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

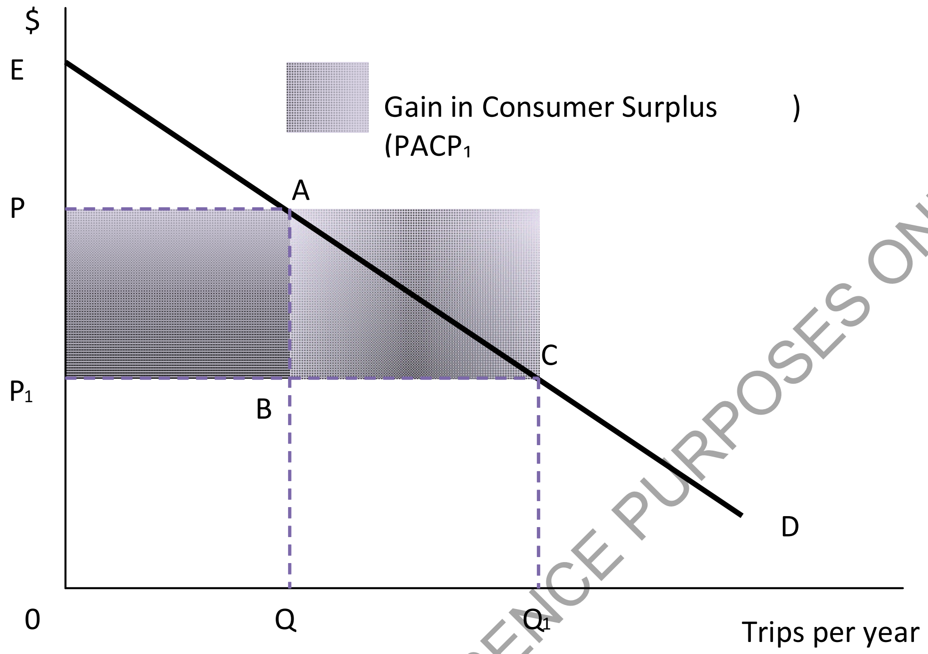
The theory of consumer surplus is based on an individual's willingness to pay for particular goods or services. It provides a link between individual preferences through consumer behaviour theory.

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 P1. Consumer Q has therefore achieved a satisfaction surplus of {P-P1}. This consumer has valued the goods or services at P, but only had to pay P1 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-P1-C when the price is P1.

In the event that the price level was originally P, and is subsequently reduced to P1, the increase in consumer surplus can be measured as the area P-A-C-P1 (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 P1. Road users at Q now experience a cost reduction of P1-P. The aggregate benefit to these users can be measured by (P1-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.

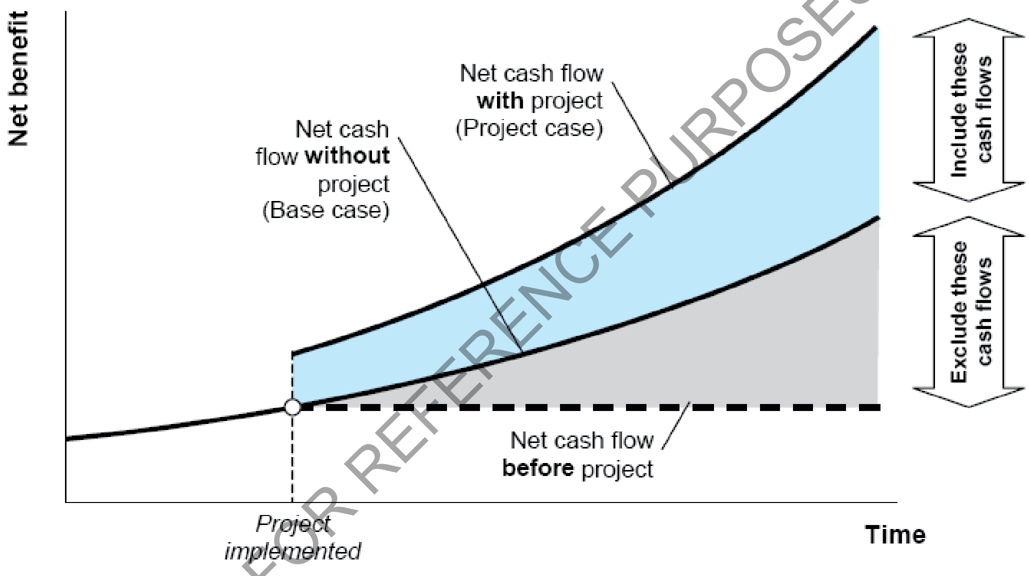
1.6 Definition of cases

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].

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[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.

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[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'.

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[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*.

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[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.

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.

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[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.

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[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.

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[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].

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[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.