TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

M2 - Roads

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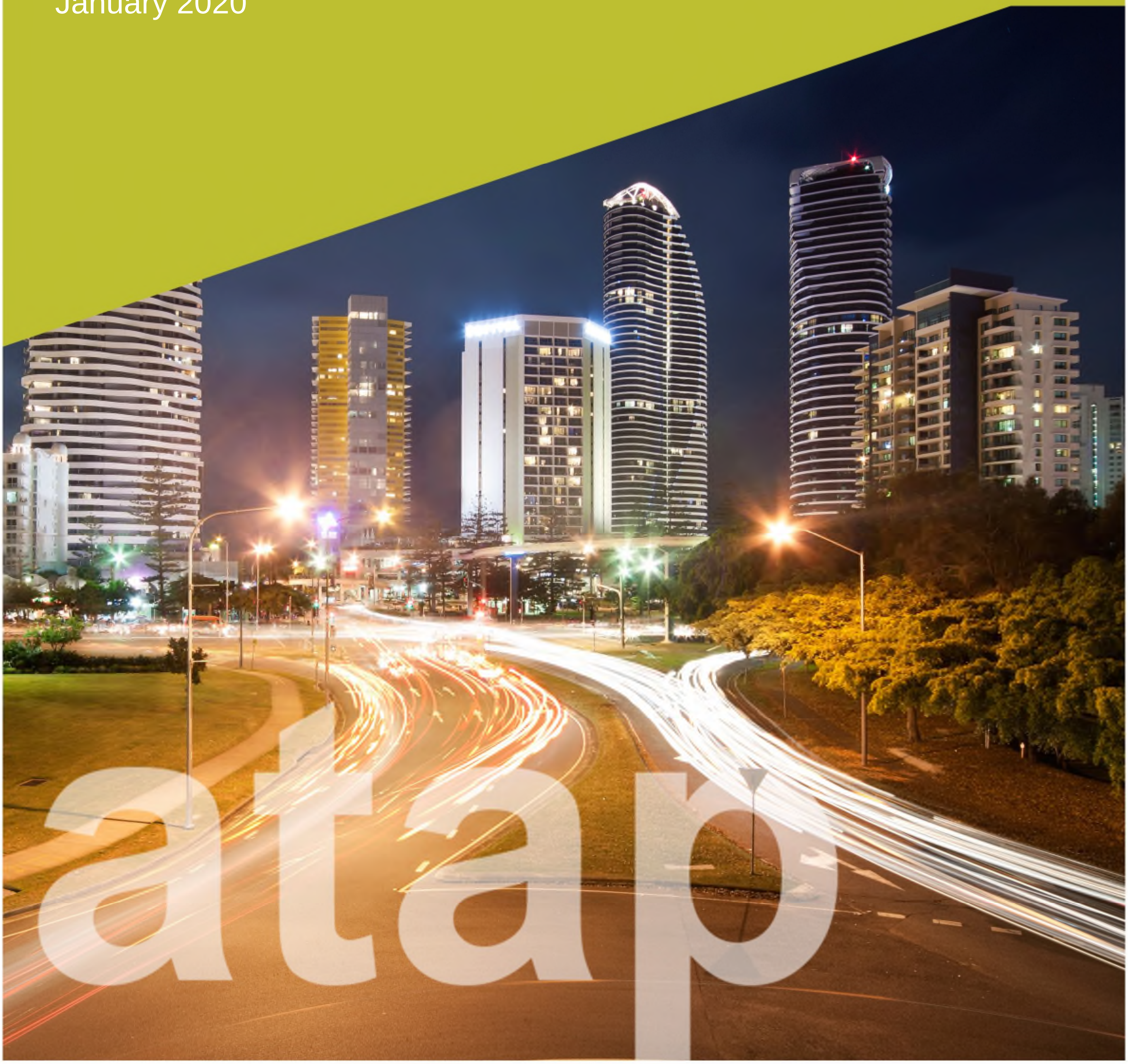

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At a glance

- This mode specific guidance - Roads - outlines methodologies for the assessment of road initiatives in urban and rural areas. The guidance supplements the general methodology guidance provided elsewhere in ATAP, in particular Parts F1, F2, F3, T2 and PV2.
- The differences between urban and rural settings results in some important differences in methodologies for assessing initiatives in each, particularly in the estimation of user benefits.
- Evidence-based problem assessment is the starting point for considering transport system improvements. For roads (Chapter 2), problems are largely associated with two groups of effects: the user costs (travel time and vehicle operating costs) experienced by road users; and the external effects of roads (environmental and safety impacts).
- A wide range of options need to be generated and assessed (Chapter 4). The options must focus on the problem(s) being addressed. It is critical that initiatives are clearly specified and that any key relationships between initiatives are identified. Initiatives can be independent, complementary or substitutable, with the latter two being more likely in urban areas where network effects are stronger.
- The quality of travel demand estimates (Chapter 5) is critical to effective appraisal. Base–year traffic volume, forecast growth and traffic composition all influence benefit estimates. The appraisal of urban initiatives will typically be supported by the outputs of a travel demand model that forecasts trips between origins and destinations by transport mode, and traffic volumes on each link in the network. Close collaboration is required between the appraiser and the demand modeller. Induced demand is a factor in urban networks but can be relevant also to rural initiatives. For rural initiatives, appraisers are much more likely to make their own traffic forecasts using the various methods discussed here.
- As with all cost–benefit analysis (CBA, Chapter 6), correct specification of the Base Case and Project Case is critical in the appraisal of road initiatives. Sensitivity testing allows the robustness of the assessment results to be checked
- Three benefit categories apply in road appraisals (Chapter 7), changes in: consumer surplus (with any required resource corrections); producer surplus, and; third party external effects. User costs and external costs on society (crashes, environmental impact) are estimated for each year of the appraisal period, with the incremental change providing the basis for estimating the benefits of the initiative.
- In the estimation of benefits for urban road initiatives (Chapter 8), transport/traffic models play a central role. A hierarchy of demand models (strategic, mesoscopic, microscopic) are used individually or in combination depending on the scale and type of initiative. Close collaboration is required between the appraiser and the demand modeller.
- In the estimation of benefits for rural road initiatives (Chapter 9), rural road user models play a central role.
- Road infrastructure costs (Chapter 10) are of two types: capital costs (typically up-front) and recurrent costs (maintenance and operating). Estimates of these need to be established for each year of the appraisal period for the Base Case and the Project Case, with the incremental change included in the CBA. ATAP Part O1 provides guidance on capital cost estimation. Road initiatives can impact maintenance costs in all ways (neutral, increase or decrease) depending on the initiative.
- Measurement and monitoring of performance (Chapter 11) assess whether transport system objectives are being met and whether road initiatives have been successful. Performance indicators are required to enable ex-post evaluation and benefit management.

1. Introduction

This document (ATAP Part M2) provides specialist Mode Specific Guidance on roads. It complements other parts of the ATAP Guidelines, applying the generic ATAP principles, framework and methodologies to roads. The material will assist practitioners in the assessment and planning of roads, most specifically in appraising road initiatives.

1.1 Links to other parts of the Guidelines

This guidance — M2 Road — is one of several areas of Mode Specific Guidance provided in the ATAP Guidelines. As with all ATAP mode specific guidance, M2 is built on, and applies, the generic principles and methodologies underpinning the Guidelines.

This guidance cross-references relevant concepts and data in other parts of the Guidelines to minimise duplication. The most closely related parts of the Guidelines are:

- F3 Options Generation and Assessment
- T2 Cost–Benefit Analysis (CBA)
- Other mode specific guidance (M1 public transport, M3 rail freight, M4 active travel) — reflecting the fact that road competes with other modes for some traffic.

While this guidance can be used on a standalone basis, users are advised to also be familiar with these complementary parts.

The range of initiatives that M2 can be applied to is very wide, from the sealing of low volume rural roads through to the construction of major motorways. For that reason, an important feature of M2 is separate treatment of urban and rural benefits. While the same body of theory underpins the estimation of urban and rural benefits, the principal differences between the two settings — namely network effects or linkages, allied with large differences in traffic volumes — call for different approaches and emphases. A significant difference is the role that travel demand modelling (see ATAP Part T1) plays in the appraisal of urban initiatives.

1.2 Roads

The appraisal process for road initiatives is generally similar to that for other modes although the details will vary. Even so, particular attention should be given to several matters throughout the appraisal process for roads:

- Large road initiatives involve complex effects, especially:
  - Network effects within the road network
  - Inter-modal effects, such as the transfer of travellers between car and public transport, and between road and rail freight
  - The two-way inter-relationship between roads and land use.

- Optimism bias, wherein costs tend to be under-estimated and demand over-estimated, is prevalent in major infrastructure projects, including major road initiatives. Analysts need to use best practice techniques to estimate costs and demand, and should benchmark estimates against evidence from other comparable locations and situations. In undertaking such comparisons, it is important that analysts seek corroborating evidence, and also identify a range of other experiences and calibrate their own estimates against these experiences. For further discussion see ATAP Part O1 Optimism Bias.
- Road infrastructure recurrent costs (infrastructure operating and maintenance costs) are generally small compared to capital investment cost. This contrasts with public transport where ongoing costs associated with public transport are typically proportionately larger, and therefore require careful estimation.

Road initiatives will typically have a number of effects that need to be taken into account in an economic appraisal. These impacts can be broadly categorised as:

- Investment costs — Investment costs incurred with the initiative (the Project Case), along with investment costs to the Base Case in the absence of the initiative, need to be taken into account. While investment costs are primarily a feature of the Project Case, small investment and asset replacement costs are commonly incurred in the Base Case.
- Operating and maintenance costs — Over the life of most road initiatives, there will be operating and maintenance costs , although they are generally modest in scale compared to investment costs.
- Benefits — The term ‘benefits' includes all user benefits to travellers, and non-user benefits in the wider community, that result from the initiative relative to the Base Case. The impacts may be positive, or negative (disbenefits) if some people are adversely affected. The relatively poor safety record makes roads almost unique relative to scheduled air, rail and sea. Different access controls and autonomous behaviour of road users create crash and congestion outcomes that differ to other modes.

The results of the economic appraisal are driven by the incremental changes that occur between the Base Case and the Project Case. In all cases, the Guidelines recommend that Base Case and Project Case numbers are explicitly reported to show how the incremental changes arise.

1.3 Relevance by scale of initiatives

The assessment of roads and road initiatives will vary with the scale of the initiative. The smaller the initiative, the smaller is the need for the more detailed assessment techniques. Discussion is provided throughout M2 regarding application to larger and smaller initiatives.

Users should proceed as follows:

Major initiatives

For major initiatives, the guidelines presented here in M2 will apply in full. Major initiatives lead to impacts across various modes, and usually require the use of multi-modal demand models (see ATAP Part T1 Travel Demand Modelling for guidance). Chapter 5 discusses estimating road demand more generally.

Smaller initiatives

Smaller initiatives will be less complex, have lower costs and lower risks. Simpler assessment techniques will usually suffice — although rigour in their application is still important.

In assessing smaller initiatives, the following points will assist the appraiser in simplifying their task:

- Chapter 5 — Travel demand: Demand effects will generally be restricted to roads, meaning that a multi-modal demand model will not be required.
- Chapter 7: Assessments that assume there are no modal shifts will simply result in benefits to existing road users. This simplifies the assessment of benefits, not requiring use of the ‘rule-of-a-half’ or the logsum methods.
- Chapter 10: Cost estimation for smaller initiatives will usually only require deterministic methods rather than probabilistic. The Australian Government only requires probabilistic estimation if the cost of the initiative is greater than $25 million.

1.4 Structure of this guidance

The remaining chapters in M2 are structured as follows:

- Chapter 2 provides a brief summary of the ATAP assessment approach as context for the remaining chapters
- Chapter 3 describes problem assessment in the road context
- Chapter 4 discusses options identification, including network considerations for urban road initiatives
- Chapter 5 discusses travel demand estimation relating to both urban and rural roads. It introduces the issue of induced demand which is important in urban networks but can sometimes be relevant to rural initiatives
- Chapter 6 addresses CBA methodology specifically relevant to roads including treatment of Base Case and Project Cases, and dealing with initiatives that are related, e.g. synergistic initiatives
- Chapter 7 provides an overview of benefit categories associated with road initiatives. Distinctions are made where relevant between urban and rural initiatives
- Chapters 8 covers the estimation of urban benefits. It places particular emphasis on the role of transport/traffic models in the estimation of urban benefits
- Chapters 9 covers the estimation of rural benefits. The use of rural user cost effects models is an important component of Chapter 9
- Chapter 10 addresses infrastructure costs — capital, maintenance and operating. In addition to identifying issues relevant to the treatment of capital costs, the interplay between capital initiatives and maintenance costs is discussed
- Chapter 11 briefly discusses performance measurement and monitoring, and the role of road performance indicators in problem identification and assessment and post-completion (ex-post) evaluation.

2. The ATAP assessment approach

This chapter provides a brief overview of the ATAP assessment approach as the relevant context for the guidance in the rest of M2. The approach provides the basis for assessing all problems, options and initiatives, including for roads.

2.1 The ATAP assessment model

The ATAP assessment model is presented in Section 3.3 of ATAP Part F3. It consists of:

- Clarification of relevant jurisdictional goals, transport system objectives and targets — It is important to be clear from early in an assessment about which of these are relevant in the given assessment
- Consideration of strategic merit / alignment — The degree of strategic alignment of the initiative being assessed (or the problem being solved) with goals, transport system objectives, targets, policies and strategies
- Generation of a wide range of options for solving the problem being assessed. Note that IA (2018) require that at least two Project Cases be presented in business cases submitted to them
- Assessing options and initiatives through the use of cost–benefit analysis (CBA) and the Appraisal Summary Table (AST) (see ATAP Part T2). The AST provides the mechanism for presenting all appraisal results — monetised and non-monetised — side-by-side in a single location. This approach recognises that all benefits and costs — monetised and non-monetised — are relevant to the appraisal of initiatives
- The AST also includes quantitative and qualitative impact descriptions — these are necessary inputs to calculating monetised and non-monetised benefits, costs and impacts. Presentation of these inputs can also be of assistance to the decision-maker. Non-monetised impacts that are non-quantifiable can only be described in qualitative terms
- Bringing together all aspects of the assessment into a Business Case (see ATAP Part F4).

2.2 Cost-benefit analysis

CBA plays a central role in ATAP assessment (and is a strong focus of M2). ATAP Part T2 discusses how CBA should be applied in the appraisal of transport in Australia. The rest of this chapter summarises the most important features in CBA as a backdrop for the discussion in the rest of M2.

- A CBA is a comparison of the Base Case and the Project Case over the appraisal period where the:
  - Base Case is the situation over the appraisal period *without* the option/initiative being assessed
  - Project Case is the situation over the appraisal period *with* the option/initiative being assessed
- The Guidelines recommend that the Base Case be defined as the "Do-Minimum" option. For further discussion on defining the Base Case, see ATAP Part T2, Section 1.6.
- The benefits, costs and results in a CBA are calculated from incremental changes between the Base Case and Project Case

- Where an asset reaches the end of its economic life before the end of the appraisal period, the asset is re-invested at the end of its life
- When assets have part of their economic life left at the end of the appraisal period, a suitable residual value should be included at the end of the appraisal period (see T2, Section 3.3)
- The primary results from a CBA are the net present value (NPV) and the benefit cost ratio (BCR). An option/initiative is considered economically viable when NPV > 0 and BCR > 1. When trying to identify the economically best option by comparing options of varying scale within an initiative, incremental BCR (IBCR) is required. Formulas are presented here in Appendix A.
- The following distinctions are drawn between several categories of travel:
  - Existing: Trips in the Base Case that continue in the Project Case
  - Induced: The sum of diverted and generated:
    - Diverted: Trips that switches from one mode, route, time of day, origin or destination as the result of an initiative
    - Generated: Altogether new trips that are only made because an initiative is implemented.

3. Problem assessment

3.1 Understanding the problem to be solved and the strategic context

The ATAP Guidelines require that solutions to transport problems need to be developed with an understanding of:

- The nature of the particular problem(s) being addressed (see ATAP Part F3), and
- With the prevailing jurisdictional goals, transport system objectives, targets, policies and strategies for management of the transport system (see ATAP Parts F1 and F0.1).

The specific problem(s) being addressed must be clearly defined, preferably in consultation with stakeholders. For example, in relation to roads:

- If it is a safety problem, it is important to research the nature of crashes contributing to the problem and then to understand the causal factors, and/or
- If it is a congestion (or travel delay) problem, it is important to understand specifically where the delays occur, how the delays affect and are affected by the traffic patterns on the adjoining network, and the nature of the trips being undertaken, and/or
- If it is a problem of high asset maintenance costs, the cause of those high costs and their implications for the agency should be identified.

It is also important that problems are analysed in the context of the outcomes sought by the jurisdiction. These outcomes are expressed as goals, transport system objective, targets (see ATAP Part F1), policies and strategies (see ATAP Part F0.1) that are directed towards a sustainable economic, social and environmental system — i.e. a system that benefits the generations of today without compromising the benefits to future generations.

This involves examining issues at the strategic level, will often bring a broader view to the options that should be investigated, including the influence of:

- Current and planned land use
- The current and planned network and hierarchy of roads
- The role of public transport, and current and planned routes and services
- Policies for access management, traffic management and demand management for both passengers and freight.

3.2 Problem assessment in the roads setting

In the road setting, problems are largely associated with two groups of effects: the user costs experienced by road users; and the external effects of roads (environmental and safety impacts). The primary components are listed below.

User costs

- Travel time / speed:
  - Average
  - Variability (and hence reliability)
- Vehicle operating costs:
  - Fuel
  - Other operating (oil, tyres)
  - Repair and maintenance
  - Tolls
  - Financing costs

External costs

- Crashes:
  - Fatalities, injuries, vehicle damage, emergency services
- Environmental impacts:
  - Local air pollution, greenhouse gas emissions, water and land pollution, biodiversity impacts, barrier effects.

4. Options/initiatives identification

As indicated in Chapter 2, the ATAP Guidelines promotes the generation of a wide range of options for solving a given problem being assessed. Broad guidance on options generation can be found in the following ATAP Parts:

- F3 Options generation and assessment
- O6 Alternative options to large capital investment
- O7 Regulatory initiatives.

This chapter provides supporting discussion in the roads context.

4.1 Sources of proposals

Proposals for transport initiatives generally come from four sources:

- Objectives-led strategic planning
- Other areas of government agencies
- The private sector, and
- Political processes.

Making transport system objectives, policies and strategies widely available maximises opportunities for bottom-up and private sector proposals to be consistent with government objectives.

It is critical that initiatives are clearly specified and that key relationships between initiatives are identified. Initiatives can be independent, complementary or substitutable (also see section 6.2).

4.2 Transport network considerations

For transport infrastructure initiatives, an assessment needs to be undertaken to identify possible impacts at the network, corridor and link levels. For example, initiatives at the link level must consider how changes made at that level may affect the wider road network.

Because of these potential network implications, urban initiatives, especially largescale initiatives, should be identified in a strategic context. This is less of a concern for rural initiatives, but some rural initiatives do call for a strategic approach to options identification if benefits are to be maximised. Flood immunity initiatives and initiatives to enhance access for higher productivity are examples. In both instances an initiative at location A will not realise its full benefit potential if road users then face a similar constraint at location B a few kilometres down the road.

Strategy development (See ATAP Part F0.1) can also be important in establishing priorities between objectives (e.g. safety or efficiency), between corridors or between initiatives to address a specific policy problem (e.g. wide centre lane treatments versus overtaking lanes as measures to reduce head-on crashes).

4.3 Developing possible solutions

It is important to think broadly and creatively in identifying and developing options / solutions to the particular road problem being addressed. Options might include:

- Capital investment
- A range of alternatives to capital investment such as better utilisation of the existing network. For example, by smarter traffic management or priority systems, changes to the adjoining road hierarchy, facilities to encourage or advantage different modes, possible changes to future land use and various demand management approaches. ATAP Part O6 discusses alternatives to large capital investment in more detail.

Potential options must focus on the primary problem being addressed as identified in the problem assessment. If there are other problems that could be addressed concurrently, the additional investment required should be assessed on its merits in terms of 'incremental' costs and benefits. Without this discipline, what was initially an effective solution to the primary problem can become a less efficient investment because of scope creep.

When combining initiative elements in this way, appraisers should be aware of how the scope of costs and benefits will expand. For example, a widening that could be carried out conveniently with pavement strengthening will require the estimation of the impact on user benefits of reduced roughness and also the maintenance cost implications for the road agency of a stronger pavement. In addition, the CBA will need to be structured so that the costs and benefits of the widening vs widening plus rehabilitation can be separated for the purposes of incremental CBA.

4.4 Staged appraisal process

In urban transport networks, because of their complexity and interdependencies, initiatives are more likely to arise from a staged planning and assessment process. Rural initiatives emerge from similar processes but, being more discrete, are more likely to emerge from ad hoc influences. Examples could include a bridge upgrade prompted by a flood event that exposed an unexpected weakness in the design, construction or siting of the bridge; or an intersection upgrade prompted by a new industry such as a coal mine or a feed-lot. Even so, the design and timing of initiatives might nevertheless be informed by wider road corridor or network strategies, and as noted earlier, some rural initiatives are more subject to network influences than others (see Table 1).

Table 1 High level options list

Option level or type	Urban application examples	Rural application examples
Status quo (do minimum, do nothing or no action required)	Routine and periodic maintenance	Routine and periodic maintenance
Use existing transport system in a different way or more efficiently	Transit or high occupancy vehicle lanes	Performance-based standards for heavy vehicles
Modify or add to existing transport system with:		
• New infrastructure	Motorways, interchanges	Town bypasses, route realignments

Option level or type	Urban application examples	Rural application examples
• Modified service	Transit lanes, signal modifications, additional lanes	Road widening and pavement strengthening, overtaking lanes, higher bridges for better flood immunity
• New regulations	Changes in speed limits, road rules	Driver management (e.g. fatigue); vehicle operation (e.g. load restraint, axle load limits)
Alter proposed transport task in conjunction with other options	Divert road commuting demand to an expanded light rail, heavy rail or ferry service or to active travel modes	Upgrade a rail line to encourage diversion of freight from road to rail
Technological solutions	Managed motorways, variable speed limits, autonomous vehicles	High productivity freight vehicles, automated flood warning systems
Organisational or process change	Private sector involvement in toll roads	Partnering between state and local governments for infrastructure management and delivery.
Education or information provision	Give way at roundabouts; safety at work zones	Managing interactions with heavy vehicles; reducing risk at flooded crossings

Source: Adapted from ATC (2006a, Box 3)

5. Demand estimation

This chapter is concerned with principles and methods for estimating future demand for road use, and the impact on demand of road initiatives.

The quality of demand estimates is critical to effective appraisal. Base–year traffic volume, forecast growth and traffic composition all influence benefit estimates.

5.1 Urban initiatives

Appraisal of urban initiatives will typically be supported by the outputs of a traffic or strategic transport model that forecasts trips between origins and destinations, by transport mode, and traffic volumes on each link in the subject network. The models are underpinned by demographic forecasts prepared by the Australian Bureau of Statistics (ABS) and/or state and territory forecasting agencies. Section 8.3 discusses urban travel demand models.

The appraiser will be unlikely to have a direct role in preparing those estimates, but close liaison between appraisers and traffic modellers is essential to ensure that traffic modelling captures an initiative's expected range of traffic impacts.

For urban roads, this chapter should be read in conjunction with T1, which covers travel demand modelling and forecasting methods for transport generally. The multi-modal metropolitan/regional ('four stage') models discussed in T1 are used to assess major urban transport initiatives, including urban roads.

5.2 Traffic growth rates

Typically, forecast traffic growth rates are linear rather than compound or exponential.

There is danger in urban appraisals that are reliant on microsimulation traffic models (see section 8.3.5), and in rural appraisals generally (see section 9.14), that traffic growth rates will be applied even once the capacity of a road has been reached. It might be prudent to assume no further traffic growth will occur once the capacity of a road has been reached. Failure to cap traffic volumes will result in the overstatement of benefits. Having traffic models that are able to model the effects of peak spreading, which occurs when road users bring forward or delay their trip to avoid congestion, would allow appraisers to address capacity constraints more effectively than they are able to do at present (also see section 5.4 below).

5.3 Rural initiatives

For rural initiatives, appraisers are much more likely to make their own traffic forecasts. Sources or methods for rural traffic forecasts include:

- Strategic studies at the network, region or link level
- Industry transport demand studies
- Broader policy studies — e.g. on freight or the future of regional economies

- Demographic forecasts for places in the catchment of the subject road section
- Econometric analysis
- Extrapolation from historical trends in traffic volume
- Some combination of the above.

5.4 Low volume remote rural roads

For initiatives on low volume, remote rural roads, extrapolation from historical trends would be appropriate to the size of investments being contemplated. Appraisers should be aware that traffic volumes on these roads can fluctuate in the short to medium term according to changes in the weather and market conditions so care is needed that short-term trends are not given undue weight. Unlike other parts of the national road network, these roads can also experience long-term declines in volume (albeit sometimes gentle). Contributing factors include declines in rural workforces, the effects of long-term climate change, more efficient freight vehicles and perhaps changes in tourist visitation patterns. Population and agricultural production statistics from the Australian Bureau of Statistics (ABS) may be useful in confirming patterns of activity evident in the traffic record.

If there is doubt about a defensible traffic growth rate, an assumed zero traffic growth rate supported by sensitivity testing of +2% per year and –0.5%[1] per year would not unduly distort the analysis. On the low volume network, although AADT can fluctuate from year to year, there is generally an overall pattern of stability or slow decline. The +2% figure approximates the long term Australian population growth rate. Adopting this assumes a stable trip rate, which would be reasonable in mature rural areas. The –0.5% figure is suggested to simulate long term decline. The rate could be lower than that, but the data is often not good enough to say any more.

5.4.1 Other rural roads

The remainder of the rural network is diverse, ranging from major regional roads through to state and national highways. For these roads, particularly at the national highway level, a wider source of data to support forecasting is likely to be available. On the low volume network, AADT on individual roads can jump around from year to year but exhibit patterns of stability or slow decline across a network.

The use of models, even simple models, will be limited by the availability of trip origin and destination data. Factors that cause transport demand operate at trip origins and destinations, so without that data the potential for forecasting is limited. However, patterns in volumes along successive links in a route — say Sydney to Melbourne or Brisbane to Rockhampton — may provide clues about the importance of through volumes relative to local trip volumes. Employment and production forecasts at each end of the route and for major intermediate regions could support the development of traffic forecasts for local and through traffic. Comparisons with other similar routes could provide guidance as to how traffic composition changes with changes in volume but often it will be necessary to assume continuation of the traffic composition evident in the base year.

[1] The selection of a –0.5% growth rate reflects the possibility that traffic volumes may already be close to their long-term floor.

When making forecasts for years beyond the availability of demographic data, growth rates should not exceed those of the final forecast period in ABS or other official statistics. Also take care that the adopted growth rates do not result in traffic volumes that exceed base case road carrying capacity. Road user tolerance of congestion on rural roads will be less than on urban roads so high levels of congestion may have feedbacks to land use that are difficult to predict. If base case volumes are assumed to eventually 'flat line' due to capacity constraints, any new traffic in the project case above and beyond those volumes should be treated as generated traffic and be subject to the rule of half.

5.5 Induced demand

Induced traffic comprises both:

- Traffic diverted from other modes, routes, times of day, origins or destinations, and
- Generated traffic, that is, altogether new demand caused by the initiative (ATAP Part A2).

The diverted traffic component of induced demand will be an issue only in denser parts of rural networks and only for relatively large improvements in road quality that might only occur over long periods of time. If there is a possibility of induced demand, the subject road and other related roads should be analysed as a small network.

Generated traffic effects can be difficult to forecast. Trip origin and destination data will be needed to forecast generated traffic because people make transport decisions with reference to trips, not links. ATAP Generated trips could comprise:

- Existing users travelling more frequently (an increase in the propensity to travel), and
- New users appearing as a result of land use changes (a new residential estate, factory or shopping centre) that occur in the project case but not in the base case. .

Note that benefits from generated traffic caused by land use changes are conditional upon the land-use changes being caused by the initiative. Land use changes that are expected to occur in both base and project cases do not give rise to generated demand, though the effects of such changes still need to be forecast and included in both base and project cases. Land use changes are difficult to predict so estimation of benefits arising from them should be confined to major road upgrades.[2]

Traffic models may use demand elasticities to estimate increases in trip demand in response to an infrastructure improvement that reduces travel costs. For calculating the diverted trip component of induced demand, traffic models sometimes use Wardrop's principle. This principle holds that whenever there are alternative routes between an origin-destination pair individual drivers will always choose the quickest route (or the cheapest route in terms of generalised cost) so that, in equilibrium, travel time (or generalised cost) is equalised for all alternative routes where there is congestion. Note this does not apply to uncongested routes for which travel times are free flow times.

[2] This issue is further complicated to the extent that official demographic forecasts of workforce and population might not take account of the availability or otherwise of supporting infrastructure.

Note that base and project case traffic levels can be affected by different degrees of peak spreading. Growth in peak period traffic on congested roads causes demand to spill into the off-peak periods. This can occur in the project case scenario as well as base case, but not to the same extent. An initiative that expands road capacity can reverse peak spreading as road users forced into the off-peak in the base case take advantage of the reduction in peak period congestion in the project case. At present, traffic models are unable to replicate peak spreading. This limits the range of solutions that can be modelled and can lead to unrealistic demand assumptions.

If new traffic grows in the project case due to improved capacity, the AADT difference between the project and base cases is considered to be induced traffic. In figure 1, base case traffic during the peak periods has been supressed by a capacity constraint. In the project case, the capacity constraint is relaxed, and the suppressed demand appears as induced traffic.

The benefit accruing to the induced traffic can be estimated using the rule-of-a-half as $(P_1 – P_2)(Q_2 – Q_1)/ 2$, where P is perceived costs, Q is quantity of traffic and the subscripts 1 and 2 represent the base case and project case respectively, as explained in ATAP T2. The benefit areas to existing and induced traffic are shown in figure 2 under the simplifying assumption that perceived costs equal average social costs. The benefit on other routes and modes from which traffic is diverted, the decongestion benefit, is shown in figure 3, also assuming perceived costs equal average social costs. The total benefit in a network can estimated using the method in Neuberger (1971) as

$$\sum_{All\ trips} \frac{1}{2}(Q_1 + Q_2)(P_1 - P_2)$$

The same expression works for both the figure 2 and figure 3 situations, so it can be summed over all trips.

As perceived costs differ from social costs, resource corrections will be required. From the formula in ATAP T2, the resource correction is

$$\sum_{All\ trips} (P_2 - ASC_2)(Q_2 - Q_1)$$

where ASC_2 is average social cost.

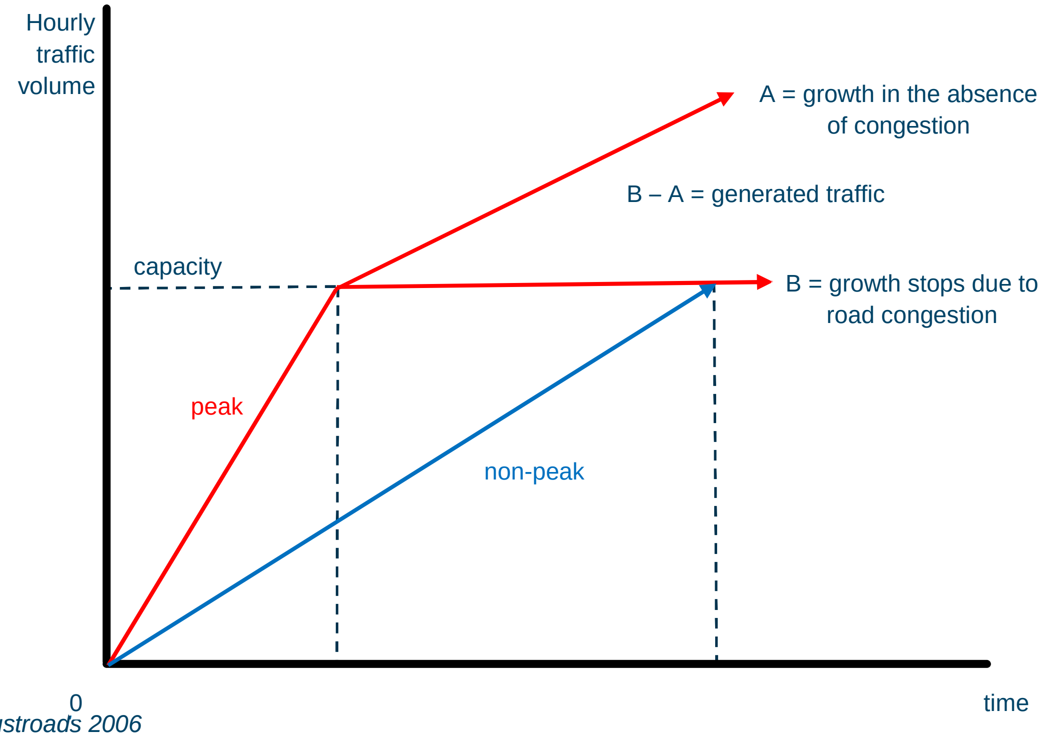
The fuel excise ($P_2 > ASC_2$), considered in isolation, gives rise to positive correction for induced traffic ($Q_2 > Q_1$) (additional willingness-to-pay generated for road users but passed onto the government in higher tax receipts) and a negative correction for a congested road from which traffic is diverted (vanished willingness-to-pay that translates into reduced tax revenue). A toll on a road would received the same treatment but noting that the revenue accrues to the road operator.

Where perceived costs are below social costs due to drivers being unaware of some vehicle operating costs (ignoring fuel excise), as suggested below in section 7.2 ($P_2 < ASC_2$), there is negative resource correction for induced traffic ($Q_2 > Q_1$) (additional costs to society not offset by increased willingness-to-pay which related to perceived costs) and a positive correction for diverted traffic ($Q_2 < Q_1$) (the vanished willingness-to-pay based on perceived costs does not count the full saving in social costs).

Where computer models are used to estimate benefits, it is important check of whether the model differentiates between perceived and social costs, and if so, how perceived costs are defined (which particular costs are assumed not to be perceived). Normally, urban transport models work entirely in perceived costs and the resource correction has to be made outside the model.

The above arguments are not just restricted to high volume roads. An initiative that involves sealing a gravel road can result in significant traffic diversion if it provides a shorter sealed route between origin and destination pairs with sizeable large traffic flows. The same rules apply to these situations and induced traffic can amount to significant benefits.

Figure 1 Base case traffic constrained by capacity during peak



Source: Austroads 2006

Figure 2 Benefit to existing and induced traffic on road with initiative

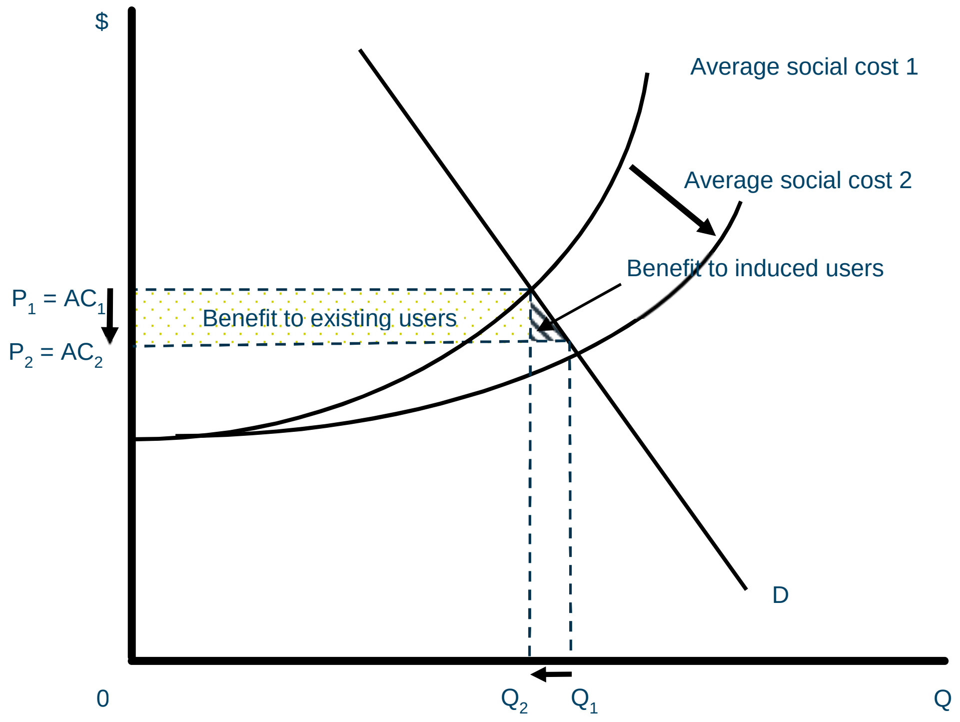
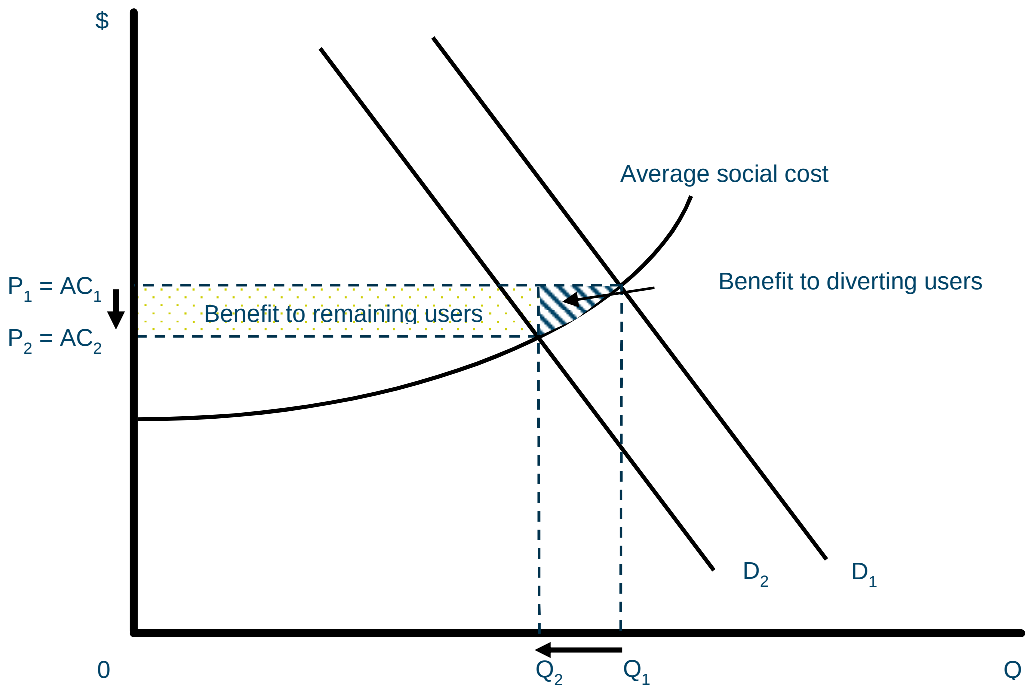


Figure 3 Decongestion benefit on road from which traffic is diverted



6. Cost–Benefit Analysis methodology

Cost–benefit analysis (CBA) is central to the ATAP appraisal system as explained in Part F3. The general features of a transport CBA are set out in Part T2 of the Guidelines. This chapter briefly restates key points and addresses matters related to the application of CBA that are specific to public transport initiatives.

6.1 Specifying the Base Case and the Project Case

An appraisal investigates the merit of a proposal relative to some alternative approach (i.e. the Project Case relative to the Base Case). The general features of the Base Case and the Project Case are described in Chapter 1 of Part T2 of the ATAP Guidelines. It is of note that the Base Case impacts the results of an appraisal as much as the Project Case, so careful consideration is needed in defining and analysing both cases.

6.1.1 Base Case

The Base Case (see part T2 Section 1.6) consists of a 'real world assessment' (IA 2017) of what would be done in the absence of the Project Case being implemented. A 'Do-Minimum' Base Case is preferred, and should:

- Include ongoing maintenance of associated assets for structural integrity and public safety
- Include a 'minimum' level of intervention (based on existing capacity) to manage the problem. It could maintain the existing level of service over the appraisal period if possible (i.e. prevent the problem from getting worse), or at least minimise the rate of degradation in service level (i.e. minimise the rate at which the problem gets worse)
- Be of modest cost (If the cost is too high, the option should be treated as a project case option)
- Not include significant asset augmentation or enhancement to meet incremental demand beyond the capacity of the existing infrastructure. However, include modest spending to improve the effectiveness of existing assets, such as minor road intersection improvements or minor improvements on a rail corridor such as fixing a signalling system
- Adopt the option that is most effective at maintaining level of service at least cost (if several options fit the do-minimum definition)
- Include relevant initiatives elsewhere in the network where funding for those initiatives is approved, committed or expected in the absence of the proposed initiative being appraised
- As with the Project Case, the Base Case should include capital and recurrent expenditures needed over the appraisal period.
- Where Base Case assets are likely to become technologically obsolete, or to reach the end of their economic life during the appraisal period, allowance should be made in the Base Case for their replacement by assets as similar in function as possible.

6.1.2 Project Case

The Project Case is the situation expected if the initiative is implemented. Usually there are multiple options available for solving a problem, so more than one project case should be assessed.

The Project Case could include non-core improvements that could, at low cost, be implemented in the Base Case. In these cases, the appraisal should compare the Base Case with two options: (1) an Alternative Scheme (the Base Case plus the non-core or uncommitted improvement); and (2) the Project Case. This allows the merit of the initiatives in the Alternative Scheme and the incremental merit of the additional initiatives in the Project Case to be separately appraised.

There will be occasions where there is some other proposal not already 'committed' (i.e. with contracts for implementation) that is not a formal part of the proposed initiative, but which may affect the merits of the initiative being appraised. In such cases, it may be best to appraise the initiative with and without other proposal in place, treating the less likely of the two possibilities as a sensitivity test. The aim is to ensure the costs and benefits of each initiative are separately identified. In this manner, the benefits and costs specifically associated with the non-core or uncommitted improvements are appraised separately, and are not attributed to the main project.

6.1.3 Urban road initiatives

Base and project cases

For urban initiatives, it is important to note the distinction between the *base network* and the *base case*, in order to avoid confusion. The term 'base network' is sometimes used in travel demand modelling (see ATAP T1) to refer to the existing network, and comprises a description of its characteristics (e.g. number of lanes, presence and capacity of intersections, etc). The Base Case is the situation in the absence of the proposed initiative, which will include committed and funded initiatives. The Base Case would start with the base network and build the Base Case from it. (Note the discussion above regarding the treatment of related initiatives.)

In urban contexts, particularly where volumes are growing quickly, specification of the base case can present difficulties. For example, relatively short-term actions such as intersection/interchange upgrades may be needed to manage a degradation in level of service while a longer-term motorway widening is being planned and determined. Some judgement will be needed to interpret the 'modest cost' criterion in ATAP T2.

Incremental analysis is a way to address such situations. Using incremental analysis, the base case is do-minimum, and the project cases are then progressively more costly responses to the identified problem. This is illustrated in the example in Table 2, where incremental analysis is used to identify the economically preferred option.

Table 2 Example of incremental analysis: Urban base and project cases

Base case (do minimum)	Project case 1	Project case 2	Project case 3
	Safety response only	1+ maintain existing level of service	1+improve level of service
Routine and periodic maintenance only	Routine and periodic maintenance of existing pavement only	Routine and periodic maintenance of existing and augmented assets	Routine and periodic maintenance of new pavement
	Signalise all unsignalled intersections	Signalise all unsignalled intersections including turn arrows	Replace existing pavement and widen on new alignment

Base case (do minimum)	Project case 1	Project case 2	Project case 3
	Variable message signs	Widen intersections and approaches including additional turn lanes and storage	Grade separate major intersections; all other intersections to be signalised or left in-left out

For lower impact initiatives specification of base and project cases is more straightforward. Examples are shown in Table 3.

Table 3 Examples of simple urban base and project cases

Problem	Related transport system objective	Base case	Project case
High rate of pedestrian injuries near a bus stop	Reduce the pedestrian crash rate to the level of the city average	Improve lighting and signage	Improve lighting and signage; install signals
Increasing congestion (declining level of service) on sub-arterial road serving several bus routes	Improve level of service and improve bus travel times	All minor intersections to be left in-left out only	Minor intersections to be left in-left out; major intersections to be signalised; bus pull in bays to be installed at the busiest bus stops
Increasing congestion at a signaled level crossing	Reduce intersection delays; reduce crash risk	Road marking and signage to keep nearby intersections clear	Widen the intersection approaches to increase vehicle storage and facilitate free left turns where possible
A mid-block section is experiencing declining level of service	Reduce travel times/reduce delays	Install bus pull in bays	Widen the road from two lanes to four lanes

6.1.4 Rural road initiatives

Base and project cases

Specification of base and project cases is inherently simpler in rural road appraisals because of the absence of network effects. Pavement condition will be more important because:

- The rural integrated models used for estimating user benefits (see Chapter 9) contain pavement detail not present in traffic models and in the ATAP urban VOC algorithms
- Heavy vehicles which place considerable load on pavements can form a relatively high proportion of traffic flow.

In rural contexts, four factors are likely to be relevant in the specification of base and project cases:

- Cross section capacity (seal width, number of lanes including overtaking lanes; provision of town bypasses)
- Pavement capacity in terms of heavy vehicle loadings, pavement condition (roughness) and pavement maintenance costs
- Safety, which can be affected by posted speed, seal width, horizontal and vertical alignment, whether the road is undivided or divided; intersection treatments and whether the traffic flows on single carriageway roads are separated by medians or wide centre lines
- Road closure risk due to flooding.

In rural environments with static or declining traffic volumes,[3] do minimum, comprising routine and periodic maintenance with minor safety works would be an appropriate base case, because without the pressures of traffic growth and perhaps with falling traffic volumes, widening and pavement refurbishment can be increasingly postponed. When traffic volumes are increasing project cases could then represent successively more costly initiatives — some short term, some medium to long term — to accommodate traffic growth.

As in the urban context, incremental analysis could then be used to identify the more economically efficient option. This is illustrated in Table 4.

Table 4 Example of incremental analysis: Rural base and project cases

Base case (do minimum)	Project case 1	Project case 2
	Maintain existing level of service	1+improve level of service\
Minor safety work including improved line marking and lighting	Early rehabilitation followed by longer periodic maintenance intervals	Construction of a wider, stronger road adjacent to the existing road
Routine and periodic maintenance	Strengthening and sealing of shoulders	Longer periodic maintenance intervals
	Routine maintenance	Routine maintenance

As in urban contexts, there will be instances where specification of base and project cases will be relatively straight forward. Examples are shown in Table 5.

Table 5 Examples of simple rural base and project cases

Problem	Objective	Base case	Project case
High rate of head on crashes	Reduce the rate of head on crashes	Install additional warning signage; routine and periodic maintenance	Provide wide centre line treatment

[3] Sometimes, rural traffic volumes can be cyclical, reflecting the effects of drought and flood as well as fluctuations in rural product markets. Appraisers should be careful to distinguish these short term (cyclical) influences from the long term (secular) trends.

Problem	Objective	Base case	Project case
High rates of head on and run off road crashes	Reduce the incidence of casualty crashes	Improve line marking and install warning signage; routine and periodic maintenance	Seal shoulders and install wide centre line treatment; establish roadside clear zones to reduce impact of run off road crashes
High timber bridge maintenance costs	Reduce agency bridge maintenance costs; extend higher mass limits (HML)for heavy freight vehicles; improve network reliability	Repair and strengthen timber bridge; continue routine bridge maintenance and inspections	Replace the timber bridge with modern concrete structure that is wider, stronger and at increased height to improve flood immunity
Increased traffic volumes are increasing travel times	Reduce road user costs by providing additional capacity	Routine and periodic maintenance	Widen the seal including by sealing shoulders; routine and periodic maintenance
Unsealed road reduces reliability of livestock transport and deters tourists	Provide a more resilient and reliable road surface to reduce costs for the livestock industry and attract additional tourist traffic	Reduce the intervals between grading; routine maintenance	Seal the road; routine and periodic maintenance

6.2 Synergistic or complementary initiatives

Sometimes one initiative will enhance the benefits accruing to another initiative. In extreme cases, an initiative might only be economically viable if complementary initiatives are also implemented. In these circumstances, the full range of complementary initiatives should be appraised as a group, or alternatively benefit estimation should reflect the limitations of isolated initiatives. Examples include the following:

- Improving flood immunity: Unless all flood sites on a route are improved to the same level of immunity improving any one site will only benefit localised traffic because through traffic will be delayed at the next flood site encountered and will gain no benefit from the improvement. Obviously, the length of route along which complementarity is relevant is affected by boundaries between stream catchments and even by patterns of weather events, but the general principle holds
- Improving accessibility for heavy freight vehicles: Again, the more localised are the initiatives to strengthen bridges and pavements and reduce curvature the more localised will be the benefits and the less likelihood that benefits for longer distance through traffic will be realised. Through traffic will not fully benefit until all constraints are removed[4]
- Town bypasses: If a town bypass has only two entry points (one at each end) no benefits will materialise until the whole bypass is completed. The more entries that are proposed, the more likelihood that benefits can accrue progressively as individual sections of the bypass are opened to traffic.

[4] The 'last mile' problem falls into this category. The initiatives on a route to improve heavy vehicle accessibility will not be realised until the 'last miles' at freight origins and destinations along the route are also upgraded. Often these last mile sections are in urban areas where road users are sensitive to the presence of large heavy vehicles.

- Urban duplications or widenings: Benefits may be constrained if a duplication or widening feeds into a (narrower) bottleneck at either end or if critical intersections within the duplication/widening length remain congested

6.3 Sensitivity testing

ATAP T2 (Table 3) presents a recommended set of sensitivity tests in which the BCR and NPV are calculated for ranges around the values of key variables (e.g. costs + or –20%). It is also essential that other more targeted tests related to the specifics of the given initiative being appraised also be undertaken (IA, 2018). Examples of other more targeted tests that could be adopted in the appraisal of road initiatives are described in Table 6 (- for each initiative the listed tests are illustrative and not comprehensive).

Table 6 Examples of targeted sensitivity tests

Initiative	Benefit or cost	Test
Wide centre line treatment to reduce head on crashes	Crash benefits	Test for a range of wide centre line crash reduction factors from the literature
Improve flood immunity	Road user delay and diversion	Test for alternative proportions of users who wait/do not travel and divert around the road closure site (also see ATAP Part O4 Flood Resilience Initiatives)
Extend higher mass limits access	Heavy vehicle productivity	Test for alternative rates of take up of HML scheme (also see ATAP Part O7 on Regulatory Initiatives)
Strengthen pavement to reduce agency maintenance costs	User benefits	Test for alternative rates of roughness progression in the project case
Provision of additional rest areas	Reduced crash costs	Test for alternative ‘capture’ rates (i.e. higher and lower percentages of passing users who pull into the rest area)
Widen a sealed road	Road user travel time and vehicle operating cost savings	Test for alternative estimates of vehicle occupancy
		Test for effects of higher or lower posted speeds
		Test for alternative traffic growth rates
Duplicate an urban motorway	Road user travel time and vehicle operating cost savings	Test for alternative cross-elasticities of demand between private and public passenger transport; inclusion of reliability benefits; inclusion of wider economic benefits
Extend an urban motorway	Road user travel time and vehicle operating cost savings	Test for alternative public transport fares structures; inclusion of reliability benefits; inclusion of wider economic benefits

When appraisals are supported by travel demand modelling, some of the standard tests in ATAP T2 (those related to traffic growth rate, speed, proportion of traffic diverted by an initiative and vehicle occupancy rates) will need to be run in the model to enable the trip and traffic response to be estimated as a precursor to re-estimation of benefits. In the list of 'targeted' sensitivity tests in Table 6, the tests for alternative cross-elasticities of demand and alternative fare schedules would need to be run initially in the model. Appraisers should liaise with traffic/transport modellers at an early stage to identify a range of meaningful and practicable sensitivity tests.

6.4 Presentation of results

Comprehensive reporting of results enhances the reader's and the appraiser's understanding of the outcomes of the appraisal. Costs should be reported by category (construction and related costs, maintenance and operations). Benefits should be reported by category and also by vehicle type or and/or trip type. A suggested typology is provided in Table 7.

Table 7 Suggested results pro-formas

Urban initiatives excluding localised intersection appraisals	Localised intersection appraisals	Rural appraisals
Costs	**Costs**	**Costs**
Construction	Construction	Construction
Maintenance	Maintenance	Maintenance
Operations	Operations	Operations
Total costs	Total costs	Total costs
Benefits	**Benefits**	**Benefits**
Travel time savings	Travel time savings (Note 1)	Travel time savings
Private cars	Light vehicles	Private cars
Commercial cars	Heavy vehicles	Commercial cars
Vans		Vans
Rigid trucks		Rigid trucks
Semi-trailers		Semi-trailers
B-Doubles		B-Doubles
Road trains/ high productivity vehicles		Road trains/ high productivity vehicles
Sub-total travel time savings	Sub-total travel time savings	Sub-total travel time savings
Vehicle operating cost savings	Vehicle operating cost savings (Note 1)	Vehicle operating cost savings
Private cars	Light vehicles	Private cars
Commercial cars	Heavy vehicles	Commercial cars

Urban initiatives excluding localised intersection appraisals	Localised intersection appraisals	Rural appraisals
Vans		Vans
Rigid trucks		Rigid trucks
Semi-trailers		Semi-trailers
B-Doubles		B-Doubles
Road trains/ high productivity vehicles		Road trains/ high productivity vehicles
Sub-total vehicle operating cost savings	Sub-total vehicle operating cost savings	Sub-total vehicle operating cost savings
Safety benefits	Safety benefits	Safety benefits
Environmental benefits	Environmental benefits	Environmental benefits
Residual value	Residual value	Residual value
Other benefits	Other benefits	Other benefits
Total benefits	Total benefits	Total benefits
Decision criteria	Decision criteria	Decision criteria
NPV	NPV	NPV
BCR1 or BCR2 (Note 2)	BCR1 or BCR2 (Note 2)	BCR1 or BCR2 (Note 2)
IRR	IRR	IRR
FYRR	FYRR	FYRR

Note 1: Benefits may be estimated and shown by vehicle/trip type if classification count data is available for each leg of the subject intersection.
Note 2: Incremental BCR and incremental NPV should also be calculated when an incremental appraisal is being carried out.
Note 3. In some cases, it may be possible to provide further breakdowns by vehicle categories as per Table 7 of ATAP PV2.

7. Benefits overview

A CBA measures net benefits as changes in national economic welfare. This can be measured in two equivalent ways (see discussion in Chapter 6 of T2):

- As the total increase in willingness to pay less the increase in resource costs, or
- As the sum of the sum of the increase in welfare (or net benefits) to the various parties affected (of an initiative as the sum of the following components (IA, 2018):
  - The change in consumer surplus (CS) — user benefits
  - The change in producer surplus (PS) — net benefits to service providers and government
  - The change in third party (externality) effects.

Chapters 6 and 7 of T2 discuss in detail the measurement of the user benefits using the change in willingness to pay less the change in user resource cost, and also the change in consumer surplus (measured with the rule-of-a-half) plus any required resource correction. Table 2 therein provides formulas for estimating user benefits — and apply here.

Chapters 8 and 9 of T2 discuss the measurement of changes in externality effects.

The principles and formulas in Chapters 6 to 9 of Part T2 continue to apply here.

This chapter provides complementary guidance for use in cost-benefit analyses of road initiatives. Analysts should draw on both of these sources when undertaking an appraisal of an initiative.

The benefits of road initiatives can be categorised into:

- Road user benefits for:
  - Trips that use the same roads in the Base and Project Cases
  - Trips that change roads
  - Trips attracted from other modes (public transport, active travel, rail freight)
  - Generated road trips
- Benefits to those who continue to use other modes in the Project Case, in the form of reduced congestion on those modes. These are likely to be small
- Benefits from reduced road crashes
- External benefits that accrue to the entire community (reduced environmental pollution, improved amenity)
- Resource corrections that include changes in unperceived costs incurred by road users and government tax receipts
- Changes in producer surplus accrued by service providers and governments

For some very large urban road projects, there is a further category of the benefit arising from productivity improvements that are not captured by standard CBA, called wider economic benefits (WEBs).

User benefits are estimated here as the change in consumer surplus of the various groups of travellers, with adjustments made to take account of any travellers' misperceptions of the resource costs of their travel.

7.1 Benefits

Descriptions of monetised and non-monetised benefits and costs are shown in Table 8**Error! Reference source not found.**. Note that 'secondary impacts' can be considered as consequences of the benefits that initiatives cause. Secondary impacts are not included as benefits in CBA.

Not all costs and benefits are quantifiable in monetary terms. ATAP M2 addresses only quantifiable costs and benefits. ATAP T2 (Cost–Benefit Analysis) describes approaches to consideration of non-quantifiable initiative effects.

Table 8 List of benefits

Monetised	**Non-monetised****	Secondary impacts
Benefits and disbenefits*		
Savings in vehicle operating costs	Improvements to amenity	Access to services
Savings in time costs for passengers and/or freight	Reductions in damage and pilfering to freight	Production levels
Improvements in service reliability	Improvements in driver comfort or reductions in driver stress	Productivity for industries
Savings in crash/accident costs		Tourism
Reduced environmental externalities (noise, pollution)		Employment
Savings in infrastructure operating costs including maintenance and administration		
Benefits associated with diverted and generated traffic		
Scrap or residual values of assets		

** Some of these benefits could have a negative sign because they are disbenefits, e.g. increases in environmental externalities*
*** In most cases, the reason these benefits and costs are 'non-monetised' is because it is too expensive to undertake the surveys necessary to produce reasonable estimates of the values people place on them. See section 9.11 for a brief discussion of the techniques available for estimating externality costs. For damage and pilferage to freight, consigners and transport operators are often unwilling to divulge the extent of the problem.*

7.2 User benefits

User benefits represent road users' willingness to pay for the improvements in service quality that initiatives offer. Typically, those improvements are conceptualised in terms of reductions in travel time costs and vehicle operating costs. More recently, increasing emphasis is being placed on including the benefits of improved network reliability in appraisals. This is more an urban than a rural issue.

User benefits are calculated using the concept of generalised costs of travel that can be divided into:

- Perceived generalised costs — travel time, fuel, parking charges and tolls (sometimes referred to as 'behavioural costs' because they influence changes in travel behaviours), and
- Unperceived generalised costs — vehicle repairs and maintenance, tyre costs and depreciation costs

The concept is illustrated in Table 9[5] in which the amount paid for a trip is 22 cents/km, the perceived cost is 48.9 cents/km and the cost to society (the economic cost) is 55.5 cents/km. The social cost reflects both costs unperceived by the user but also the exclusion of taxes from all cost items other than travel time.

For existing trips, benefits are calculated as the full difference in social costs between the base and project cases.

For induced trips, the benefit is equal to half the difference in perceived user costs plus an increase in perceived costs between the base and project cases.

Table 9 Perceived and unperceived costs of car travel (cents per vehicle km)

Item	Money cost	Perceived cost	Social cost
Travel time	-	40.0	40.0
Vehicle operating cost			
Fuel	8.9	8.9	3.8
Tyres	1.0	-	1.0
Maintenance	7.3	-	7.3
Depreciation	4.8	-	4.8
Sub-total	22.0	8.9	15.5
Total user cost	22.0	48.9	55.5
External costs			
Crashes	-	-	5.0
Environmental costs	-	-	4.5
Total social generalised costs	22.0	48.9	65.0

Source: ATC (2006c) table 2.1 based on Bray and Tisato (1997)
Note: Excluding the average cost per km of road supply which is not included in the typical generalised cost formulation

Table 10 shows the elements of user costs. These are broadly relevant to urban and rural contexts with the difference being that:

- Urban appraisals use simplified VOC algorithms from PV2 that do not account for differences in pavement conditions and relate to broad road stereotypes. Speed will be provided from an urban traffic model
- Rural appraisals that use integrated travel cost-based models will calculate VOCs and speeds within the model taking account of the characteristics in Table 10.

[5] Table 9 shows social generalised costs as comprising user costs plus safety and environmental costs. In practical terms, appraisals will generally calculate the user and other components of social generalised cost separately so that user, safety and environmental benefits can be reported separately.

Table 10 Travel cost categories and variables used in rural user effect models

Travel Costs Category	Travel Costs Variables	
Vehicle operating cost	• hourly flow rate distribution throughout the year • traffic volume • traffic composition • vehicle type • seal or gravel pavement width	• surface type • road roughness • speed of travel • road curvature • road gradient
Speed of travel	• number of lanes • lane width • gradient • curvature	• roughness • traffic volume • change in flow rate throughout the year
Fuel consumption	• vehicle type • fuel type • speed • gradient	• curvature • surface type • roughness
Oil consumption	• engine size	
Tyre wear	• vehicle type (no. of tyres) • speed • gradient	• curvature • surface type • roughness
Vehicle depreciation	• vehicle type • speed	• surface type • roughness
Vehicle repair and maintenance	• vehicle type • speed	• surface type • roughness
Persons per vehicle	• trip purpose	
Tolls		
Road crash costs	• traffic volume • road stereotype • weather conditions	• curvature • speed limit

Source: Adapted from Austroads 2012c

Further details on the measurement and valuation of the components of generalised cost are provided in ATAP PV2.

7.3 Estimation of consumers' surplus

The largest component of benefits of many road initiatives will generally be changes in consumer surplus for travellers. The change in consumer surplus comprises:

- The increase in consumer surplus gained by people who use roads in the Base Case and Project Case *('existing' trips*), and
- The consumer surplus gained by *new users* of roads, which in turn includes:
  - *Generated trips* (i.e. travel not previously made at all), and
  - *Diverted trips* (i.e. trips that were made in the Base Case by road, public transport or active travel that are attracted to the improved roads in the Project Case). (For definitions, see A2, Glossary 2 — Traffic Types)

For further details on the estimation of changes in consumer surplus see:

- Chapters 6 of ATAP Part T2, in particular Table 2 and ATAP M2, section 5.5 above provide formulas for calculating changes in consumer surplus, plus resource corrections required from any misperception of costs by users, and for taxes, subsidies and tolls (see section 7.2 above).
- Section 4.2 of ATAP Part M1 which discusses various methods of calculation.

7.4 Residual value

Residual value is calculated in the same way for urban and rural appraisals.

The residual value of an infrastructure asset is its value at the end of appraisal period and is a measure of the asset's capacity to produce benefits beyond the end of the appraisal period. Residual values should be calculated in two circumstances:

- When options have varying lives (e.g. a pavement with a 20 year life and a more costly pavement with a 30 year life. Here the residual value is calculated to ensure consistent estimation of benefits
- For assets with very long lives (100 years) relative to the standard appraisal period of 30 years.

T2 recommends that residual value be calculated using the straight-line depreciation method. The formula for residual value is:

$$\text{Residual value (SLD)} = \text{Capital cost} * \text{Asset life remaining after appraisal period} / \text{asset life}$$

All capital costs incurred are depreciated at a constant rate during the estimated asset life for the whole road initiative without discounting such that the reduced value at the end of the appraisal period is simply a fraction of the capital costs.

Sometimes the residual value will need to be calculated for individual components of the capital costs, e.g. pavements and bridges. An example could be an initiative which included a tunnel (100-year life) and pavements (up to 40 year life)[6].

Calculation of residual values may also be relevant in appraisal of maintenance initiatives (see section 10.3.3)

7.5 Crash benefits

Crash benefits of an initiative are equal to the reduction in crash costs attributable to the initiative.

For urban initiatives the range of methods for estimating crash benefits is limited because of the interdependence in urban networks. When a large initiative results in route shifting (trip diversion), crash risk may change at a myriad of locations in the network and not only at the site of the initiative. It then becomes difficult to estimate changes in crash risk at a site-specific level of detail. In these circumstances, estimation will focus on changes in risk exposure in the network as a whole (that is, the overall change in vehicle km of travel). The exceptions are those very site-specific initiatives that do not have network effects, for example, installation of a pedestrian crossing or pedestrian signals, installation of a raised median or a roundabout.

In rural appraisals crash benefits can be estimated on a risk exposure basis or by applying crash reduction factors to the site-specific or link-specific crash record.

7.6 Environmental benefits

Environmental benefits arise from changes in the impact of road use of the atmosphere, on ecosystems and on some elements of human amenity, in particular noise and community severance. Environmental costs in the base and project cases can be estimated in a number of ways. The simplest although not necessarily the most comprehensive method uses default values of environmental cost per vehicle kilometre of travel (see ATAP PV2).

7.7 Flood resilience benefits

Flood resilience benefits are addressed in ATAP Part O4 Flood Resilience Initiatives They are more a rural than an urban road issue. Road closure due to flooding increases road user costs because users are forced to either postpone or delay their trip, wait at the closed road until the road re-opens or divert around the closed road if alternative routes are available. The principal benefit of the flood immunity element of initiatives[7] is reductions in user wait and diversion costs.

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[6] For asset lives see (ATC 2006b)

[7] Flood immunity initiatives may be part of initiatives intended to achieve a broader range of objectives (for example, a realignment or replacement of a high maintenance timber bridge, or they may produce other benefits as a by-product (for example, replacement of a flood prone section of road incorporates provision of a wider, stronger pavement).

7.8 Wider economic benefits

The identification and valuation of wider economic benefits (WEBs) is addressed in Part T3 of these Guidelines. WEBs only occur for large urban initiatives in dense urban areas. They are likely to be most relevant to road projects that carry large numbers of workers to major employment centres. There are no methodological differences in WEBs estimation specific to road projects. Care is required to avoid double-counting of WEBs with any valuation of the benefits of increased employment of socially disadvantaged people (see Section 4.11 of Part M1).

7.9 Network access benefits

This is a less typical class of benefit that can arise when road agencies allow more productive vehicles to access the road network. The benefit is typically a reflection of reduced heavy vehicle operating costs and driver/vehicle time costs and possibly reduced crash costs because a given amount of freight can be carried with fewer vehicles. There may be some offsetting costs for other vehicles in the traffic stream because heavy vehicles are typically slower and more difficult to overtake.

Access changes are regulatory changes, so readers are directed to ATAP Part O7 where the economic assessment of regulatory initiatives is addressed.

Network effects may also arise in the form of transfer of freight from rail to road. ATAP T2 discusses the treatment of cross-modal effects in benefit estimation.

7.10 Construction disbenefits

Initiatives may cause delays to road users during construction, typically travel time delays or increases due to traffic diversion, or reduced speed limit, over the main construction period. In addition, negative disamenity effects during construction include noise, dust and vibration for nearby residents and businesses. Construction disbenefits are typically not estimated in Australia but are required for transport appraisals in New Zealand (NZTA 2016 p 2-9). At this stage, there is no generally accepted process for estimating construction disbenefits or for determining the type of scale of initiative for which construction disbenefits should be estimated.

8. Urban benefits

8.1 Definition of urban

The boundary between what we refer to as urban and rural is not precise. In general, urban refers to situations in our cities, and rural to situation outside those cities. For this chapter and the next, we refer to them as they relate to the appraisal of transport initiatives.

In urban environments, large road initiatives can result in traffic changing route, changing its destination, its time of travel or people choosing to travel by a different mode. Appraisals in urban areas must consider a sufficiently large portion of the transport system in the assessment to contain all the changes in travel that occur as a result of the initiative.

However, there are also exceptions to this general rule. Small initiatives, such as a local intersection upgrade, or the addition of a right turn pocket on a sub-arterial road, might have only small non-localised (network) benefits but the general proposition stands, that urban initiatives are more likely to have network effects that require appropriate solutions for the measurement of benefits.

8.2 Types of benefit

Table 11 shows the range of urban initiatives and the benefits they give rise to.

Table 11 Sources of benefit for urban initiatives

Initiative	Major benefit category	Minor benefit category
New motorways	Travel time cost saving Vehicle operating cost saving (but could be negative if trip distance increases) Environmental cost saving (could be negative if for example ambient noise levels and amenity of nearby residents are negatively affected)	Crash reduction
Additional through lanes on motorway or urban arterial	Travel time saving Vehicle operating cost saving	Environmental (possibly negative)
Intersection upgrades (signals, additional storage lanes, additional turning lanes, roundabouts, grade separation)	Travel time saving Vehicle operating cost saving	Crash reduction
Mid-block median closure	Crash reduction	Travel time and vehicle operating cost savings (both could be negative)
ICT solutions such as managed motorways	Travel time saving Vehicle operating cost saving	
High occupancy vehicle lanes including T2 or T3 lanes	Travel time saving Vehicle operating cost saving	Environmental

Speed management (use of variable message signs) for intra-day speed variation, permanent raising or lowering of speed limits	Travel time saving Vehicle operating cost saving	Environmental
Unsignalled pedestrian crossing	Crash reduction	Travel time and vehicle operating cost savings (both could be negative)

8.3 Estimating user benefits with travel demand model outputs

8.3.1 Role of travel demand models

Travel demand models (transport and traffic models) play a central role in urban road assessments because of the significant number of complex travel choices people make. The urban road network is dense, so alternative routes are almost always available. In addition, there are alternative mode choices such as walking, cycling and public transport. Any change in the road or intersection capacity will almost always result in a change of route for at least some traffic. If the initiative is big enough, there may also be a change in the choice of mode, the choice of a destination, or the time of travel for some trips. Demand models are able to assess this range of choices by simulating trips, traffic volumes and behaviour across both large networks and at individual sites.

Until recently, in the urban context, the effect of congestion and intersections has been thought to have a much bigger impact on travel effects than road roughness or lane width. Roughness has been assumed not to be relevant to user costs in urban environments where maintenance interventions are typically more frequent to manage high traffic volumes. Hence it has been normal practice in urban appraisals to assume that roughness and geometry effects of the road network are neutral in terms of assessing user benefits.

ATAP is presently reviewing the influence of width, roughness and alignment (horizontal and vertical) impacts on urban user costs. In the meantime, appraisers should continue to use the user cost algorithms in ATAP Part PV2.

Urban CBAs typically receive outputs from a demand model, whether it be a traffic model of a single intersection upgrade with highly localised impacts, or a strategic model of a major motorway having traffic impacts throughout its region.

8.3.2 Interface between appraisers and modellers

Two-way dialogue between demand modellers and appraisers, and the associated disciplines involved in planning, designing and appraising an initiative, are critical. The dialogue should start early, and occur throughout the planning and assessment process. Without this dialogue, suitable demand model outputs required by the appraiser may not occur.

Sometimes the demand modeller will be able to make an unambiguous judgement as to the appraisal's demand modelling requirements. In other instances, the demand modeller may need to advise on the initiative's likely footprint in terms of travel and traffic impacts, using graphic presentations such as traffic volume plots and heat maps. At the same time, the appraiser needs to clearly communicate the type of outputs required from the demand model at the various stages of the process.

Issues that should be addressed by appraisers and demand modellers at an early stage prior to commencement of a CBA include:

- Selection of an appropriate model
- The number of time periods to be modelled in each day (including whether inter-peak or off-peak periods should be modelled)
- The number of modelled days that should be modelled in each modelled year (including whether weekends and school holiday weekdays[8] should be modelled)
- The number of years to be modelled
- Whether a fixed trip or a variable trip matrix is to be used[9].

The interface between appraiser and modeller should also involve discussion and agreement at the beginning of the process as to what generalised cost values were to be applied in the model to ensure that any subsequent adjustments were made in the full knowledge of what values drove the traffic outputs.

8.3.3 Urban demand models used in Australia

ATAP T1 (pp 39-40) lists five types of urban travel and traffic demand modelling of which the first three are most directly relevant to urban road appraisal:

- Strategic models (including macrosimulation and macroscopic)
- Mesosimulation models
- Microsimulation models
- Nanosimulation models (not typically used in Australia)
- Hybrid modelling in which microsimulation and mesoscopic models are combined.

Proprietary models in each of the first three categories are shown in Table 12.

Table 12 Urban traffic models in use in Australia

Strategic	Mesosimulation	Microsimulation	Multilevel models
CUBE Voyager	Aimsun	SIDRA	VISUM
EMME	CUBE Avenue	Paramics	Aimsun
TransCAD	DYNAMEQ	VISSIM	CUBE
VISUM	SATURN		OMNITrans
	TRACKS		

[8] Typically, the modelled day is a working weekday outside of school holiday periods. See discussion regarding selection of expansion factors in Section 8.3.8.

[9] See ATAP T1 p 29 for an explanation of fixed and variable trip matrices and section 8.3.6 below.

Source: Roads & Maritime Services NSW (2013), p 3

Strategic models

Strategic models employ a four-step process — trip generation, trip distribution, mode split and trip assignment — and exist for most large metropolitan areas/regions. Strategic models support appraisals of large initiatives such as motorways and tunnels. They also provide traffic volume and route choice information that feeds into (and provides the boundary conditions) for detailed, localised models (mesosimulation and microsimulation). This type of model has the largest footprint but the lowest precision of the three main model types. On the other hand, these models are capable of accommodating a variable trip matrix and therefore of estimating induced demand.

Mesosimulation models

Mesosimulation (sometimes called mesoscopic) models are used to simulate traffic behaviour in a town or in part of a larger modelled region. If the latter, traffic volumes into and out of the local area are first determined by the region-wide strategic model. Route shifting then only occurs within the boundaries of the local area. Mesosimulation models are more detailed than strategic models but less detailed than microsimulation models. They do not have the capacity to estimate induced demand.

Microsimulation models

Microsimulation models are used to study traffic behaviour at the site level or the level of a small sub-network of roads and/or streets. The level of detail in microsimulation models is very fine and they are used to estimate queue lengths, waiting times and turning movements at intersections.

Microsimulation models use traffic volumes on links derived from large area models (see above) and hence have no capacity to estimate induced traffic. Therefore, microsimulation models have no ability to account for network level changes that result from site specific initiatives and hence no ability to estimate induced demand.

8.3.4 Application to initiative types

Examples of model selection according to initiative footprint are shown in Table 13.

Table 13 Traffic model selection according to initiative footprint

Initiative type and footprint	Traffic model type	Variable or fixed trip matrix
Major Motorway expansion or extension, or other major road initiative, with one or more of: • Influences beyond the immediate local network • Impact on trip number, trip distribution (origin-destination) or mode choice	Strategic	Variable
Major intersection with local area network implications only	Mesoscopic	Fixed
Program of local area network changes only	Mesoscopic	Fixed
Localised intersection upgrade	Microsimulation	Fixed

Note: Microsimulation models may be informed by trip demands from a mesosimulation model, which in turn might be informed by strategic models.

8.3.5 Issues with traffic models

Strategic models

Strategic models have the most comprehensive network coverage and the capacity to accommodate both fixed and variable trip matrices but relative to mesoscopic models their inability to simulate the effects on traffic flow of intersections and queuing leads them to estimate unrealistic network loads. They also lack the ability to model traffic behaviour (weaving, intersection delays) that is present in mesosimulation models.

Strategic models are best used to:

- Model very large initiatives for which the scope of impacts (for example mode shift or generated traffic) is more important than the detail of changes in traffic behaviour on individual links and at individual intersections
- Inform the more detailed mesoscopic or microsimulation models by providing the travel inputs at the region or local boundaries of those sub-models.

Mesoscopic models

Mesoscopic models have processes for constraining the entry of vehicles into the modelled area according to the available network capacity. Because each run of a mesoscopic model is time bound — for example, one hour AM peak — traffic volume may be higher in the project case than in the base case because additional capacity in the project case allows more traffic to proceed through the modelled intersection or network within the modelled period compared with the base case. The result is understatement of benefits because project case total user costs will be higher than base case user costs.

One solution would be to treat the additional project case traffic as generated traffic but this may not be appropriate because some of that additional project case traffic will represent traffic that was queued in the project case, waiting to enter the network or intersection. The effect of the initiative is, in part, to allow more road users to travel at their preferred time rather than to generate trips.

An alternative solution is available if the traffic model reports uncleared queues for the base and project case in terms of vehicles queued at the end of the modelled period and the average time spent in the queue. Where this data is available, include vehicle hours spent in queues in the base case and project case vehicle hours of travel to facilitate comparability of base case and project case demand[10] .

[10] Also see Roads & Maritime Services NSW (2013), pp 124-125

Microsimulation models

Microsimulation models have no ability to account for network level changes that result from site-specific initiatives — in other words there is no feedback from the initiative to the network. Hence the use of microsimulation models in appraisals is best confined to localised initiatives. As an example, the grade separation of an open level crossing (OLC) could cause a change in route choice at the wide area network level. The microsimulation model would estimate changes in vehicle hours travelled (including delay) through the intersection and sometimes in vehicle km travelled through the local network but would not be able to simulate the effects of trip diversions outside of the modelled area as road users alter their route choice in response to the removal of the OLC. Use of microsimulation model outputs in these circumstances could cause the benefits of the initiative to be overstated as unrealistic queues build up at the subject site in the base case.

Where this problem arises, a solution might be to have the analysis period end just before the modelled year during which the intersection or network 'breaks down' in the base case (reaches an unsustainable level of congestion or queuing). Alternatively, it might be prudent to use the outputs from a local area or wide area model so that the network effects of worsening congestion in the base case can be captured in the appraisal.

8.3.6 Desirable model outputs

Strategic models using variable trip matrices

When a strategic model is run with variable trip matrices (one for each mode), user costs must be calculated on an origin to destination (O-D) trip basis for each transport mode. This is required in order to derive changes in the generalised cost of travel, associated changes in trip numbers, and using these the changes in consumer surplus.

This means that much of the initial estimation of benefits will take place within the strategic model before being passed to the CBA model for further analysis.

Likely outputs from the strategic model for each modelled period would be:

- Matrices of the generalised costs of travel and trip numbers, for each mode, for consumer surplus change calculations, and for aggregation of calculations into relevant summary information
- A breakdown into benefit components such as travel time benefits and vehicle operating cost savings, when feasible and requested
- A range of other aggregate and disaggregated outputs, e.g.:
  - By area, corridor, route or link
  - By road type, vehicle type and speed categories.

As mentioned in sections 5.5 and 0, correct estimation of benefits may necessitate resource corrections to account for the effects of taxes, charges, subsidies and any misperception of user costs (see ATAP T2 Chapter 6 for relevant discussion).

If the initiative is expected to have cross-modal effects, the CBA will need to consider whether there are benefits or disbenefits in other modes (including resource corrections, e.g. for public transport fares paid — see ATAP M1 p 27).

Appraisers and modellers should ensure that the strategic model uses suitable unit travel time costs and that an appropriate algorithm is used for the estimation of vehicle operating costs (see section 8.3.13 and 8.3.14 below). Unit travel time costs (value of travel time savings) should ideally be behavioural values in demand modelling and equity values in appraisal (see discussion in ATAP M1 section 5.1).

Strategic models using a fixed road trip matrix

Some road initiatives may affect route choice across a significant part of the road network, but not be significant enough to affect mode choice, destination choice or the number of trips made. In this situation, the initiative is assessed using a fixed road trip matrix, with road trips between origins and destinations fixed (the same) in both the base case and project case. User benefits can then be calculated as the difference between base case and project case user costs based on the model's network-wide outputs of:

- Vehicle hours of travel in the base and project case in each modelled period
- Vehicle kilometres of travel in the base and project case in each modelled period.

Mesoscopic models

Mesoscopic models should provide the following outputs for each modelled period in each modelled year:

- Vehicle hours of travel
- Vehicle kilometres of travel
- Number of vehicles queued on the model boundaries at the end of each modelled period
- Time spent in queues by vehicles queued on the boundaries of the model
- Numbers of trips in the network.

Microsimulation models

Microsimulation models will provide some or all of the following inputs relevant to CBA for the base and project cases) for each modelled period in each modelled year:

- Vehicle hours of delay
- Fuel burn
- Vehicle hours of travel
- Vehicle kilometres of travel
- Air emissions (kg)
- Road user costs (note these should not be used unless the underlying cost algorithms comply with ATAP guidance).

As noted earlier, very high levels of base case congestion should be treated with caution.

8.3.7 Selecting appropriate model years, periods and days

Years

Demand modelling exercises typically produce model outputs for a limited number of years because of the expense and time involved in modelling. This can have serious implications for the quality and reliability of the appraisal. From an appraisal perspective, outputs for three modelled years should preferably be provided to the appraiser as follows:

- One year close to the initiative's first year of operation
- A horizon year determined by either:
  - The limit of the available demographics underpinning the traffic modelling (in the best circumstances that might be 30 years after the initiative's first year of operation), or
  - The year in which the initiative begins to 'break down' (reach undesirable levels of congestion).
- At least one intermediate year is required to assist in 'shaping' the benefit profile. This is usually important in urban settings because benefits (especially travel time related) can grow at different rates over the appraisal period, for a number of reasons:
  - Travel time grows at an increasing rate compared to increases in traffic level (a non-linear relationship) as congestion builds
  - Population growth may grow at different rates over the appraisal period.

Travel and traffic statistics, and benefit estimates, for years between modelled years can be found by linear or exponential interpolation (see below).

Periods

It is helpful to be able to run the model for multiple periods throughout the day. The ideal is to run the model for each of the four periods: AM peak; PM peak; Inter-peak (from AM peak to PM peak); Off-peak (from PM peak to AM peak), This is best practice, and some jurisdictions do this.

The alternative, adopted by some jurisdictions, is to just model the peak periods because they are influential in determining the design characteristics of the initiative. In these cases, appraisers should seek outputs for both the AM and PM peak periods because often the peaks are not the same in terms of traffic behaviour.

Days

The appraiser should also consider whether the model should be run for some of the weekend period, e.g. the Saturday shopping peak if site, link or network volumes are high relative to weekday volumes. In areas where recreational traffic is important on weekends and/or during school holidays, consideration should be given to carrying out modelling that represents these periods.

Having model outputs for multiple periods across the day, week and the year reduces the uncertainties in the use of expansion factors (see below).

8.3.8 Expansion factors

The CBA requires annual user costs and benefits in the modelled years. These need to be estimated by applying ‘expansion factors’ to the demand model outputs discussed above. The modelled period or modelled day user costs or benefits obtained from demand model outputs need to be ‘expanded from each modelled period’ to a modelled day and then from a modelled day to a modelled year so that annual benefits can be calculated. This section provides general discussion on estimating parameter values. Each jurisdiction can then apply the methodology using local data to develop local expansion factors.

Expansion from peaks, inter-peak and off-peak to all day

Where all four of the AM peak, PM peak, inter-peak and off-peak periods have been modelled, all day benefits are calculated by simply aggregating across the periods. Typically, each of these periods would be modelled for a representative hour, so aggregation to all day requires recognition of the number of hours in each period.

Expansion from peak to all day

Desirably, traffic modelling will have covered at least the AM and PM weekday peaks.

Because network speed or delay at an intersection is not necessarily linear with volume, there is no ready way to expand from peak to all day user costs.

For localised initiatives (those having no significant network effects), a modelled off-peak hour could be expanded according to the number of hourly periods in which traffic volumes are similar to those of the modelled off-peak hour (provided turning movements are fairly symmetrical across the off-peak period; referred to here as ‘matching’).

For initiatives with significant local area or wide area network effects, this ‘matching’ approach is not recommended because user costs and hence benefits are not just dependent on volumes. Other factors including variations across the off-peak period in trip origin and destination and route might also be relevant resulting in differences in user costs between time slices in the off-peak. For example, trip characteristics around school pick-up times are unlikely to be similar to those during the middle of the day.

Similar considerations are relevant in applying day to year expansion factors (see below) in that network trip patterns on weekdays are unlikely to be similar to those of weekend days. To a lesser extent there may be variations in trip patterns (and trip volumes) between school period weekdays (from which the modelled day is typically derived) and school holiday weekdays.

In these circumstances there is no substitute for widening the range of modelled hours if a comprehensive estimation of benefits is to be achieved. Methods for estimating expansion factors that rely on ratios between annual volumes or annual user costs and daily volumes or daily user costs are not recommended because the marginal relationships between modelled period user costs and daily and annual user costs might not be the same as the average relationship[11] particularly if an initiative encourages generated or induced trips or it affects peak trip behaviour more strongly than trip behaviour in the off-peak.

Expansion from day to year

The most common practice is for model outputs to be generated for the average weekday, for which there are typically 250 (that is, 260 weekdays less an allowance for around 10 public holidays annually). An expansion factor is then required to convert the average weekday results to annual results, in order to reflect the benefits on public holidays and weekends. If there are no benefits on weekends and public holidays, the expansion factor would be 250, representing just the average weekdays. If benefits are expected to occur on weekends and public holidays, an expansion factor above 250 would is required. The factor must reflect the 'equivalent number of average weekdays' of benefit that are expected to occur on weekends and public holidays. Key determinants will be the level of congestion during those times, traffic volume, traffic composition and route choice.

The expansion factor to use will vary between jurisdictions, and between urban and rural settings, and should be evidence-based as much as possible. Where jurisdictional guidelines exist, they should be consulted for suitable evidence-based expansion factors.

If it is feasible, modelling of weekend and public holiday periods greatly reduces the uncertainties associated with the use of expansion factors. In towns and cities where holiday period volumes are high relative to volumes in non-holiday periods separate model runs might be desirable for holiday and non-holiday periods.

8.3.9 Estimating user costs in intermediate years

Because user cost estimates are likely to be supported by only two to three individual years of traffic modelling outputs, a way is needed for estimating user costs in the intermediate years. If user cost estimates are supported by traffic model outputs for years 1, 10 and 20 for example, user cost estimates will need to be inferred for years 2 to 9 and 11 to 19. The simplest means of doing this is by linear or exponential interpolation.

8.3.10 Extrapolating beyond the last modelled year

The application of traffic models is ultimately constrained by the availability of demographic forecasts - particularly population and employment - which are the basis of trip forecasting. If official demographic forecasts have a horizon of 20 years, traffic modelling of a 30-year initiative will be constrained in the latter 10 years of the initiative life. Modellers might seek to make their own forecasts to fill in the gap but they seem generally reluctant to produce modelling that is not supported by official demographic forecasts.

[11] That is, the ratio of the change in all day costs to the change in modelled peak period costs or the ratio of change in annual costs to the change in daily costs.

The appropriate approach will be influenced by whether:

- The initiative has network implications, and
- The trip matrix is fixed or variable.

For localised initiatives it might be appropriate to extrapolate benefits at the rate of benefit growth between the penultimate and final modelled years, provided the subject site has the capacity for continuing traffic. Otherwise, assume benefits to be constant from the last modelled year onwards[12].

A similar approach could be adopted when mesoscopic or strategic modelling is used, provided the trip matrix is fixed.

The position is less clear when a variable trip matrix is employed, because induced traffic could cause benefits to start declining at some point (that is, because induced traffic increases project case user costs for existing users). In these circumstances, the assumption of a continuation of benefits of the last modelled year might be overly optimistic and accordingly the following sensitivity tests are suggested:

- Declining benefits with a sensitivity test of 'flat lining' benefits, or
- Flatlining benefits with a sensitivity test in which the final modelled year's decline over the remainder of the appraisal period. For further discussion, see DfT (2018) section 2.4.

8.3.11 Calculating user benefits according to vehicle type

Traffic models typically produce the outputs required for the CBA (generalised costs, vehicle hours and vehicle kilometres of travel) by coarse categories: light and heavy vehicles, or private and commercial vehicles. Estimates of these in finer vehicle categories can then be produced by using data from two other sources:

- For localised initiatives — nearby classification counts can provide a basis for converting model outputs into a finer vehicle class disaggregation for subsequent calculation of travel time costs and vehicle costs.
- For local and wide area network-based CBAs — road usage data from the Australian Bureau of Statistics *Survey of Motor Vehicle Use* and/or average traffic composition derived from a range of classification counting sites in the network might be used to derive traffic composition by vehicle class.

8.3.12 Induced demand benefits

Only strategic models are capable of estimating generated and induced traffic. When an initiative is expected to cause generated or induced traffic, a strategic mode with variable trip matrices needs to be used, and the rule-of-the-half is applied in estimating user benefits for any generated and induced trips. There are two reasons why strategic models only are suitable for this purpose:

[12] See DfT 2018.

- Only strategic models can operate on an origin-destination basis. Changes in demand as a function of generalised travel cost, necessary to calculate consumer surplus changes for induced traffic, can only be estimated across full trip lengths
- Only strategic models have the capacity to simulate changes in origin, destination and mode that are features of the variable trip matrix.

ATAP T2 (chapter 6) describes the analytical steps in the estimation of the change in consumer surplus. As discussed in section 8.3.6, the model outputs required are the O-D matrices of generalised cost of travel and trip number, for each mode, for each modelled period in each modelled year, broken down for light and heavy or private and commercial vehicles. Post-processing of benefits into finer groupings of vehicle types, interpolation of benefits between modelled years and extrapolation of benefits would be done in the separate CBA model (usually Excel based).

8.3.13 Travel time benefits

If a mesoscopic or a microsimulation model is feeding into the CBA model, travel time benefits are equal to the difference between user travel time costs in the base and project cases. The difference between base case and project case vehicle hours of travel from the traffic model, multiplied by the unit value of travel time savings (VTTS) for each vehicle class in ATAP PV2 will yield travel time benefits in each modelled period in each modelled day. Those estimates are then multiplied by daily and yearly expansion factors (see section 8.3.8) to obtain estimates of yearly benefits.

If a variable trip matrix is used, it is likely that travel time benefits in each modelled period will be calculated within the traffic model (see section 8.3.12).

Whichever traffic model is used, unit VTTS per person-hour in ATAP PV2 will need to be adjusted for vehicle occupancy rates (also in ATAP PV2) to convert to VTTS per vehicle hour. ATAP Part PV2 provides default average occupancy rate figures. Readers should note that there is currently some variation between the default occupancy rates provided in PV2 and those in Infrastructure Australia guidance (IA 2018 — see section D3.11 for a discussion of the differences). As with other parameter values, the ATAP default occupancy rates can be replaced if better information is available, such as reliable local project specific data or reliable traffic model outputs.

In addition, benefits will need to be calculated by vehicle type (see section 8.3.11). This is done by applying traffic composition data to the highly aggregated vehicle hours of travel estimates provided by the traffic model (usually light vehicles and heavy vehicles or private vehicles and commercial vehicles).

8.3.14 Vehicle operating cost savings

If a microsimulation model or other models with a fixed trip matrix are used to provide inputs to the CBA model, vehicle operating costs (VOC) savings are equal to the difference between vehicle operating costs in the base and project cases. The difference between base case and project case vehicle kilometres of travel from the traffic model multiplied by the unit VOC algorithms in ATAP PV2 will yield VOC savings in each modelled period in each modelled day. Those estimates are then multiplied by daily and yearly expansion factors (see section 8.3.8) to obtain estimates of yearly benefits.

As well as vehicle kilometres of travel, the traffic models also estimate vehicle speed for each of the highly aggregated vehicle types for each modelled period in the base and the project case. These speeds are then entered into the relevant VOC algorithm in ATAP PV2 to obtain unit VOC for each modelled period and case according to vehicle class. The application of the algorithms is explained in ATAP PV2.

If microsimulation modelling is limited to movements at an intersection, estimation of VOCs is confined to fuel costs (see section 9.8 below) although in NSW the VOCs of stopping at intersections (with and without fuel costs) are also estimated (see TfNSW (2016) Appendix 4).

If a variable trip matrix is used, it is likely that changes in VOCs for each of the broad vehicle classes (private and commercial or light and heavy) will be estimated within the traffic model. Because only the perceived component of VOCs is subject to the rule-of-the-half, a VOC algorithm that calculates fuel costs separately should be used (see Austroads 2008).

ATAP PV2 contains two interrupted flow algorithms for estimation of VOCs, the breakpoint between the models being an average network speed of 60km/h. The interrupted flow model is unreliable at low average network speeds. When network speeds are estimated to be 20 km/h or less, a 20 km/h speed should be used for estimation of vehicle operating costs.

It should be noted that there is currently some variation in the VOC guidance provided by ATAP in PV2 and Infrastructure Australia in its guidance (IA 2018, see section D3.11 for a discussion of the differences).

8.3.15 Reliability benefits

Reliability refers to unpredictable journey time variability, due to congestion and incidents (crashes, breakdowns, lost loads etc). Reliability does not refer to day to day, or within time travel time variations attributable to variations in demand. Reliability is in the roads context for non-public transport trips typically measured as the standard deviation of travel time (see DfT 2017, p 12).

Estimation of the benefits of improved reliability involves:

- Estimation of the change in standard deviation of travel time
- Application of a reliability ratio reflecting the unit benefits of improved reliability per hour relative to the unit benefits of improved in-vehicle travel time per hour
- Multiplying the number of trips by the change in standard deviation of travel time, the reliability ratio and the value of in-vehicle travel time.[13]

The rule-of-half will need to be applied if the initiative causes generated traffic (see DfT 2017, p 14).

At this stage pending further research on Australian applications, reliability benefits should not be included with the traditionally measured benefits in the CBA. They could be included however as a sensitivity test (see section 6.3**Error! Reference source not found.**).

[13]

8.4 Environmental benefits

Road transport can produce a range of negative environmental impacts including greenhouse gases, noxious air emissions, noise, visual and other disamenity, severance of communities and destruction of local ecosystems. Some of these impacts are mitigated in the initiative design phase by environmental, heritage and other regulation. There may also be positive impacts, such as improved amenity within a town when a town bypass is built.

ATAP Part PV5 provides unit cost estimates of these environmental impacts. ATAP PV2 also contains complementary vehicle emissions rates expressed as emissions per litre of fuel consumed. ATAP PV2 also contains algorithms for estimation of fuel use in uninterrupted flow and intercepted flow conditions.

8.5 Crash benefits

The crash benefit of an initiative in a given model year is the crash cost in the Base Case minus the crash cost in the Project Case (ATAP T2), where the crash cost in both cases are calculated as the product of two items:

- The number of crashes
- The unit crash cost.

The number of crashes can be calculated using two methods:

- Crash risk — can be estimated as the product of risk exposure (vehicle kilometres (vkm) of travel) and unit risk levels by model road state [cross-section] (crashes per vkm) — used for assessing initiatives with network effects
- Crash reduction factors — applied to the crash record at the subject site — relevant to assessing intersections, interchanges and railway level crossings.

8.5.1 For specific sites — crash reduction factors method

For specific sites such as intersections and open level crossings, crash reduction factors can be applied to the crash record to estimate base case and project case crash costs. The method is explained in Austroads (2015). Using this method, crash reduction factors (CRF) or crash modification factors (CMF)[14] are applied to the crash record which should include the number, type (DCA code) and severity of each crash. Crash modification factors are contained in Austroads (2015). Unit crash costs according to severity are contained in ATAP PV2.

[14] Crash modification factor equals 1 *minus* crash reduction factor.

The crash record should be converted to annual numbers of crashes according to type and severity by averaging across the period of the crash record. Sometimes road agencies will have crash records that go back many years. However, no more than the last 10 years of the crash record should be used because changes over time in network layout, congestion levels, vehicle technology and driver behaviour (e.g. use of mobile phones while driving) could cause underlying changes in crash propensity.

8.5.2 Initiatives with network effects — risk method

If an initiative is expected to have network effects, base case and project case crash costs will need to be estimated using the risk exposure method because it is impractical to estimate changes in crash risk at all sites in the network where crashes do or could occur. In addition, changes in traffic volumes on individual links as a consequence of an initiative reduce the relevance of the crash record as a basis for estimating savings in crash costs.

Vehicle-kilometres of travel (vkt) in the modelled network is the key data input that is then applied to network-wide estimates of crash risk per million or per hundred million vkt. A refinement of this method is to use crash risk for different levels in the road hierarchy (for example, motorway, arterial, sub-arterial) and to source vkt from the traffic model for each level of the road hierarchy within the model footprint.

Weighted average unit crash costs can be calculated at the state level, regional level or within the modelled area, subject to the availability of crash record data.

Crash rates are available at the state level according to a broad categorisation of road stereotype in Austroads (2010).

An average crash cost can be estimated by applying the unit crash costs according to crash severity in ATAP PV2 to the composition of crashes according to severity in the relevant network. Alternatively, individual road agencies might specify an average crash cost for use in their jurisdictions.

Numbers of crashes in the base case and project case/s can be assumed to grow at the rate as the traffic volume.

9. Rural benefits

9.1 Definition of rural

In rural environments where network densities are sparse and network effects are unlikely, transport links can be evaluated either in isolation, or in reference to the relatively fewer links that are affected by improvements. In addition, low traffic volumes result in alignment and surface condition being important means of reducing vehicle operating costs, and thus generating benefits. Models and procedures for rural network appraisal in Australia have been harmonised across jurisdictions, and broadly reflect ATAP Part PV2. Some jurisdictions have packaged up these models into local software (e.g. REVS, CBA6).

Regional cities and country towns could be a grey area in the distinction between urban and rural. Initiatives in provincial cities are best treated as being urban. In relatively small regional towns where the cost of developing local area traffic models might be difficult to justify, a combination of mid-block (uninterrupted flow) and rural appraisal methods supplemented by microsimulation modelling of intersections could be considered.

9.2 Types of benefit

Travel effects in the rural context typically concern road attributes only. Traditionally, economic assessment of road initiatives is built around inventory records of the road system containing details on geometry (gradient and curvature), seal or pavement width, surface type and road roughness with traffic volumes, traffic composition and growth rate being added to the inventory. The travel costs are then calculated by separately estimating the value of each of its components.

For rural contexts, vehicle operating costs are mostly assessed on the basis of uninterrupted flow conditions (i.e. no intersections).

A strong assumption that traffic is held constant between the base case and project case analysis is often made in these analyses. Where the number of lanes is not being increased, the change in travel effects will mostly come from the effect of changes in one or more of the inventory items, for example, reduction in road roughness, increasing the speed value of low speed curves or increase in lane width.

For rural applications, traffic volumes over time typically involve appraisers providing information on how traffic varies over the 8760 hours of the year. Information is usually provided for predefined sets of hourly traffic volume categories, with the unit of measurement being percent of AADT (annual average daily traffic). This practice has now been adopted by the HDM-4 procedure, whereas its predecessor the HDM III did not have this facility (see Thoresen and Michel, 2002)[15].

[15] Austroads 2005a

9.3 Rural models used in Australia

State models have been developed in various degrees by each jurisdiction over the years to use in the economic appraisal of road infrastructure investments. Each of the five larger jurisdictions in Australia uses and maintains its own computer-based model to estimate the effects on travel costs of alternative proposals and strategies for investment in road infrastructure.

Travel cost models in Australia fall into two distinct 'families', namely NIMPAC and HDM. There are differences in scope as well as detail between models in these two families. NIMPAC models are based on Australian work in the 1970s led by NAASRA and the then Commonwealth Bureau of Roads culminating in the NIMPAC Road Planning Model, completed in 1981. HDM models are based on the World Bank Highway Planning and Management Models (HDM III) released in 1987 and the Highway Development and Management model (HDM-4) released in 2000 (version 1).

Modelling procedures used by road and transport agencies fall into two categories in terms of capabilities and coverage - full models and look-up-table models. Only one agency, the Roads and Traffic Authority of New South Wales, currently employs models in both categories. Full models automatically generate travel cost estimates tailored to fit specified appraisal tasks. This is accomplished via within-model computation of travel speeds, and their subsequent utilisation in calculating speed sensitive travel cost components such as fuel costs and travel time savings. In contrast, look-up-table models provide the user with a range of intermediate travel cost data, in the form of a series of look-up tables where estimated travel cost items are cross tabulated by a set of fixed pre-determined speeds. In order to make use of this data, analysts are required to choose the appropriate speed of vehicle operation and to manually enter selected data into appraisal applications.

Despite these differences, these two model categories share common estimation methodologies and sources of data, and are both harmonised. However, full models are mostly incorporated into broader fully developed appraisal methodologies in which travel cost estimation forms one component part. Each of the look-up-table models consists of a stand-alone travel cost estimation procedure. Details of these models are described in the associated Evaluation Manuals produced and maintained by each jurisdiction.

9.3.1 Travel cost components

Each of these models generates estimates of travel costs at an individual component level. These components are subsequently aggregated to provide estimates of total travel costs. Table 14 below distinguishes between those factors which road and transport agencies can affect via road works and other interventions, and those determined by users.

There are also significant differences between NIMPAC and HDM III style models in terms of the ways they quantify the effects of pavement width, number of carriageways and access control. However, HDM-4, the successor model to HDM III, incorporates a width and road capacity speed adjustment similar to the NIMPAC relationship, which will bring the two evaluation model families closer together when the HDM-4 models become widely used in Australia.

Table 14 Factors affecting travel cost components-relationships assumed in road evaluation

Travel cost items and other units	Speed	Vehicle characteristics			Road infrastructure characteristics (7)					Traffic volume (PCEs)(7)
		Type & specs.	Mass	Fuel Type	Gradient	Curvature	Width access & capacity	Surface type & condition	Speed limits etc	
Speed		✓			✓	✓	✓ (3)	✓ (4)	✓	✓
Vehicle operating costs										
Fuel & oil	✓	✓	✓	✓	✓	✓		✓		✓
Tyres	✓	✓			✓	✓		✓		✓
Repair & maintenance		✓						✓		
Depreciation	✓ (1)	✓						✓ (2)		
Interest	✓ (1)	✓						✓ (2)		
Overheads	✓ (5)	✓								
Time costs										
Private travel	✓ (6)									
Business travel	✓ (6)									
Driver	✓ (6)									
Freight delay	✓ (6)	✓								
Other costs										

Note 1: Not for cars.
Note 2: ARRB TR variant of HDM III only. Road surface type affects depreciation in all NIMPAC style models.
Note 3: In HDM road widths affect speeds when pavement widths are less than 4.5 metres.
Note 4: Road surface type NIMPAC models only.
Note 5: HDM III models only.
Note 6: Calculations require cost per hour inputs provided in other Austroads publications, e.g. AP-R218/03 and AP-R241/104 (Austroads 2003, 2004).
Note 7: Road infrastructure characteristics affect free speed, while traffic volume combined with road infrastructure characteristics determine the volume–capacity ratio and in turn actual speed.

Source: Adapted from Austroads (2005a)

9.4 Understanding the effects of congestion

Volume–capacity ratio (VCR) measures congestion on midblock road sections. Congestion is not only an urban road concept. Even low volume roads can become congested. A midblock road section is congested in a technical sense when the traffic volume is large enough as to cause speed to fall below the road's free speed (which in turn is determined by the road's seal width, number of lanes, whether divided or undivided and alignment (horizontal and vertical) see Figure 2). Wider roads have higher capacity than narrow roads and divided roads have higher capacity than undivided roads. Austroads (2005a) contains estimates of road capacity according to model road state (MRS)(see Table 15). These capacity values are used in the NIMPAC-style rural integrated models.

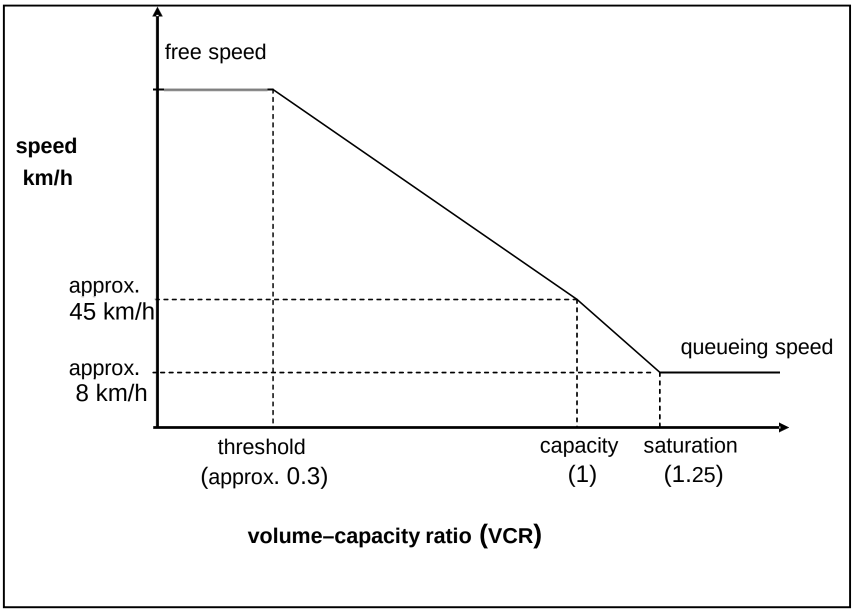
Table 15 Model road state (MRS) descriptions

<table>
<tr><th colspan="2">Road Type</th><th colspan="2">RURAL(WA)</th><th colspan="2">REVS/CBA 4</th><th colspan="2">Eval 4</th></tr>
<tr><th>Carriageway type</th><th>Surface</th><th>MRS</th><th>Sealed/paved width (m) per carriageway</th><th>MRS</th><th>Sealed/paved width (m) per carriageway</th><th>MRS</th><th>Sealed/paved width (m) per carriageway</th></tr>
<tr><td rowspan="17">Undivided</td><td>Natural surface</td><td>1</td><td></td><td>1</td><td></td><td>1</td><td></td></tr>
<tr><td>Formed roads</td><td>2</td><td></td><td>2</td><td></td><td>2</td><td></td></tr>
<tr><td rowspan="2">Gravel</td><td>3</td><td><=4.5</td><td>3</td><td><=4.5</td><td>3</td><td><= 4.6</td></tr>
<tr><td>4</td><td>>= 4.5</td><td>4</td><td>>=4.5</td><td>4</td><td>>=4.6</td></tr>
<tr><td rowspan="13">Sealed</td><td>5</td><td><= 4.5</td><td>5</td><td><=4.5</td><td>5</td><td><=4.3</td></tr>
<tr><td>6</td><td>4.51-5.2</td><td>6</td><td>4.6-5.2</td><td>6</td><td>4.3-5.2</td></tr>
<tr><td>7</td><td>5.21-5.8</td><td>7</td><td>5.3-5.8</td><td>7</td><td>5.2 - 5.8</td></tr>
<tr><td>8</td><td>5.81-6.4</td><td>8</td><td>5.9-6.4</td><td>8 (9)</td><td>5.8-6.4</td></tr>
<tr><td>9</td><td>6.41-7.0</td><td>9</td><td>6.5-7.0</td><td>10</td><td>6.4-7.0</td></tr>
<tr><td>10</td><td>7.01-7.6</td><td rowspan="4">10</td><td></td><td rowspan="4">11(12)</td><td></td></tr>
<tr><td>11</td><td>7,61-8.2</td><td>7.1-9.1</td><td>7.0-9.2</td></tr>
<tr><td>12</td><td>8.21-8.8</td><td></td><td></td></tr>
<tr><td>13</td><td>8.81-9.4</td><td></td><td></td></tr>
<tr><td>14</td><td>9.41-10.0</td><td></td><td></td><td></td><td></td></tr>
<tr><td>15</td><td>10.01-11.6</td><td>11</td><td>9.2-11.6</td><td>13(14)</td><td>9.2-11.6</td></tr>
<tr><td>16</td><td>11.61-13.7</td><td>12</td><td>11.7-13,7</td><td>15</td><td>11.6-13.7</td></tr>
<tr><td>17</td><td>>=13.7</td><td>13</td><td>>= 13.7</td><td>16</td><td>13.7-20.1</td></tr>
<tr><td rowspan="6">Divided</td><td rowspan="6">Sealed</td><td>18</td><td><= 7.6</td><td rowspan="4">14</td><td></td><td rowspan="5">17 (18)</td><td></td></tr>
<tr><td>19</td><td>7.61 -8.2</td><td><=9.1</td><td><=9.7</td></tr>
<tr><td>20</td><td>8.21-8.8</td><td></td><td></td></tr>
<tr><td>21</td><td>8.81-9.4</td><td></td><td></td></tr>
<tr><td>22</td><td>9.41-11.6</td><td>16</td><td>9.2-11.6</td><td></td></tr>
<tr><td>23</td><td>> 11.6</td><td>18</td><td>>11.6</td><td>20 (21)</td><td>> = 9.7</td></tr>
<tr><td rowspan="3">Freeways</td><td>Sealed (4 lane)</td><td>24</td><td><= 9.4</td><td>15</td><td>=<9.1</td><td>(19)</td><td></td></tr>
<tr><td>Sealed (6 lane)</td><td>25</td><td>9.41-11.6</td><td>17</td><td>9.2-11.6</td><td>(22)</td><td></td></tr>
<tr><td>Sealed (8 lane)</td><td>26</td><td>>=11.6</td><td>19</td><td>>=11.6</td><td>(23)</td><td></td></tr>
</table>

Source: Austroads 2005a

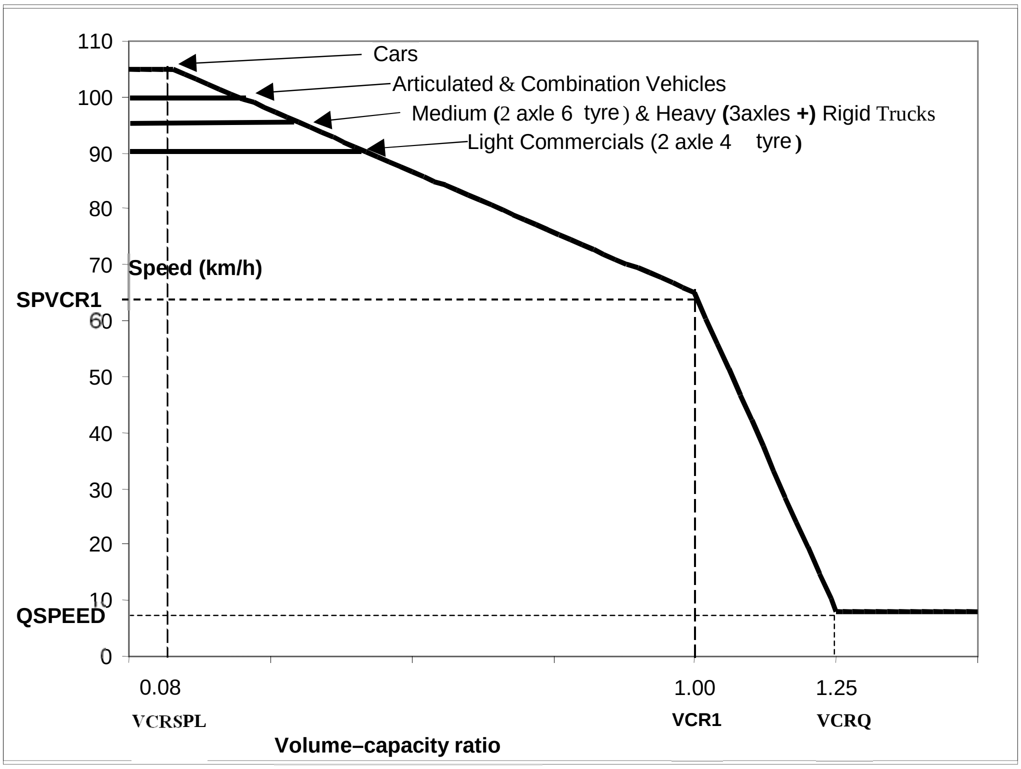
From Figure 2 it can be seen that, up to a critical volume–capacity ratio level (VCRSPL), increasing traffic measured in passenger car equivalents (PCE's) has no impact on vehicle speeds. As traffic levels grow beyond that level, effective volume–capacity ratios increase and speeds for cars fall. In Figure 3, speeds for other vehicle types are unaffected until car speeds approach their levels, and thereafter speeds for these types and for cars are the same. In the example shown in Figure 3, speeds for all vehicles conform to the car norm after speeds have reduced below 90 km/h. Speeds for all vehicles then decline linearly until a VCR of 1.0 is achieved. Vehicle travel speeds at maximum traffic flow vary by road stereotype. Figure 3 shows how the free speed varies according to vehicle type, with cars having the highest free speed and light commercial vehicles the lowest.

Figure 2 Effect of congestion on operating speed



Source: Austroads 2006

Figure 3 Effect of congestion on vehicle operating speed*



** Flat straight roads, Roughness = NRM 50, MRS = 8*

Source: Austroads 2005a

In NIMPAC style models, traffic capacity is allowed to exceed that associated with a volume–capacity ratio (VCR) of unity, for computational purposes, with such flows not being observed in practice. In this context traffic growth up to a point where a volume–capacity ratio of 1.25 and notionally beyond is permitted, with travel speed declining to a notional queuing speed. Harmonised non-urban models, to which this section applies, assume uninterrupted flow conditions and therefore shall not be used when the volume–capacity ratio would exceed 1. This extension was added to NIMPAC style models, due lack of capability in some variants to reassign excess traffic to other roads in the network in which the road initiative or initiatives being economically assessed were located. This adjustment was essential to obtaining acceptable results from the overall assessment procedure. It follows however, that speed flow relationships beyond a VCR of 1 are not comparable with relationships reported in other, particularly overseas economic assessment models.

9.5 Estimating VOC and travel time savings

The integrated rural models use a series of algorithms relating traffic volume, road seal width (sometimes expressed in terms of MRS, roughness, horizontal and vertical alignment, surface type and road stereotype to speed and hence to vehicle operating costs and travel time costs. The operation of these models is described in Austroads (2005a), which provides tables of values for free speeds, SPVCR1, VCRSPL and capacity for each MRS. MRSs are as described in Table 15 above.

9.5.1 User cost variables

Table 16 shows the variables that determine user costs in each user cost category. Speed, one of the key variables is influenced by road characteristics and traffic volume, and in turn influences other cost categories — fuel consumption, tyre wear, vehicle depreciation and vehicle repairs and maintenance.

Table 16 Variables of component costs

Travel Costs Category	Travel Costs Variables	
Vehicle operating costs	• hourly flow rate distribution throughout the year • traffic volume • traffic composition • vehicle type • seal or gravel pavement width	• surface type • road roughness • speed of travel • road curvature • road gradient
Speed of travel	• number of lanes • lane width • gradient • curvature	• roughness • traffic volume • change in flow rate throughout the year
Fuel consumption	• vehicle type • fuel type • speed • gradient	• curvature • surface type • roughness
Oil consumption	• engine size	
Tyre wear	• vehicle type (no. of tyres) • speed • gradient	• curvature • surface type • roughness
Vehicle depreciation	• vehicle type • speed	• surface type • roughness
Vehicle repair and maintenance	• vehicle type • speed	• surface type • roughness
Persons per vehicle	• trip purpose	

Source: Austroads 2012c

As mentioned in section 8.3.14 for urban roads, readers should note that there is currently some variation in the VOC guidance provided by ATAP in PV2 and Infrastructure Australia in its guidance (IA 2018, see section D3.11 therein for a discussion of the differences).

9.6 Application to initiative types

Rural integrated models are capable of analysing a wide range of initiatives, although depending on how initiatives are packaged[16], the models might need to be run more than once for some appraisals. Examples of rural initiatives are shown in Table 17.

Table 17 Application of rural integrated models

Initiative type	Change factors influencing user cost	Comment
Widen single carriageway road	Base and project case seal width (MRS); partial improvement in roughness	Widening will produce a partial reduction in roughness (in the outer wheel paths)
Duplicate single carriageway road	Number of carriageways and lanes, (MRS); improved roughness of new carriageway	Half of the AADT (the traffic on the new carriageway) will benefit from improved roughness
Overtaking lanes	Number of lanes (MRS); (partial improvement in roughness; crash risk reduction upstream and downstream (research determined)	Construction of an overtaking lane will reduce average roughness because the as-constructed roughness of the new lane will be lower than the prevailing roughness of the subject road section
Wide centre lane treatment (WCLT)	Seal width (MRS); additional crash risk reduction attributable to separation of opposing traffic flows (research determined)	The principal benefit of a WCLT initiative is sometimes the crash reduction effect of separating the opposing traffic flows (depending on what other works are incorporated in the initiative)
Pavement strengthening	Change in roughness and roughness correction; postponement of other pavement interventions	Maybe carried out in association with widening
Bridge widening	Seal width between bridge kerbs (MRS); approaches seal width (MRS) and roughness	Note that model might need to be run separately for bridge and approaches because on older road sections, bridges may be markedly narrower than approaches. Bridge upgrades are sometimes proposed also to improve flood immunity (see below)

[16] For example, appraisal of a 3 km widening initiative for which the base case comprises three contiguous sections of markedly different seal width would require the rural integrated model to be run three times, although the potentially three separate initiatives comprising the widening of three sections of road are proposed to be delivered as one package. The rural integrated models might also need to be run multiple times for a bridge widening that also includes approaches widening (bridge and approaches having different widths). A flood immunity initiative involving a diversion route might also necessitate multiple runs of the rural integrated model.

Initiative type	Change factors influencing user cost	Comment
Curve straightening	Section length; curvature (in degrees or expressed as 'straight', 'curvy' etc)	Rural integrated models contain processes to constrain speed according to horizontal curvature. In extreme cases, very curvy roads may be speed limited. Benefit potential may be enhanced if curvature reduction facilitates an increase in posted speed
Seal unsealed road	Seal width (MRS) for base and project cases and surface type	Sealing may be part of a combined initiative including seal widening, pavement strengthening and realignment
Flood immunity improvement	Existing section length, MRS and roughness; diversion distance MRS and roughness; % traffic flow waiting, diverting, not travelling	See bridge widening above
Change in posted speed	Posted speed	Initiatives such as sealing, widening and roughness reduction may be carried out to facilitate an increased posted speed (e.g. implementation of 110 km/h zones)
Realignment of a sealed road	Seal width (MRS), section length, posted speed, roughness	Realignment may be constructed to higher standards. Realignment also facilitates 'off-line' construction which reduces some elements of construction cost as well as reducing construction delays for road users
Enhanced heavy vehicle access	Could include seal width (including bridge width) and alignment, traffic composition.	The pavement strengthening element of improved HV access can be addressed through simulation of the effects of stronger pavements on roughness and roughness progression. Improved HV access should result in a change in traffic composition towards higher productivity vehicles, resulting in reduced vehicle-km to perform the same transport task
Open level crossings — removal, signalisation or grade separation	Average rail vehicle crossing delay, number of train crossings, crash record*	Microsimulation modelling might be needed for estimation of changes in road user delay at the level crossing. The number of train crossings might need to be sourced from the track owning agency
Town bypasses	Reduced in-town delay for local traffic; higher travel speeds for through traffic on the bypass	In-town traffic modelling might be needed to estimate changes in traffic volumes and speeds in the bypassed town, and the overall changes in vehicle hours and kilometres of travel. Number plate recognition surveys might be useful for estimating the percentage of traffic likely to use the proposed bypass

** Because level crossing crashes between road vehicles and trains are very infrequent, national estimates of level crossing crash incidence may be needed*

The following Table (Table 18) shows how for elements of the base and project cases differ for different types of initiatives. For example, for a widening initiative, MRS will usually change but other road characteristics may stay the same. In a realignment, MRS will probably change (unless widths are unchanged), the alignment variable will change, but other road characteristics such as curvature and gradient might not. The Table also indicates that base case and starting roughness will usually differ because the initiatives will mostly entail new work.

Table 18 Differences between base and project cases in rural appraisals

	MRS	AADT	Traffic composition	Traffic growth	Alignment	Curvature	Gradient	Starting roughness	Roughness progression	Flooding impacts**	Crash reduction at site	Crash reduction upstream & downstream	Bridge width	Construction cost incl rehabilitation	Annual routine maintenance costs	Periodic maintenance costs	Maintenance intervals
Widening for wide centre line	●	☉	☉	☉	☉	☉	☉	●	●		●			●	●	●	●
Widening for overtaking lanes	☉*	☉	☉	☉	☉	☉	☉	●	●		●	●		●	●	●	●
Pavement strengthening	☉	☉	☉	☉	☉	☉	☉	●	●		●			●	●	●	●
Sealing	☉	☉	☉	☉	☉	☉	☉	●	●		●			●	●	●	●
Realignment	●	☉	☉	☉	●	☉	☉	●	●		●			●	●	●	●
Bridge upgrade excl flood immunity	●	☉	☉	☉	☉	☉	☉			●			●	●	●	●	●
Bridge upgrade with flood immunity	●	☉	☉	☉	☉	☉	☉			●			●	●	●	●	●
Simple low-cost intersections (no delay impacts)		®	®	®	®	®	®							●	●	●	●
Other simple intersections		®	®	®	®	®	®							●	●	●	●
Major at grade intersections		®	®	®	®	®	®							●	●	●	●
Level crossings upgrades														●	●	●	●
Town bypasses		☉	☉	☉	☉	☉	☉							●	●	●	●
Change in posted speed		☉	☉	☉	☉	☉	☉							●	●	●	●

Notes: ● = usually varies between base and project cases; ☉ = never varies between base and project cases; ® = rarely varies between base and project cases
* Some NIMPAC type models might not have a specific MRS for overtaking lanes
** AATOC and ADC (See ATAP O4 Flood resilience initiatives for explanations of these abbreviations)

9.7 Manual methods using lookup tables

ATAP PV2 contains quick access lookup tables based on the above models that some appraisers might prefer to use in lieu of formally running a rural integrated model[17]. The lookup tables are:

- Free speed adjusted for gradient, curvature, roughness and average heavy vehicle loading. These tables can be used to estimate base case and project case travel time costs. Appraisers will need to constrain these speeds according to base case and project case posted speeds
- Coefficients for estimating base case and project case VOCs for ranges of road widths, gradient and curvature. The free speed VOC algorithm is also contained in ATAP PV2
- Fuel consumption coefficients for the VOC algorithm in ATAP PV2. Estimates of fuel consumption are an input to estimation of environmental benefits related to air emissions.

Appraisers using manual methods can estimate base and project case crash costs using crash rates per million vkt in Austroads (2010) and unit crash costs in ATAP PV2.

9.8 User benefits at intersections

9.8.1 Savings in travel time costs

Intersection initiatives cannot be appraised using rural travel cost-based models because those models assume free flow traffic conditions.

Instead, spreadsheet based models supported by microsimulation modelling or observations of traffic behaviour will be needed to estimate user benefits arising from changes in user delays and vehicle operating costs.

Microsimulation modelling to estimate base case and project case user delays and vehicle operating costs might be desirable in the following circumstances:

- Near towns
- When minor road volumes are a relatively high proportion of major road volumes
- When major road volumes are so large that the gaps between vehicles are too short and too infrequent to allow minor road vehicles to safely cross/enter the major road or major road vehicles to safely turn right into the minor road.

Appraisers should seek the advice of a traffic planner or traffic engineer as to the need for microsimulation modelling.

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[17] NCMPAC or HDM models. Manual methods could be paper-based or use simple computer spreadsheets.

If microsimulation modelling is not warranted, simple observation of per vehicle delays on the minor road for turning movements into the major road supported by traffic counts should be sufficient for estimation of delays. Delays to major road traffic are unlikely to be significant in such cases.

Microsimulation models typically estimate:

- Intersection delays (in terms of seconds of delay per vehicle in each modelled period)
- Intersection throughput (vehicles entering the intersection in each modelled period)
- Fuel burn (litres per hour).

Typically, the traffic modellers will run the model for at least one of the weekday peaks (AM, PM or both) for the base case and for each option. Depending on the hourly distribution of traffic through the intersection, the model might also be run for a midday period. More often than not, each modelled period will be of one hours' duration but it is wise to always confirm this with the traffic modeller. Depending on traffic volumes, modelling of Saturday or a Sunday would reduce uncertainty associated with the selection of expansion factors.

Readers are referred to Austroads (2016) which provides a simplified appraisal approach for small intersections to assist in identifying cases that may then require more detailed analysis.

9.8.2 Savings in vehicle operating costs

Fuel burn is estimated by some microsimulation models. If a microsimulation model is not being used, the NSW appraisal guidelines (TfNSW 2016) contain an estimate of vehicle operating cost per stop at intersections (with and without fuel costs). The proportion of vehicles stopping could be established by observation.

Travel time costs for the base and project cases are estimated by applying the unit values of time in ATAP PV2 to delay estimates.

9.9 User benefits in town bypass initiatives

Highway bypasses of towns are provided to:

- Reduce costs for 'through' traffic i.e. traffic that does not have an origin or destination in the town
- Reduce congestion and possibly improve safety in the town.

Depending on the size of the town to be bypassed, rural benefits on the highway sections and urban benefits in the town to be bypassed might both need to be estimated.

User benefits would be estimated as follows:

- Base case user costs on the highway sections either side of the town PLUS

- Base case costs in the town. If a large regional town is being bypassed, base case costs could be estimated using a local area model[18]. LESS
- Project case user costs on the (new bypass) LESS
- Project case user costs on the existing (old) highway sections either side of the town LESS
- Project case in-town user costs estimated as for the base case.

To estimate traffic volumes expected to use the bypass and those likely to remain on the existing highway sections, methods such as automatic number plate recognition may be appropriate to identify the two traffic streams.

Crash benefits would be calculated separately for the rural highway sections (existing and bypass) and the in-town urban sections using the methods outline earlier for rural and urban roads.

9.10 Crash benefits

A wider range of methods for estimating crash risk is available for rural initiatives because of the absence of network interdependencies. Changes in crash risk can be estimated according to risk exposure (vehicle kilometres of travel) and model road state (cross-section), or by using the crash reduction factors applied to the crash record at the subject site (relevant to intersections, interchanges and railway level crossings).

Sometimes appraisers may want to use actual crash data and crash reduction factors for different crash types to estimate crash benefits. Care should be taken, however, to ensure that if default crash rates are used for the base case they would be used for the project case also but reflecting any improvement in road characteristics. Base case actual crash rates should not be compared with project case default crash rates.

9.10.1 Where safety benefits are relatively small

For initiatives where safety benefits are a relatively small proportion of the total benefits, use default crash rates.

The most recent published sets of crash rates in Australia as a function of model road state road characteristics (e.g. width, number of lanes, divided, undivided) are Austroads (2010). These crash rates are expressed per 100 million or million vehicle-kilometres of travel, implying that total crash numbers are proportional to traffic levels and that vehicle mix (proportion of heavy vehicles) is not relevant. Clearly, these are simplifying assumptions. At some time in the future, crash rates that vary with volume–capacity ratio and traffic composition may become available.

[18] Otherwise, as a minimum, base case user costs at the major intersections should be considered, using a microsimulation model

9.10.2 Where safety is the primary objective

For initiatives where safety is the primary objective (crash cost savings comprising a high proportion of total benefits for example at intersections away from towns), consider adopting a more detailed, site-specific approach. If the data are available, estimate base case road crash rates from the history of crashes at the site. For rapid CBAs, tables are available showing percentage crash reductions by treatment type and crash type (for example, DITRDLG 2009; Austroads 2015). For detailed CBAs, to predict impacts of an initiative on crash rates, undertake statistical analysis of time-series crash-rate data from similar sites where similar initiatives have been undertaken, or of cross-section data from sites similar to the base case and project case sites. Remember to adjust for differences in traffic volume and general trends in crash frequencies due to non-site-specific factors such as changes in driver attitudes, law enforcement or car safety. There are many methodological pitfalls. For discussion of statistical analysis of site-specific crash rates, see BITRE (2012).

9.10.3 Use of unit crash costs

ATAP PV2 contains average crash costs according to severity by state/territory. If crash cost reductions attributable to an initiative are being estimated from the crash record, crash cost savings will most likely be able to be estimated according to crash severity. Unit crash costs according to severity in ATAP PV2 can then be applied directly to those estimated crash reductions to obtain estimates of reductions in crash costs.

If the crash incidence method is used, an average crash cost will need to be calculated. The unit crash cost estimates in ATAP PV2 are very aggregated values and may not be applicable to variations in risk according to for example, road stereotype, speed environment, traffic volume and traffic composition. A suggested method is to calculate an average crash cost using the crash record for a number of links that are similar links to the road in question. It is undesirable to use crash records more than say ten years old.

9.10.4 Approaches to estimation

For midblocks

On midblocks (that is, plain sections of road excluding intersections interchanges or level crossings) rural integrated models estimate base and project case crash numbers on a risk exposure basis in terms of crashes per million vkt according to MRS. Crash incidence estimates are available for casualty crashes only and for casualty crashes plus property damage only (PDO) crashes. Typically, but not always, higher model road states are associated with lower crash risk. Estimates of crash risk according to model road state are set out in Austroads (2005a).

For intersections and level crossings

For appraisals of intersections, interchanges or level crossings, apply crash reduction factors from Austroads (2015) or DITRDLG (2009) to the crash record. If there is no crash record, it might be necessary to use state or national average crash rates for similar sites. Use unit crash costs from ATAP PV2 to monetise base case and project case crash costs.

9.11 Environmental benefits

As per urban roads (see section 8.4), unit costs of environmental impacts are reported ATAP Part PV5 with complementary emission rates in ATAP Part PV2.

9.12 Application to initiative types

9.12.1 Data requirements

The following data in Table 19 will be needed to evaluate rural initiatives. Note that some initiatives might contain a number of elements (for example pavement widening and strengthening or a bridge upgrade to improve flood immunity and reduce agency maintenance costs. Data requirements should be identified accordingly.

Table 19 Data requirements for rural appraisals (base and project cases)

Initiative type	Road condition and traffic data	Other data
Mid-block initiatives (for example, sealing, widening, overtaking lanes, pavement strengthening, realignment, change in posted speed	AADT, traffic growth rates, traffic composition, initiative length in base and project cases, road type (e.g. single carriageway rural, state highway etc), MRS, surface type, curvature, gradient, current and as constructed roughness (for new work), roughness progression (base and project cases).	Construction cost and years of delivery, annual routine maintenance costs, periodic maintenance costs and maintenance intervals. For wide centre line treatment crash reduction factors for example see TMR (2012) and Levett et al (2009). Overtaking lane initiatives may reduce crash risk upstream and downstream of the proposed site, for example see TMR (2011).
Bridge upgrades (excluding flood immunity initiatives) Note: Will generally also require the same inputs as mid-block initiatives as they may also incorporate the approaches	AADT, traffic growth rates, traffic composition, alignment, bridge width, approaches seal width, roughness	Construction cost and years of delivery, routine maintenance costs, periodic maintenance costs (including surface reconditioning, bridge structural repairs and reconditioning and bridge inspections.
Bridge upgrades (flood immunity) Note: Will generally also require the same inputs as mid-block initiatives as they may also incorporate the approaches	As above plus average annual time of closure (AATOC), average duration of closure (ADC), estimated proportions of vehicles waiting at the flood site/not travelling and diverting around the flood site, as well as diversion route details	Construction cost and years of delivery, routine maintenance costs, periodic maintenance costs (including surface reconditioning, bridge structural repairs and reconditioning and bridge inspections.
Simple low cost intersections (no delay impacts)	Crash record or alternatively crash incidence at similar sites	Construction costs (additional maintenance costs are likely to be minor and could be estimated on a cost per m2 of pavement basis.

Initiative type	Road condition and traffic data	Other data
Other simple intersections	As above plus observations of base case delay; estimation of project case delay using simple behavioural assumptions	As above
Major at grade intersections or grade separations	For each modelled year, average delay and intersection volume in the modelled year from a microsimulation model. Fuel burn if available or number of vehicle stops.	Construction costs, routine and periodic maintenance costs, inspection costs for structures.
Level crossings — removal, signalisation or grade separation	Average delay and intersection volume in each modelled year for each modelled period from a microsimulation model, (motor vehicle fuel burn if available or number of vehicle stops); Numbers of train movements and average delay per train movement, average fuel burn, crash record or average national level crossing crash incidence	Construction costs, routine and periodic maintenance costs, inspection costs for structures, operations costs (checking and maintenance of signals and boom gate operation for signalised open level crossings).
Town bypasses	Base case: AADT, traffic composition, length, seal width, roughness, alignment, traffic growth; in-town delay and fuel burn Project case: AADT and traffic composition on bypass and existing route, bypass length, seal width, alignment roughness, in-town delay and fuel burn	Construction cost and years of delivery, annual routine maintenance costs, periodic maintenance costs and maintenance intervals.
Change on posted speed	AADT, traffic growth rates, traffic composition, initiative length in base and project cases, road type (e.g. single carriageway rural, state highway etc), MRS, surface type, curvature, gradient, current and as constructed roughness (for new work)' roughness progression (base and project cases).	Construction cost and years of delivery, annual routine maintenance costs, periodic maintenance costs and maintenance intervals.

9.13 Road sections should be homogeneous

Each run of a rural integrated model should refer to a length of road that is broadly homogeneous in terms of characteristics such as traffic, width, seal type, roughness and the like. The longer the proposed road initiative, the more individual runs of the model will be required.

If carrying out a 'rapid' CBA, road sections with differing characteristics might be aggregated so that seal widths, AADTs etc represent length or volume weighted averages. This averaging approach will be meaningful when adjacent road sections are relatively similar (for example generally narrow sections although with some small variations in width). Hence it would be acceptable to average 4m and 5m widths but not 4m and 9m widths. Similarly, sections with AADTs in the low hundreds could be aggregated but not one section with AADT of 100 and another with AADT of 1000.

9.14 Impact of road capacity

Long term traffic growth rates should be checked for their implications for road capacity. High rates of growth are unlikely to occur over long periods. In addition, when the volume–capacity ratio approaches one and average speed approaches 30 km/h, external forces will come into play to attenuate traffic growth rates. For example, land development will slow and road users will seek alternative routes, modes or travel times. If after consideration, the subject road section appears likely to be at capacity within the life of the initiative the specification of the base and project cases might need to be reconsidered (see section **Error! Reference source not found.** earlier).

10. Infrastructure costs

10.1 Types of infrastructure costs

Infrastructure costs are typically classified into the following two categories.

- Capital costs
- Recurrent costs — Operating costs and maintenance costs (each estimated separately).

Estimates of the costs need to be established for each year of the appraisal period for the Base Case and the Project Case.

Costs should be separated into these sub-categories to facilitate calculation of the BCR1 and BCR2 decision criteria.

10.2 Capital costs

Capital costs are typically the upfront costs incurred in constructing new road assets or enhancing existing assets. They include all costs required to implement an initiative including design and costing, land purchase, materials, construction, construction supervision, site safety management and the like.

Capital costs are estimated with varying levels of detail and certainty between initial consideration and detailed planning. As initiatives come closer to delivery, the level of detail in cost estimation increases and the level of uncertainty in the estimates should be decreasing. However, the principles for using capital costs in appraisals do not change.

For rural initiatives, it might be necessary to break capital costs out according to the objective they are targeted at — for example, a widening component and a flood mitigation component - if incremental appraisal is to be carried out. In the urban context a relevant example might be duplication and grade separation.

Elements of capital cost are described in Table 20 below.

Table 20 Elements of capital cost

Element
Planning, design and regulatory cost
Site surveying
Site preparation
Investigation, data collection and analysis
Legal costs
Administrative costs
Land acquisition

Construction works
Consequential works

Capital costs should be included in the appraisal in the year in which they are expected to be incurred.

Capital costs in road initiatives include:

- Sealing an unsealed road
- Widening an existing road carriageway to allow for sealed shoulders, wider running lanes or for wide centre line treatments (WCLT)
- Duplicating an existing road by adding an extra carriageway
- Grade separating an intersection
- Realigning a road, for example to achieve a higher level of flood immunity
- Widening or extending a motorway
- Bypassing a town
- Pavement strengthening to allow heavier loads to be carried
- Rest areas/ pull in bays
- Toll collection devices.

With road initiatives, some assets in a project will reach the end of their economic lives before the end of the appraisal period. In the appraisal, re-investment in those assets at the end of their lives will need to be included. Any remaining life in those assets will then need to be accounted for as in the residual value at the end of the appraisal period.

10.2.1 Estimating capital costs

ATAP Part O1 provides high level guidance on cost estimation, based on the detailed Guidance Notes published by the Australian Government. Practitioners are directed to these sources for estimating capital costs of road and other transport projects.

As noted in Part O1 section 3.1, the capital cost estimate to be used in a CBA must:

- Be the expected value or mean estimate (which also applies for benefit and recurrent cost estimates)
- Reflect opportunity / resource costs
- Be the 'real' cost, including the real component but excluding the nominal component of any escalation allowance (with benefits and operating costs also presented in real terms)
- Include land and property cost at their opportunity cost value
- Exclude 'sunk costs', i.e. any costs that have already been incurred at the time of the appraisal, such as planning and design. The business case may make note of sunk costs, but they should be excluded from the CBA.

- Particularly for very large initiatives, the time distribution of costs will need to be established. This is so that costs can be entered into the appraisal in the year in which they are expected to be incurred. For appraisals at business case stage the time profile of capital costs (cash flow), based on the project schedule, should be available in the costing engineers report. For earlier stage appraisals and for smaller initiatives, the advice of an experienced cost estimator should be sought about the spending profile of capital costs.

10.3 Maintenance costs

Maintenance costs are incurred to return road assets to some predetermined condition or to slow the rate of deterioration. As noted in section 9, periodic maintenance in the rural context can affect surface condition (roughness) which in turn affects per km user costs. The urban VOC algorithms in PV2 do not at present include surface condition variables that would be influenced by the level of maintenance.

There are three types of maintenance cost namely:

- Routine maintenance including activities such as mowing of edges, cleaning of drains, edge repair and pothole patching and repairs of surface cracks. These costs are largely the same each year and do not vary with usage.
- Periodic or programmed maintenance which includes scheduled works to improve pavement condition and retain strength. Examples include re-sheeting and grading of unsealed roads, resealing of sealed roads and overlays of sealed roads to correct surface defects.
- Rehabilitation or reconstruction usually at the end of a road's engineering life to restore the pavement to its original condition.[19]

10.3.1 Impact of initiatives on maintenance costs

An initiative might result in additional maintenance costs because, for example, it increases the area of pavement to be maintained. This would be the case for a road widening or duplication. Maintenance costs might also fall or be postponed as a consequence of an initiative. For example, a realignment to avoid a section of poor drainage could obviate the need to rehabilitate an existing pavement that is subject to waterlogging; or pavement strengthening could stretch out the intervals for periodic maintenance. Table 21 illustrates how maintenance initiatives can influence maintenance costs.

Table 21 How initiatives can affect maintenance requirements

Type of initiative	Maintenance impacts	Direction of impact on agency maintenance costs
Seal an unsealed road	• Grading and gravel re-sheeting • Resealing • Costs of managing wet weather road closure	↓ ↑ ↓

[19] Some jurisdictions may classify rehabilitation as capital

Type of initiative	Maintenance impacts	Direction of impact on agency maintenance costs
	• Pothole patching and edge repair	↑
Replace a timber bridge	• Replacement of worn components • Inspections • Management of drains and stream banks	↓ ↓ ↓
Widen a sealed road	• Pothole patching • Periodic maintenance • Edge repair • Shoulder maintenance	↑ ↑ ↓ ↓
Grade separation	• Structural inspections • Intersection maintenance (e.g. seal repairs, traffic signal repairs)	↑ ↓

Note: The arrows indicate whether each initiative type increases or decreases each aspect of maintenance impact

A number of methods can be used to estimate the impact on maintenance costs depending on the nature of the initiative:

- If the initiative is simply increasing the area of an existing pavement (through widening), annualised unit maintenance costs per m2 would be suitable, or alternatively additional maintenance costs as an annual percentage of outturn costs could be estimated by reference to other, similar initiatives
- If the initiative is expected to have a range of cost impacts, some positive and others negative, or if achieving a saving in maintenance costs is an objective of the initiative, a more detailed elemental exercise might be needed in which the current maintenance cycle or schedule is built up by work type. Work types which will reduce or increase in cost as a consequence of the initiative can then be identified in terms of the maintenance cycle. For a pavement strengthening for example, the frequency of periodic maintenance may be reduced as well as the intensity of cost (cost per maintenance intervention). Replacing a timber bridge could result in annual savings in inspection costs and the elimination of periodic replacement of worn bridge materials and components. (It may also reduce user costs associated with full or partial road closure for bridge maintenance.)

CBAs of road initiatives require maintenance costs to be estimated for the base and the project cases, with the incremental change then embedded in the discounted cash flow analysis. In the case of the provision of additional lanes, the change is usually the increase in maintenance cost reflecting the increase in surface area of the road. If there are associated changes in fixed maintenance costs, those should also be accounted for. For example, on-site overheads such as mobilisation of equipment, site offices and amenities to complete a job. The cost of mobilisation of specific equipment to a project site (especially rural or remote) could have large impacts on costs, which would be allocated by surface area very differently for maintenance of smaller (higher cost) and larger sections (lower cost) although costing the same to get the equipment there initially.

Sometimes base case maintenance cost estimates might be distorted because the road agency has been delaying maintenance in anticipation of the proposed initiative proceeding. It will be necessary then to simulate an active base case maintenance regime with the assistance of maintenance engineers, or draw estimates from similar sections of road elsewhere.

10.3.2 Residual value in maintenance cash flows

In some instances, base case or project case periodic or programmed maintenance might be scheduled towards the end of the analysis period and not be fully consumed by the end the analysis period. A residual value should be attributed to the unconsumed component of the maintenance work at the end of the analysis period to enable consistent comparison of base and project cases (see section 3.3 in ATAP T2 regarding the estimation of residual value).

10.3.3 Maintenance effects on roughness and user costs

For rural roads, in the NIMPAC-style rural integrated models, road roughness influences speed which in turn has an effect on travel time costs. Roughness also directly affects some vehicle operating cost components including tyre wear and fuel consumption. If an initiative is expected to have significant effects on pavement condition, the rural integrated models should show a change in unit VOC and speed each time programmed maintenance or rehabilitation reduces roughness. If manual methods are being used to estimate unit VOCs and total VOCs, section 5.3.2 in ATAP PV2 provides a recommended algorithm and associated parameter values that will allow VOC to be estimated according to changes in roughness.

At present the urban VOC algorithms in PV2 do not contain surface condition variables.

10.3.4 Operating costs

Various infrastructure components involve operating costs, for example, the operation of tolling booths and equipment, traffic signals and variable message signs, and the processing of toll collections. and ICT (information and communication technology). Here we also include under operating costs maintenance of these assets.

Like routine maintenance, operating costs are relatively insensitive to traffic volume or composition.

When estimating operations costs on a per route km basis, some cost items will not vary directly with road width. For example, the width of a single carriageway road would not increase lighting costs or the costs of operating variable messaging signs, but a duplication of the road could increase the amount of equipment to be maintained and periodically replaced.

11. Performance measurement and monitoring

Measurement and monitoring of the performance are important because they provide the basis for assessing whether our transport system objectives are being met and whether road initiatives have been successful.

Several parts of the ATAP Guidelines relate to this:

- F1: Goals, Objective, Targets and KPIs. Step 1 of the ATAP Framework involves the setting of jurisdictional goals, transport system objectives, targets and performance indicators
- F2: Problem identification and assessment. In step 2 of the ATAP Framework, problems in the transport system are identified, that provide the starting point for considering transport system improvements. Performance indicators contribute to the identification of problems and evidence of their nature, extent and severity. At this 'before' stage, current (and projected) performance should be measured and modelled, providing the basis for estimating benefits in the appraisal (ATAP F3). Chapter 3 above discusses the types of problems that arise in relation to roads. Performance indicators of factors underpinning these problems are required: travel time, vehicle operating costs, crashes and environmental impacts.
- F7: Review and Post Completion Evaluation. This Part discusses the importance of review processes and steps for undertaking those reviews, or evaluations
- T6: Benefits Management. This Part discusses the need for indicators that enable measurement and monitoring of benefits. The process ensures that benefits are identified and measured in the planning of initiatives (ex-ante appraisal) and after their delivery (ex-post evaluation).

Performance indicators

Performance indicators play a key role in each of the above processes. Jurisdictions typically consider a wide range of performance indicators across the transport system, including indicators involving roads and relevant to road initiatives. Austroads also monitors performance indicators.

Post-completion evaluation

In relation to road initiatives, urban initiatives are more likely to be evaluated individually because of their cost, size, complexity and implications for other parts of the road and transport networks. Rural initiatives tend to be smaller, less complex and costly and are more likely to be evaluated as parts of:

- Programs (e.g. a program to reduce crash rates involving a range of initiatives across a network or within a corridor) or
- Strategies (e.g. a strategy to enhance heavy vehicle access; or to encourage more road-based tourism in regional areas).

Post completion, or ex post, evaluation of road initiatives presents a range of challenges, particularly in urban networks:

- Related initiatives expected to be delivered during the life of the initiative being evaluated might not be delivered in the order that was originally intended, or they might be postponed or cancelled (urban)

- Unanticipated external economic factors (general upturns or downturns) could affect propensities to travel for work or non-work purposes (urban and rural)
- Industries or specific enterprises (mines, factories, tourist resorts) could expand or contract more than expected (more rural than urban)
- Land-use changes in urban areas may differ from forecasts, for example, new suburbs.
- An unexpected change in general economic conditions could lead to higher or lower prices in the civil construction sector
- Climatic factors (particularly droughts) could influence demand levels (rural)
- Extreme weather events could result in a rescheduling of maintenance activities including pavement reconstruction.

Factors such as these could change the base case for appraisal of the initiative or the project case changes delivered by the initiative. This will be more the case with evaluation of individual initiatives than in the evaluation of programs and strategies in which localised influences will be less significant.

Appendix A CBA results formulas

General

- All benefits and costs in each future year of the appraisal period are discounted back to the base year
- The summation of all annual discounted present values of a stream of benefits or costs is called the ‘present value’ of that stream

Net present value (NPV)

- The NPV of an initiative is the difference between the discounted stream of benefits and the discounted stream of costs. The NPV is given by:

$$NPV = \sum_{t=0}^{n} \frac{B_t - OC_t - IC_t}{(1+r)^t}$$

where:

- t is time in years
- n is the number of years during which benefits and costs occur
- r is the discount rate
- B_t is benefits in year t
- OC_t is infrastructure operating and maintenance costs in year t
- IC_t is investment costs in year t.

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

Benefit cost ratio (BCR)

There are two alternative definitions of BCR depending on whether one puts infrastructure operating costs in the numerator or the denominator.

$$BCR1 = \frac{PV(B)}{PV(OC + IC)}$$

$$BCR2 = \frac{PV(B - OC)}{PV(IC)}$$

where $PV(x) = \sum_{t=0}^{n} \frac{x_t}{(1+r)^t}$

- A BCR greater than one implies a positive NPV

Incremental BCR

- The incremental BCR (IBCR) is defined as:

$$IBCR = \frac{PV(B_2 - OC_2) - PV(B_1 - OC_1)}{PV(IC_2) - PV(IC_1)}$$

where the subscripts represent options 1 and 2, and option 2 has the greater investment cost. The IBCR is well-suited for comparing options involving different scales of initiative. Increases in the scale of initiative are worthwhile as long as the IBCR for each scale exceeds one.

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