 50 NRM |
| | Safe operating speed | 0 km/h | 100 km/h |
| | Pavement type | Unpaved | Rigid |
| | Surface type | Unsurfaced | Asphaltic concrete |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 0 | 2000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 100% | 76% |
| | Cars – commercial | 0% | 13% |
| | Non-articulated | 0% | 5% |
| | Buses | 0% | 1% |
| | Articulated | 0% | 2% |
| | B-double | 0% | 3% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $10 000 000 year 1 and $70 000 000 year 2 |
| | Routine maintenance costs | $50 000 yearly | $20 000 yearly excluding years 1 and 2 |
| | Periodic maintenance costs | $0 | $1 000 000 in years 8, 15 and 29 |
| | Reduction in roughness from periodic maintenance | NA | 5 NRM each time |
| | Rehabilitation | $0 | $3 000 000 in year 22 |
| | Roughness after rehabilitation | NA | 50 NRM |
| | Residual value | 0 | 0 |

## Existing section 1

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 1 km | 1 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 4000 | 2000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 88.0% |
| | Cars – commercial | 11.0% | 9.0% |
| | Non-articulated | 3.3% | 1.6% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.2% |
| | B-double | 1.6% | 0.2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Existing section 2

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 4 km | 4 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 8000 | 6000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 84.1% |
| | Cars – commercial | 11.0% | 10.3% |
| | Non-articulated | 3.3% | 2.7% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.8% |
| | B-double | 1.6% | 1.1% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Existing section 3

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 4 km | 4 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 8000 | 6000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 84.1% |
| | Cars – commercial | 11.0% | 10.3% |
| | Non-articulated | 3.3% | 2.7% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.8% |
| | B-double | 1.6% | 1.1% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Existing section 4

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Road details | MRS | 9 | 9 |
| | Section length | 1 km | 1 km |
| | Initial roughness | 75 NRM | 75 NRM |
| | Safe operating speed | 40 km/h | 40 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 4000 | 2000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 82.0% | 88.0% |
| | Cars – commercial | 11.0% | 9.0% |
| | Non-articulated | 3.3% | 1.6% |
| | Buses | 1.0% | 1.0% |
| | Articulated | 1.1% | 0.2% |
| | B-double | 1.6% | 0.2% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |

## Linking analysis (arterial road)

| Screen | Inputs | Base case | Project case |
|---|---|---|---|
| Create new evaluation | Road class | Regional | Regional |
| | Region | South Coast | South Coast |
| | Zone | Wet non-reactive | Wet non-reactive |
| | Evaluation period | 11 | 11 |
| | Discount rate | 6% | 6% |
| | Speed environment | Rural | Rural |
| Road details | MRS | 10 | 13 |
| | Section length | 1 km | 1 km |
| | Initial roughness | 100 NRM | 50 NRM |
| | Safe operating speed | 60 km/h | 60 km/h |
| | Pavement type | Flexible | Flexible |
| | Surface type | Sprayed surface seal | Sprayed surface seal |
| | Horizontal alignment | Straight | Straight |
| | Vertical alignment | Level or flat | Level or flat |
| Road traffic data | AADT year 1 | 10 000 | 10 000 |
| | Traffic growth rate | 3% linear | 3% linear |
| | Cars – private | 93% | 93% |
| | Cars – commercial | 5% | 5% |
| | Non-articulated | 1% | 1% |
| | Buses | 1% | 1% |
| | Articulated | 0% | 0% |
| | B-double | 0% | 0% |
| | Road train 1 | 0% | 0% |
| | Road train 2 | 0% | 0% |
| Capital and maintenance costs | Capital | 0 | $2 500 000 |
| | Routine maintenance costs | $10 000 yearly | $20 000 yearly |
| | Periodic maintenance costs | 0 | $500 000 in year 8 |
| | Reduction in roughness from periodic maintenance | NA | 5 NRM each time |
| | Rehabilitation | $500 000 in year 7 | 0 |
| | Roughness after rehabilitation | 80 NRM | NA |
| | Residual value | 0 | $1 600 000 |


# Appendix B: CBA6 lookup tables

# Free speed array

*Table 1: Free speed array*

| Vehicle type | Road type* | Straight gradient 0–2% | Straight gradient 4% | Straight gradient 6% | Straight gradient 8% | Straight gradient 10% | Curvy gradient 0–2% | Curvy gradient 4% | Curvy gradient 6% | Curvy gradient 8% | Curvy gradient 10% | Very curvy gradient 0–2% | Very curvy gradient 4% | Very curvy gradient 6% | Very curvy gradient 8% | Very curvy gradient 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cars – private | <= 4.5 m | 83.0 | 82.0 | 76.0 | 66.0 | 56.0 | 77.0 | 76.0 | 72.0 | 64.0 | 55.0 | 69.0 | 68.0 | 66.0 | 60.0 | 53.0 |
| Cars – commercial | <= 4.5 m | 82.0 | 79.3 | 72.0 | 61.7 | 52.0 | 75.0 | 73.0 | 68.0 | 59.7 | 51.0 | 67.0 | 65.3 | 62.3 | 56.3 | 49.3 |
| Non-articulated | <= 4.5 m | 82.4 | 68.8 | 55.6 | 44.6 | 36.0 | 73.0 | 63.4 | 53.2 | 43.4 | 35.8 | 64.2 | 57.6 | 49.8 | 42.2 | 35.6 |
| Buses | <= 4.5 m | 86.0 | 72.0 | 57.0 | 45.0 | 37.0 | 77.0 | 67.0 | 55.0 | 45.0 | 37.0 | 67.0 | 61.0 | 53.0 | 44.0 | 36.0 |
| Articulated | <= 4.5 m | 86.0 | 49.0 | 39.0 | 32.0 | 24.0 | 71.0 | 45.0 | 38.0 | 32.0 | 24.0 | 59.0 | 41.0 | 36.0 | 31.0 | 24.0 |
| B-double | <= 4.5 m | 88.0 | 38.0 | 27.0 | 20.0 | 16.0 | 72.0 | 35.0 | 27.0 | 19.0 | 16.0 | 59.0 | 32.0 | 26.0 | 19.0 | 16.0 |
| Road train 1 | <= 4.5 m | 88.0 | 38.0 | 27.0 | 20.0 | 16.0 | 72.0 | 35.0 | 27.0 | 19.0 | 16.0 | 59.0 | 32.0 | 26.0 | 19.0 | 16.0 |
| Road train 2 | <= 4.5 m | 88.0 | 38.0 | 27.0 | 20.0 | 16.0 | 72.0 | 35.0 | 27.0 | 19.0 | 16.0 | 59.0 | 32.0 | 26.0 | 19.0 | 16.0 |
| Cars – private | > 4.5 m | 105.0 | 102.0 | 88.0 | 72.0 | 59.0 | 90.0 | 89.0 | 81.0 | 68.0 | 57.0 | 75.0 | 74.0 | 71.0 | 63.0 | 55.0 |
| Cars – commercial | > 4.5 m | 99.7 | 95.0 | 81.3 | 66.3 | 54.3 | 85.7 | 83.3 | 75.0 | 63.0 | 52.7 | 72.0 | 70.3 | 66.3 | 58.7 | 51.0 |
| Non-articulated | > 4.5 m | 93.8 | 74.2 | 58.0 | 45.4 | 36.2 | 79.8 | 67.2 | 55.0 | 44.2 | 36.0 | 67.2 | 60.2 | 51.4 | 42.8 | 35.8 |
| Buses | > 4.5 m | 100.0 | 78.0 | 59.0 | 46.0 | 37.0 | 85.0 | 71.0 | 57.0 | 45.0 | 37.0 | 70.0 | 63.0 | 54.0 | 44.0 | 36.0 |
| Articulated | > 4.5 m | 100.0 | 52.0 | 40.0 | 32.0 | 24.0 | 75.0 | 47.0 | 39.0 | 32.0 | 24.0 | 60.0 | 42.0 | 36.0 | 31.0 | 24.0 |
| B-double | > 4.5 m | 100.0 | 40.0 | 28.0 | 20.0 | 16.0 | 75.0 | 36.0 | 27.0 | 19.0 | 16.0 | 60.0 | 33.0 | 26.0 | 19.0 | 16.0 |
| Road train 1 | > 4.5 m | 100.0 | 40.0 | 28.0 | 20.0 | 16.0 | 75.0 | 36.0 | 27.0 | 19.0 | 16.0 | 60.0 | 33.0 | 26.0 | 19.0 | 16.0 |
| Road train 2 | > 4.5 m | 100.0 | 40.0 | 28.0 | 20.0 | 16.0 | 75.0 | 36.0 | 27.0 | 19.0 | 16.0 | 60.0 | 33.0 | 26.0 | 19.0 | 16.0 |
| Cars – private | Freeway | 110.0 | 106.0 | 90.0 | 72.0 | 59.0 | 93.0 | 90.0 | 82.0 | 69.0 | 58.0 | 76.0 | 75.0 | 71.0 | 63.0 | 55.0 |
| Cars – commercial | Freeway | 105.0 | 99.3 | 83.3 | 66.3 | 54.3 | 88.7 | 84.7 | 76.0 | 63.7 | 53.3 | 73.0 | 71.3 | 66.7 | 58.7 | 51.0 |
| Non-articulated | Freeway | 99.0 | 77.2 | 58.8 | 45.4 | 36.2 | 82.0 | 68.4 | 55.6 | 44.2 | 36.0 | 68.6 | 60.8 | 51.6 | 42.8 | 35.8 |
| Buses | Freeway | 110.0 | 82.0 | 60.0 | 46.0 | 37.0 | 89.0 | 73.0 | 58.0 | 46.0 | 37.0 | 72.0 | 64.0 | 54.0 | 44.0 | 37.0 |
| Articulated | Freeway | 106.0 | 53.0 | 40.0 | 32.0 | 24.0 | 77.0 | 47.0 | 39.0 | 32.0 | 24.0 | 60.0 | 42.0 | 36.0 | 31.0 | 24.0 |
| B-double | Freeway | 105.0 | 41.0 | 28.0 | 20.0 | 16.0 | 76.0 | 36.0 | 27.0 | 19.0 | 16.0 | 60.0 | 33.0 | 26.0 | 19.0 | 16.0 |
| Road train 1 | Freeway | 105.0 | 41.0 | 28.0 | 20.0 | 16.0 | 76.0 | 36.0 | 27.0 | 19.0 | 16.0 | 60.0 | 33.0 | 26.0 | 19.0 | 16.0 |
| Road train 2 | Freeway | 105.0 | 41.0 | 28.0 | 20.0 | 16.0 | 76.0 | 36.0 | 27.0 | 19.0 | 16.0 | 60.0 | 33.0 | 26.0 | 19.0 | 16.0 |

*Source: Austroads report bs.e.n.548 n.bs.9903 part 1, p. 12, Table 6.*



* Corresponds with model road states detailed at Appendix 6:

- < 4.5 m – model road state 1–5
- > 4.5 m – model road state 6–14, 16, 18
- Freeway – model road state 15, 17, 19.

## Pavement speed condition factor

*Table 2: FSRG1 pavement speed condition factor at 110 NRM*

| Vehicle type | Road type | Straight flat | Straight gradient 4% | Straight gradient 6% | Straight gradient 8% | Straight gradient 10% | Curvy flat | Curvy gradient 4% | Curvy gradient 6% | Curvy gradient 8% | Curvy gradient 10% | Very curvy flat | Very curvy gradient 4% | Very curvy gradient 6% | Very curvy gradient 8% | Very curvy gradient 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cars – private | < 4.5 m | 0.98 | 0.98 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 |
| Cars – commercial | < 4.5 m | 0.97 | 0.98 | 0.99 | 1.00 | 1.00 | 0.98 | 0.99 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 |
| Non-articulated | < 4.5 m | 0.95 | 0.97 | 0.98 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.98 | 0.98 | 0.99 | 0.99 | 1.00 |
| Buses | < 4.5 m | 0.97 | 0.98 | 0.99 | 1.00 | 1.00 | 0.98 | 0.99 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 |
| Articulated | < 4.5 m | 0.95 | 0.97 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| B-double | < 4.5 m | 0.94 | 0.97 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| Road train 1 | < 4.5 m | 0.94 | 0.97 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| Road train 2 | < 4.5 m | 0.94 | 0.97 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| Cars – private | > 4.5 m | 0.96 | 0.96 | 0.98 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 |
| Cars – commercial | > 4.5 m | 0.96 | 0.96 | 0.98 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 |
| Non-articulated | > 4.5 m | 0.93 | 0.96 | 0.98 | 0.99 | 1.00 | 0.96 | 0.97 | 0.98 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 |
| Buses | > 4.5 m | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 0.97 | 0.98 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 |
| Articulated | > 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| B-double | > 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| Road train 1 | > 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |
| Road train 2 | > 4.5 m | 0.91 | 0.96 | 0.99 | 0.99 | 1.00 | 0.97 | 0.98 | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 |

*Source: Adopted from Table 8, Austroads Publication AP-R264/05.*

*Table 3: FSRG22 pavement speed condition factor (PCSPDF) at 250 NRM*

| Vehicle type | Road type | Straight flat | Straight gradient 4% | Straight gradient 6% | Straight gradient 8% | Straight gradient 10% | Curvy flat | Curvy gradient 4% | Curvy gradient 6% | Curvy gradient 8% | Curvy gradient 10% | Very curvy flat | Very curvy gradient 4% | Very curvy gradient 6% | Very curvy gradient 8% | Very curvy gradient 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cars – private | < 4.5 m | 0.76 | 0.77 | 0.80 | 0.87 | 0.92 | 0.79 | 0.80 | 0.83 | 0.88 | 0.92 | 0.84 | 0.85 | 0.87 | 0.90 | 0.94 |
| Cars – commercial | < 4.5 m | 0.75 | 0.77 | 0.81 | 0.88 | 0.93 | 0.79 | 0.80 | 0.83 | 0.89 | 0.93 | 0.84 | 0.85 | 0.87 | 0.90 | 0.94 |
| Non-articulated | < 4.5 m | 0.68 | 0.76 | 0.84 | 0.91 | 0.95 | 0.74 | 0.79 | 0.86 | 0.91 | 0.95 | 0.79 | 0.83 | 0.87 | 0.92 | 0.95 |
| Buses | < 4.5 m | 0.74 | 0.81 | 0.89 | 0.95 | 0.97 | 0.79 | 0.84 | 0.90 | 0.95 | 0.97 | 0.85 | 0.87 | 0.91 | 0.95 | 0.97 |
| Articulated | < 4.5 m | 0.61 | 0.78 | 0.87 | 0.93 | 0.97 | 0.71 | 0.82 | 0.89 | 0.94 | 0.97 | 0.81 | 0.87 | 0.91 | 0.94 | 0.97 |
| B-double | < 4.5 m | 0.60 | 0.79 | 0.88 | 0.94 | 0.97 | 0.71 | 0.83 | 0.89 | 0.94 | 0.97 | 0.81 | 0.88 | 0.91 | 0.95 | 0.97 |
| Road train 1 | < 4.5 m | 0.60 | 0.79 | 0.88 | 0.94 | 0.97 | 0.71 | 0.83 | 0.89 | 0.94 | 0.97 | 0.81 | 0.88 | 0.91 | 0.95 | 0.97 |
| Road train 2 | < 4.5 m | 0.60 | 0.79 | 0.88 | 0.94 | 0.97 | 0.71 | 0.83 | 0.89 | 0.94 | 0.97 | 0.81 | 0.88 | 0.91 | 0.95 | 0.97 |
| Cars – private | > 4.5 m | 0.63 | 0.65 | 0.73 | 0.83 | 0.90 | 0.71 | 0.72 | 0.77 | 0.85 | 0.91 | 0.81 | 0.81 | 0.84 | 0.88 | 0.93 |
| Cars – commercial | > 4.5 m | 0.64 | 0.67 | 0.75 | 0.85 | 0.91 | 0.72 | 0.74 | 0.79 | 0.86 | 0.92 | 0.81 | 0.82 | 0.85 | 0.89 | 0.93 |
| Non-articulated | > 4.5 m | 0.62 | 0.71 | 0.83 | 0.90 | 0.95 | 0.70 | 0.77 | 0.85 | 0.91 | 0.95 | 0.77 | 0.82 | 0.87 | 0.92 | 0.95 |
| Buses | > 4.5 m | 0.65 | 0.76 | 0.88 | 0.94 | 0.97 | 0.75 | 0.81 | 0.89 | 0.95 | 0.97 | 0.83 | 0.86 | 0.91 | 0.95 | 0.97 |
| Articulated | > 4.5 m | 0.53 | 0.74 | 0.86 | 0.93 | 0.97 | 0.68 | 0.81 | 0.88 | 0.94 | 0.97 | 0.80 | 0.86 | 0.91 | 0.94 | 0.97 |
| B-double | > 4.5 m | 0.54 | 0.75 | 0.87 | 0.94 | 0.97 | 0.68 | 0.82 | 0.89 | 0.94 | 0.97 | 0.80 | 0.87 | 0.91 | 0.95 | 0.97 |
| Road train 1 | > 4.5 m | 0.54 | 0.75 | 0.87 | 0.94 | 0.97 | 0.68 | 0.82 | 0.89 | 0.94 | 0.97 | 0.80 | 0.87 | 0.91 | 0.95 | 0.97 |
| Road train 2 | > 4.5 m | 0.54 | 0.75 | 0.87 | 0.94 | 0.97 | 0.68 | 0.82 | 0.89 | 0.94 | 0.97 | 0.80 | 0.87 | 0.91 | 0.95 | 0.97 |

*Source: Adopted from Table 8, Austroads Publication AP-R264/05.*

# Fuel consumption gradient correction factors

*Table 4: Fuel consumption gradient correction factors*

| Vehicle type | Gradient | Speed description | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spd_01 | Spd_02 | Spd_03 | Spd_04 | Spd_05 | Spd_06 | Spd_07 | Spd_08 | Spd_09 | Spd_10 | Spd_11 | Spd_12 | Spd_13 |
| | | 8–15 km/h | 16–23 km/h | 24–31 km/h | 32–39 km/h | 40–47 km/h | 48–55 km/h | 56–63 km/h | 64–71 km/h | 72–79 km/h | 80–87 km/h | 88–95 km/h | 96–103 km/h | 104–112 km/h |
| Cars – private | 4% | 0.03 | 0.07 | 0.07 | 0.07 | 0.08 | 0.09 | 0.09 | 0.10 | 0.08 | 0.05 | 0.04 | 0.04 | 0.03 |
| Cars – commercial | 4% | 0.02 | 0.06 | 0.06 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
| Non-articulated | 4% | 0.06 | 0.09 | 0.08 | 0.08 | 0.11 | 0.16 | 0.25 | 0.22 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 |
| Buses | 4% | 0.08 | 0.11 | 0.10 | 0.13 | 0.20 | 0.26 | 0.39 | 0.52 | 0.42 | 0.29 | 0.19 | 0.10 | 0.00 |
| Articulated | 4% | 0.06 | 0.14 | 0.13 | 0.19 | 0.28 | 0.37 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| B-double | 4% | 0.06 | 0.15 | 0.15 | 0.22 | 0.31 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| Road train 1 | 4% | 0.07 | 0.16 | 0.15 | 0.19 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| Road train 2 | 4% | 0.16 | 0.17 | 0.13 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Cars – private | 6% | 0.04 | 0.11 | 0.10 | 0.11 | 0.12 | 0.14 | 0.17 | 0.19 | 0.16 | 0.12 | 0.11 | 0.10 | 0.08 |
| Cars – commercial | 6% | 0.04 | 0.09 | 0.09 | 0.09 | 0.10 | 0.11 | 0.12 | 0.14 | 0.11 | 0.09 | 0.08 | 0.08 | 0.07 |
| Non-articulated | 6% | 0.10 | 0.18 | 0.22 | 0.28 | 0.34 | 0.43 | 0.52 | 0.47 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| Buses | 6% | 0.15 | 0.24 | 0.32 | 0.42 | 0.54 | 0.65 | 0.83 | 0.98 | 0.84 | 0.70 | 0.57 | 0.45 | 0.32 |
| Articulated | 6% | 0.18 | 0.29 | 0.40 | 0.52 | 0.66 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| B-double | 6% | 0.10 | 0.30 | 0.42 | 0.54 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 |
| Road train 1 | 6% | 0.11 | 0.29 | 0.39 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Road train 2 | 6% | 0.39 | 0.29 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| Cars – private | 8% | 0.05 | 0.19 | 0.17 | 0.17 | 0.18 | 0.21 | 0.26 | 0.30 | 0.25 | 0.21 | 0.18 | 0.15 | 0.12 |
| Cars – commercial | 8% | 0.05 | 0.17 | 0.16 | 0.16 | 0.17 | 0.18 | 0.19 | 0.22 | 0.18 | 0.15 | 0.13 | 0.12 | 0.10 |
| Non-articulated | 8% | 0.19 | 0.39 | 0.47 | 0.55 | 0.62 | 0.68 | 0.70 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| Buses | 8% | 0.26 | 0.50 | 0.62 | 0.76 | 0.91 | 1.05 | 1.25 | 1.42 | 1.25 | 1.08 | 0.92 | 0.78 | 0.62 |
| Articulated | 8% | 0.33 | 0.60 | 0.75 | 0.90 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| B-double | 8% | 0.18 | 0.62 | 0.76 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 |
| Road train 1 | 8% | 0.21 | 0.61 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| Road train 2 | 8% | 0.60 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| Cars – private | 10% | 0.06 | 0.28 | 0.27 | 0.28 | 0.30 | 0.35 | 0.42 | 0.47 | 0.42 | 0.34 | 0.28 | 0.25 | 0.21 |
| Cars – commercial | 10% | 0.07 | 0.27 | 0.27 | 0.28 | 0.30 | 0.32 | 0.35 | 0.39 | 0.35 | 0.30 | 0.26 | 0.24 | 0.21 |
| Non-articulated | 10% | 0.30 | 0.61 | 0.72 | 0.83 | 0.89 | 0.93 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| Buses | 10% | 0.39 | 0.76 | 0.93 | 1.11 | 1.28 | 1.45 | 1.69 | 1.90 | 1.69 | 1.49 | 1.31 | 1.13 | 0.95 |
| Articulated | 10% | 0.47 | 0.90 | 1.08 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 |
| B-double | 10% | 0.27 | 0.93 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Road train 1 | 10% | 0.30 | 0.91 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| Road train 2 | 10% | 0.75 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

*Source: Adopted from Table 13, Austroads Publication AP-R264/05.*

## Fuel consumption roughness correction factors

*Table 5: Fuel consumption roughness correction factors*

| Vehicle type | Speed description | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spd_01 | Spd_02 | Spd_03 | Spd_04 | Spd_05 | Spd_06 | Spd_07 | Spd_08 | Spd_09 | Spd_10 | Spd_11 | Spd_12 | Spd_13 |
| | 8–15 km/h | 16–23 km/h | 24–31 km/h | 32–39 km/h | 40–47 km/h | 48–55 km/h | 56–63 km/h | 64–71 km/h | 72–79 km/h | 80–87 km/h | 88–95 km/h | 96–103 km/h | 104–112 km/h |
| Cars – private | 0.02 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| Cars – commercial | 0.03 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 |
| Non-articulated | 0.04 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.07 |
| Buses | 0.05 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.14 | 0.15 | 0.13 | 0.12 | 0.12 | 0.11 | 0.10 |
| Articulated | 0.03 | 0.10 | 0.11 | 0.13 | 0.14 | 0.16 | 0.18 | 0.19 | 0.19 | 0.17 | 0.16 | 0.15 | 0.13 |
| B-double | 0.05 | 0.10 | 0.12 | 0.14 | 0.16 | 0.17 | 0.19 | 0.20 | 0.20 | 0.22 | 0.19 | 0.18 | 0.17 |
| Road train 1 | 0.06 | 0.11 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.22 | 0.24 | 0.24 | 0.20 | 0.20 | 0.20 |
| Road train 2 | 0.06 | 0.12 | 0.14 | 0.15 | 0.17 | 0.20 | 0.23 | 0.27 | 0.22 | 0.26 | 0.23 | 0.23 | 0.21 |

*Source: Adopted from Austroads Publication AP-R264/05.*


# Appendix C: Improved route calculation

## Improved Route Calculation – CBA6

VOC and TTC are given as negative values for the improved route. This is intuitively incorrect, however the differences in values derived (benefits) are the same.

The formula used in CBA6 to derive VOC is shown in Equation 96.

*Equation 96: Total VOC*

$$TOTVOC_{VT} = SectionLength_{IR} \times (-AATOC \times \%D) \times AADT_i \times \frac{VOC_i}{100}$$

This formula is applied to both the base and project cases and can be written as in Equation 97 for the base case and Equation 98 for the project case.

*Equation 97: Total VOC base case*

$$TOTVOC_{VT} = SectionLength_{IR} \times (-AATOC_{BC} \times \%D_{BC}) \times AADT_i \times \frac{VOC_{BC}}{100}$$

*Equation 98: Total VOC base case*

$$TOTVOC_{VT} = SectionLength_{IR} \times (-AATOC_{PC} \times \%D_{PC}) \times AADT_i \times \frac{VOC_{PC}}{100}$$

If Equation 98 is subtracted from Equation 97, the benefits to the improved route can be derived by Equation 99.

*Equation 99: VOC benefits to improved route*

$$Ben_{\text{Im}\,p} = \frac{[(VOC_{BC} \times (-AATOC_{BC} \times (\%D_{BC}))) - (VOC_{PC} \times (-AATOC_{PC} \times (\%D_{PC})))] \times (AADT_i \times SectionLength_{IR})}{100}$$

The correct formulae to derive VOC for the base case (improved) and project case (improved) for the improved route are stated in Equation 100 and Equation 101 respectively. Benefits are derived when Equation 101 is subtracted from Equation 100. This derivation can be found in Equation 102.

*Equation 100: Correct formulae for total VOC base case*

$$TOTVOC_{VT} = SectionLength_{IR} \times (365.25 - AATOC_{BC} \times \%D_{BC}) \times AADT_i \times \frac{VOC_{BC}}{100}$$

*Equation 101: Correct formulae for total VOC project case*

$$TOTVOC_{VT} = SectionLength_{IR} \times (365.25 - AATOC_{PC} \times \%D_{PC}) \times AADT_i \times \frac{VOC_{PC}}{100}$$

*Equation 102: VOC benefits to improved route (correct)*

$$Ben_{\text{Im}\,p} = \frac{[(VOC_{BC} \times (365.25 - AATOC_{BC} \times (\%D_{BC}))) - (VOC_{PC} \times (365.25 - AATOC_{PC} \times (\%D_{PC})))] \times (AADT_i \times SectionLength_{IR})}{100}$$

Equation 102 can be rearranged as shown in Equation 103.

*Equation 103: Re-arranged VOC benefits to improved route*

$$Ben_{\mathrm{Im}\,p} = \frac{\left[\left(VOC_{BC} - VOC_{PC}\right) - \left((365.25 - AATOC_{BC} \times (\%D_{BC})) - (365.25 - AATOC_{PC} \times (\%D_{PC}))\right)\right] \times \left(AADT_i \times SectionLength_{IR}\right)}{100}$$

365.25 can be eliminated from the equation, hence Equation 104 is derived which is equal to Equation 99.

*Equation 104: Second re-arrangement of VOC benefits to improved route*

$$Ben_{\mathrm{Im}\,p} = \frac{\left[\left(VOC_{BC} \times (-AATOC_{BC} \times (\%D_{BC}))\right) - \left(VOC_{PC} \times (-AATOC_{PC} \times (\%D_{PC}))\right)\right] \times \left(AADT_i \times SectionLength_{IR}\right)}{100}$$

The same mathematical manipulation of TTC as VOC can be done. The benefits derived in CBA6 are correct even though the VOC and TTC for the improved route have been stated as negative values in the reports.

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# Appendix D: Casualty crash rates for major urban intersections

Table 6 shows major urban intersection casualty crash rates suitable for use within eastern Australia.

*Table 6: Estimated Crash Rates — Major Urban Intersections*

| | Major rural intersection casualty crash rates | Crashes per 106 vehicles entering |
|---|---|---|
| **Intersection stereotype** | Signalised | 0.16 |
| | Roundabout | 0.13 |
| **Freeway-arterial interchange** | Signalised | 0.1 |
| | Unsignalised | 0.11 |

*Source: Austroads AP-R184*

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# Appendix E: Heavy vehicle types

*Table 7: Austroads standard vehicle types*

| Vehicle types | Configuration | Maximum length (m) | Gcm (t) | Hml (t) |
|---|---|---|---|---|
| Semi-trailer | | 19 | 42.5 | 45.5 |
| Quad-axle semi-trailer | | 19 | 46.5 | 50 |
| B-double | | 26 | 62.5 | 68 |
| Type 1 road train (A-double) | | 36.5 | 79 | 85 |
| B-triple | | 36.5 | 82.5 | 90.5 |
| AB-triple | | 36.5 | 99 | 107.5 |
| Type 2 road train (A-triple) | | 53.5 | 115.5 | 124.5 |
| AAB-quad | | 53.5 | 142.5 | By special assessment |
| BAB-quad | | 53.5 | 119 | By special assessment |
| ABB-quad | | 53.5 | 119 | By special assessment |

*Mandy Haldane 2009, Comparison of Queensland freight vehicles.*

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# Appendix F: Roughness conversion

Equation 10 is the standard roughness conversion between two measures of road roughness, the NAASRA roughness measure (NRM) and the international roughness index (IRI). In CBA6, all IRI values should be converted to NRM for input.

*Equation 10: NRM to IRI conversion*

$$NRM = 26.49 \times IRI - 1.27$$

Where:

- $NRM = NAASRA\ roughness\ level$
- $IRA = International\ Roughness\ Index$

This conversion is also illustrated in Table 48.

*Table 48: Roughness conversion NRM–IRI and IRI–NRM*

| NRM | IRI |
|---|---|
| 30 | 1.18 |
| 40 | 1.56 |
| 50 | 1.94 |
| 60 | 2.31 |
| 70 | 2.69 |
| 80 | 3.07 |
| 90 | 3.45 |
| 100 | 3.82 |
| 110 | 4.20 |
| 120 | 4.58 |
| 130 | 4.96 |
| 140 | 5.33 |
| 150 | 5.71 |

| IRI | NRM |
|---|---|
| 1.0 | 25 |
| 1.5 | 38 |
| 2.0 | 52 |
| 2.5 | 65 |
| 3.0 | 78 |
| 3.5 | 91 |
| 4.0 | 105 |
| 4.5 | 118 |
| 5.0 | 131 |
| 5.5 | 144 |
| 6.0 | 158 |
| 6.5 | 171 |
| 7.0 | 184 |


# Appendix G: CBA6 model road state categories

*Table 9: Model Road State*

| Carriageway | Surface | Model road state | Road width description |
|---|---|---|---|
| Undivided | Natural surface | 1 | Unsealed natural surface |
| | Formed roads | 2 | Unsealed formed road |
| | Gravel | 3 | Paved < 4.5 m |
| | | 4 | Paved >= 4.5 m |
| | Sealed | 5 | Narrow seal <= 4.5 m |
| | | 6 | Narrow seal 4.6 m–5.2 m |
| | | 7 | 2 lane seal 5.3 m–5.8 m |
| | | 8 | 2 lane seal 5.9 m–6.4 m |
| | | 9 | 2 lane seal 6.5 m–7.0 m |
| | | 10 | 2 lane seal 7.1 m–7.6 m |
| | | 11 | 2 lane plus shoulder seal 7.7 m–8.2 m |
| | | 12 | 2 lane plus shoulder seal 8.3 m–9.0 m |
| | | 13 | 2 lane plus shoulder seal 9.1 m–9.4 m |
| | | 14 | 2 lane plus shoulder seal 9.5 m–10 m |
| | | 15 | 2 lane plus shoulder seal 10.1 m–11.6 m |
| | | 16 | 3 lane for overtaking |
| | | 17 | 4 lane undivided sealed |
| | | 18 | 6 lane undivided sealed |
| Divided | Sealed | 19 | 4 lane divided sealed |
| | | 20 | 6 lane divided sealed |
| | | 21 | 4 lane divided (limited access) |
| | | 22 | 6 lane divided (limited access) |
| | | 23 | 8 lane divided (limited access) |

*Source: Adapted from Austroads 2005, page 22.*

# 5

## Glossary

This glossary defines concepts that are unique to CBA, as well as important or frequently used terms found in the manual.

Definitions have been derived from, and are complementary to, the glossary in Volume 3 of the ATC Guidelines (2006).

**Average annual daily traffic (AADT):** The total number of trips passing a point on a road in a year divided by the number of days in a year.

**ARRB Group Ltd (ARRB):** A national organisation that focuses on addressing transport policy and other related issues through high quality road safety, road construction and maintenance practices.

**Australian Transport Council (ATC):** A ministerial forum represented by commonwealth, state and territory transport ministers that advises government on the issues of coordination and integration of transport and road policies at a national level.

**Austroads:** An association of Australian and New Zealand road transport authorities that aims to improve road transport outcomes.

**Base case:** Represents the state of the world in absence of the proposed initiative. The base case is the benchmark that the project case is compared to.

**Base year:** Is the year to which all values are discounted when determining a present value. It is usually the year in which the analysis has been undertaken.

**Benefit-cost analysis (BCA):** A technique used to assess the economic efficiency of resource allocation by quantifying the costs and benefits of a proposed initiative. BCA and CBA are used interchangeably.

**Benefit-cost ratio (BCR):** The ratio of the present value of economic benefits to the present value of economic costs of a proposed initiative.

**Benefit:** A quantified positive impact due to the implementation of a project.

**Bypass:** A permanent re-routing of traffic, for instance around a mountain or a town.

**Capacity factor:** The factor which represents the proportion of daily traffic in peak periods.

**Compound growth:** See *Technical Guide*.

**Congestion adjustment:** Is a factor that adjusts the speed of the fleet relative to the effects of the congested road.

**Consumer surplus:** Is the difference between the amount the consumer is willing to pay for a good or service and the amount the consumer actually pays.

**Copy to clipboard:** A CBA6 feature which allows the user to transfer the data on the selected screen to another application such as Microsoft Excel.

**Corrected free speed:** The calculated vehicle speed accounting for various road characteristics including roughness.

**Cross elasticity of demand:** Measures the responsiveness of the quantity of demand of a particular product or service to a change in the price of another product or service.

**Decision criteria:** Decision criteria are the conditions a project is required to meet to be considered viable, and encompass an objective series of rules regarding whether to reject or to proceed with a proposed project.

**Depreciation:** The amount that an asset reduces in value over one year, due to wear and tear or environmental factors.

**Discounting:** The process of converting multiple cash flows that occur in different years to a common year or in present value terms.

**Discounted cash flow:** Present value of future cash flows generated by a project.

**Diversion:** A temporary re-route of traffic onto an alternative existing route, e.g. due to flooding or rock fall.

**Disbenefit:** A negative economic outcome due to the implementation of a project.

**Externality:** An effect that one party has on another that is not transmitted through market transactions. An example is noise pollution from vehicles; those operating the vehicles disturb other parties such as nearby residents, but a market transaction between these parties is absent (Page 219, Volume 5, ATC Guidelines).

**Existing route:** The existing route in a bypass is the section of road which will be bypassed and represents the base case.

**Ex-post evaluation:** (Post Completion Evaluation) A review of a completed set of actions to determine whether the desired forecast ends have been realised, and to explain the reasons for the outcomes.

**Free speed:** Free speed represents the average speed of a vehicle and is related to the vehicle type, MRS, and vertical and horizontal alignment.

**First year rate of return (FYRR):** Represents benefits minus operating costs in the first full year of operation of an initiative, divided by the present value of the investment costs, expressed as a percentage. The first year rate of return is used to determine the optimum timing of initiatives.

**Generated traffic:** Freight or passenger traffic that has been induced by an initiative, that is the new traffic would not exist but for the initiative, e.g. an unsealed track being sealed generating new traffic to a beach village.

**Gradient adjustment:** An adjustment factor added to a value to account for changes in the gradient of the road. The adjustment factor varies by vehicle type and by the road gradient.

**Highway Demand Management (HDM-4):** A road investment analysis tool that was initially developed by the world bank.

**Hourly capacity:** Refers to the maximum amount of vehicles per hour a given road type can accommodate.

**Incremental benefit-cost ratio (IBCR):** The IBCR is the present value of additional costs when going from one size or standard to the next. It is used to select between mutually exclusive options (Page 89, Volume 5, ATC Guidelines).

**Improved route:** Refers to the road which is being upgraded, from the start of the diversion to where the diverting route rejoins the upgraded route.

**Inputs:** Inputs refer to entered information within CBA6 which is used to calculate the final inputs and includes roughness and speed.

**Intermediary output:** Refers to those calculations in CBA6 which are used to calculate the final outputs from the inputs and includes fuel, tyres, oil, repairs, operating speed, travel time and vehicle operating costs.

**Linear growth:** See *Technical Guide*.

**Model road state (MRS):** Refers to the 23 categories of road types.

**Million vehicle kilometres travelled (MVKT):** Refers to distance travelled over a one year period.

**Multi-combination vehicle:** All articulated combinations of vehicles exceeding 19 m in length or 42.5 tonne gross mass, including B-doubles, road trains and truck-trailer combinations.

**NAASRA Improved Model for Project Assessment and Costing (NIMPAC):** NIMPAC is an economic model first developed by NAASRA in the 1980s to determine the effects of changes in vehicle limits on Australian roads.

**National Association of Australian State Road Authorities (NAASRA):** The predecessor of Austroads.

**Network effects:** Effects/impacts that occur on the wider road network as a result of the proposed initiative.

**Network cost-benefit analysis (network CBA):** Is a cost-benefit analysis which identifies and incorporates effects in the wider road network as a result of the impact of the proposed initiative.

**Net present value (NPV):** Net Present Value is the present value of benefits accruing from a project minus the present value of operating costs.

**Operating speed:** A prediction on the average speed each vehicle type will travel on a road when adjustments are made for congestion and the road characteristics.

**Opportunity costs:** The value foregone by society from using a resource in its next best alternative use.

**Outputs:** Outputs of the cost-benefit analysis model including the road user cost results and decision criteria.

**Passenger car equivalents (PCE):** Used to calculate traffic volume. PCE factors exist for each vehicle type.

**Price year:** The year in which prices prevailing are used in a cost-benefit analysis for the valuation of the costs and benefits over the life of a project. This is usually the base year.

**Present value:** The current value of a future cashflow or series of future cashflows, discounted to reflect the time value of money.

**Producer surplus:** The difference between the amount that a producer receives from the sale of goods and the lowest amount that a producer is willing to accept for those goods.

**Real prices:** Prices that have been adjusted to remove the effects of inflation. They apply for a particular base year, e.g. 2004 dollars (Page 221, Volume 5, ATC Guidelines).

**Residual value:** The value of an asset at the end of the evaluation period.

**Roughness:** A measure of the unevenness of a road surface. It is reported as either NAASRA Roughness Measurement (NRM) or International Roughness Index (IRI). NRM can be reliably converted to IRI by a linear equation, and vice versa, where required.

**Road user costs (RUC):** The costs of operating vehicles on roads, including time costs. Crash costs may or may not be included.

**Sensitivity analysis:** Changing a variable, or a number of variables, in a model to discover how it affects the model's outputs.

**SIDRA:** An advanced micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models for intersection simulation. SIDRA output is a key input to CBA6.

**Transport and Main Roads (TMR):** The Queensland Government department incorporating the former departments Queensland Transport and Main Roads.

**Travel time costs (TTC):** Represents the economic value of time taken to travel for road users. Travel time is a key output of a road project evaluation.

**Vehicle volume capacity ratio (VCR):** A measure of the level of congestion on a road given the traffic volume on road capacity.

**Vehicle operating costs (VOC):** The costs of operating a vehicle, including fuel, oil, tyres and repairs and maintenance costs.

# 5

## References

The sources used to research and write the *Cost-benefit analysis manual* include a range of state and national standard project appraisal literature and other related publications.

Australian Transport Council (2006), *National Guidelines for Transport System Management in Australia Volume 1-5:* Canberra, ACT.

Austroads (1996), *Benefit Cost Analysis Manual*, Austroads Publications AP-42/96, Sydney, New South Wales.

Austroads (2005), *Economic Evaluation of Road Investment Proposals: Harmonisation of Non-Urban Road User Cost Models*, Austroads Publications AP-R264, Sydney, New South Wales.

Austroads (2005), *Guide to Project Evaluation Part 2: Project Evaluation Methodology*, Austroads Publications AGPE02/05, Sydney, New South Wales.

Austroads (2008), *Guide to Project Evaluation Part 4: Project Evaluation Data*, Austroads Publications AGPE04/08, Sydney, New South Wales.

Bannock, G. (2003) *Dictionary of Business*, (Economist Series), Profile Books, London.

Bray, D (2007), *Economic Appraisal of Urban Transport Projects*, Economic and Policy Services Pty Ltd, Brisbane, Queensland.

Bray, DJ and Wallis, I (1999), *Public Transport Costs in Adelaide: Assessment and Implications*, paper presented to 21st Australian Transport Research Forum, Perth, Western Australia.

Bureau of Transport and Regional Economics (2007), *Ex-post economic evaluation of National Highway projects – Case study 1: Wallaville Bridge*, Working paper 70.1, Commonwealth of Australia, Canberra, Australian Capital Territory.

Campbell, HF and Brown, RB (2003), *Benefit-cost analysis: financial and economic appraisal using spreadsheets*, Cambridge University Press, Cambridge, United States.

Department of Finance and Administration (2006), *Handbook of Cost-Benefit Analysis*, Commonwealth of Australia, Canberra, Australian Capital Territory.

Dixon, PB; Parmenter, BR (1994), *Computable general equilibrium modelling*, Monash University Centre of Policy Studies and IMPACT Project, Clayton, Victoria.

*Estimating the Economic Impacts of Investment in Roads*, (1999) A Modelling Approach, (An internal DMR document)

Land Transport New Zealand (2008), *Economic Evaluation Manual Volume 1*, New Zealand Transport Agency, Wellington, New Zealand.

Queensland Department of Infrastructure and Planning (2010), *Project Assurance Framework*, Brisbane, Queenlsand, viewed 19 February 2010, <http://www.dip.qld.gov.au/processes-frameworks/project-assurance-framework.html>.

Perkins, F (1994), *Practical Cost Benefit Analysis*, Macmillan, South Melbourne, Victoria.

Renne, JL (2005), *Transit Orientated Development: Measuring benefits, analysing trends, and evaluating policy*, Rutgers State University, New Jersey, United States.

Roads and Traffic Authority (1999), *Economic Analysis Manual Volume 2*, Roads and Traffic Authority, Sydney, New South Wales.

Sinden, J.A. and Thampapillai, D.J (1995), *Introduction to Benefit-Cost Analysis*, Longman Australia Pty Ltd, Melbourne, Australia.

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