TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

F2 Problem identification & assessment

Public Consultation Draft

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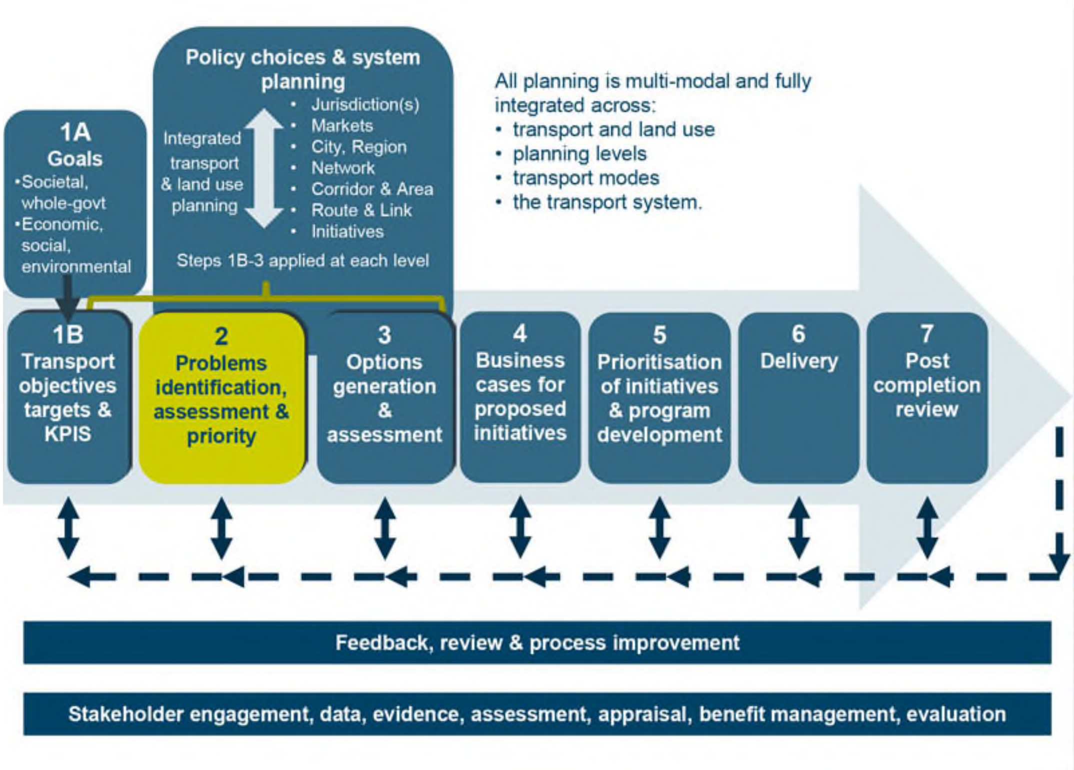


At a glance

- Step 2 of the Framework provides guidance on identifying, assessing and prioritising problems and opportunities in the transport system.
- Overcoming problems, and pursuing opportunities, moves us towards achieving jurisdictional goals and transport system objectives defined in Step 1.
- A problem is a cost to be avoided or saved. An opportunity is a benefit to be gained.
- The purpose of this step is to:
  - Identify current and emerging problems and opportunities
  - Provide data-rich evidence of the problems and opportunities: their scale, extent, cause, and their associated economic, social and environmental costs — over short, medium and long terms time frames
  - Determine the priority of problems and opportunities — based on: alignment with jurisdictional goals, transport system objectives, policies, strategies and plans; current and future demand; the scale, extent and cost; and whether the problem / opportunity occurs under multiple future scenarios.
- This step should result in clear statements of problems, and documented evidence of their scale, extent, costs, causes and priority.

1. Introduction

This part of the ATAP Guidelines considers problems and opportunities in the transport system. Overcoming problems, and pursuing opportunities, moves us towards achieving jurisdictional goals and transport system objectives. The infrastructure Australia Assessment Framework (IA 2018)[1] notes that:

- A problem is a cost to be avoided or saved
- An opportunity is a benefit to be gained (or a cost if the opportunity is not pursued).

The term 'problem' in the context of the ATAP Guidelines includes issues, deficiencies and challenges.

The guidance in this document is presented in three stages: identification; assessment; and prioritisation. Both current and emerging (future) problems / opportunities should be considered.

The guidance is consistent with the Infrastructure Australia Assessment Framework (IA 2018), which requires a strong evidence-base for presenting problems and opportunities.

A robust consideration of problems and opportunities in the transport system provides a sound basis for transport policy and planning. A recent example is the Australian Infrastructure Audit (2019).

This guidance is set out as follows:

- Chapter 2 explains where in the ATAP Framework transport problems are addressed, and provides a brief initial overview of the three-stage process presented here
- Chapter 3 discusses stage 1, problem identification, the link to goals and objectives and scoping the problem
- Chapter 4 considers stage 2, problem assessment, explaining why it is important and its key dimensions, especially having a rich evidence-base
- Chapter 5 presents stage 3, problem prioritisation, as the mechanism for deciding which problems are the most important and should be tackled first
- Chapter 6 discusses the important role played by stakeholder engagement, mentioning tools for engagement and providing a checklist for practitioners.

[1] Note that IA Assessment Framework (IA 2018) is in the process of being updated with a new release likely mid-2021.

2. Overview

2.1 ATAP context

The consideration of problems and opportunities fits into the ATAP Framework as follows:

- **Step 1** of the Framework provides guidance on setting a clear set of jurisdictional goals and transport system objectives (see F1).
- **Step 2** — addressed in this part, F2, of the Guidelines — explains how to identify, assess and prioritise current and future problems and opportunities.
- In **Step 3**, options are generated to address the problems / opportunities identified in step 2. Problem / opportunity identification and assessment therefore establishes the platform from which options are generated and assessed.

2.2 Stages and refinement

Step 2 can be broken down into three distinct stages: problem identification, problem assessment, and problem prioritisation. These stages are depicted in Figure 1.

The completion of this step of the Framework should result in clear statements of problems and opportunities, acknowledgment of the goals and objectives to which they relate, and documented evidence of their scale, extent, cost, causes, and priority.

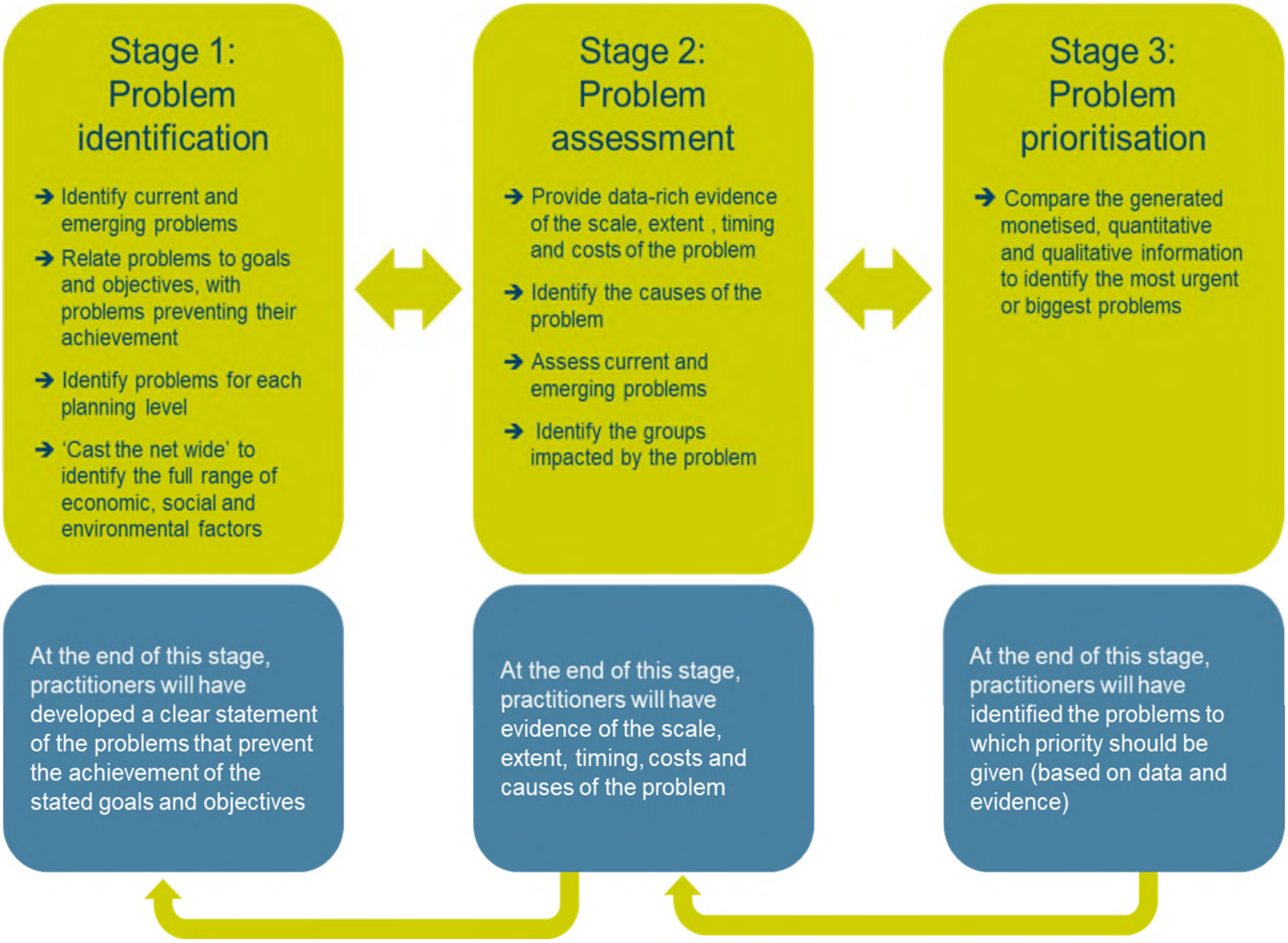
Problems and opportunities identified in this step should continue to be tested and refined in subsequent steps of the Framework, recognising that:

- Problems / opportunities and priorities may change over time and/or in light of other developments. For example, the development of a transport initiative on another part of the network or the introduction of road tolls may reduce the extent and scale of a problem. Similarly, unexpected population changes over time or a new housing development may increase the scale of the problem and require problems to be reprioritised.
- It may reveal additional problems / opportunities not identified in the initial identification stage.

The identification and assessment of problems and opportunities is an iterative process that will cycle through :

- Identifying the problem / opportunity as it is currently understood
- Identifying and collecting all relevant data and evidence.
- Analysing the available data and refining the problem / opportunity statement (validating, rejecting or redefining the problem).

Figure 1 Step 2 of the Framework — Problem identification, assessment and prioritisation



Box 1 Avoiding the pitfalls

Common pitfalls in problem identification, assessment and prioritisation include:

- Only seeing part of the problem
- Lack of evidence to demonstrate, quantify and monetise the problem
- Failure to prioritise problems
- Failing to see that there are other related problems
- Dealing with effects rather than causes
- Lack of evidence to support problem prioritisation
- Viewing the problem through the lens of a preconceived solution.

3. Stage 1: Problem identification

This stage identifies and describes problems and opportunities.

Problem identification should result in clear, straightforward statements that describe the nature of the problems facing the transport system and its components.

Problem statements should relate directly to specific goals and transport system objectives identified in step 1 of the ATAP Framework. The problem statements should clarify how the problem is preventing, or will prevent, the achievement of these goals and objectives, taking into account and based on:

- The full range of goals and objectives identified in the previous step – including objectives for different levels of planning and markets (see F1, section 3.1).
- Empirical observations, such as data and information obtained from stakeholders, surveys, demand modelling, interviews and studies from a wide range of sources.

3.1 Scoping the problem

When scoping problems, the following should be taken into account:

- What is preventing the achievement of the objectives?
- Don't be confined to the present. Consider emerging and potential future problems.
- Problems can be different for the various planning levels. For example, achieving a goal of reducing road crashes may require a specific engineering 'fix' at the link level (such as safety barriers or road widening), a series of rest areas at the corridor level and safety education initiatives at the network level.
- Problems should be seen as multidimensional, so it is important to 'cast the net wide' when identifying problems. This means considering the full range of economic, social and environmental factors, including technology and behavioural change, and canvassing a broad spectrum of potential problems, such as accessibility, business needs, availability, prices/cost, capacity, emissions, and safety.

When scoping, it can be helpful to map out what the problem is and its relationship to transport system objectives. A couple of mapping techniques can be used to undertake this exercise:

- Investment Logic Mapping
- Benefit Dependency Mapping.

The techniques are discussed further in Part T6 of the Guidelines. These techniques may assist in gaining an early understanding of the problem and its relationship with transport system objectives, and in identifying the underlying rationale for an associated intervention. Investment logic mapping goes a step further and maps out early concepts for potential solutions to the problem, which are then properly assessed in Step 3 of the Framework (see F3). Other techniques include value management studies, desk-top investigations, and stakeholder engagement. It is critical to note that, when applying these techniques, care should be taken not to specify a solution before undertaking appropriate problem definition and options assessment.

4. Stage 2: Problem assessment

This stage involves assessing the scale, extent, timing, costs and causes of the problem. They should be expressed in evidence-based monetised and quantitative terms, supported by qualitative descriptions.

Problem assessment focuses on examining and validating the problem statements identified in Stage 1 of the analysis.

4.1 Why is problem assessment important?

Developing a sound understanding of the scale, extent, timing, cost, cause of problems:

- Enables practitioners to prioritise the worst problems first
- Provides a strong evidence base for generating options (/solutions) for resolving identified problems, including generation of appropriate cost options.

Failure to obtain this understanding:

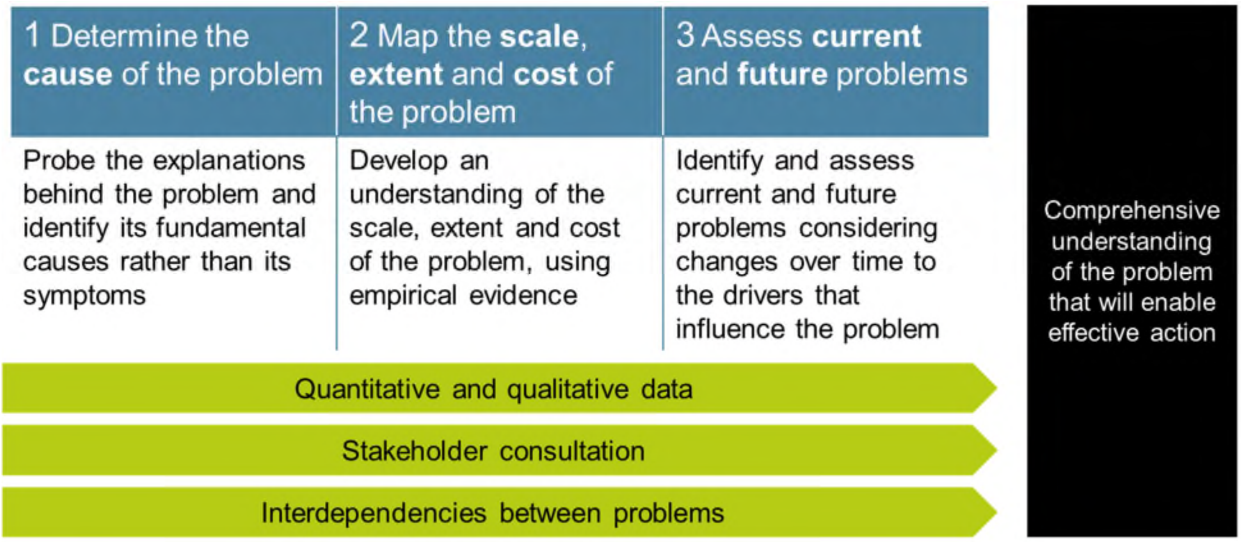
- May result in a mismatch of problems and solutions, and/or solutions that don't adequately or effectively alleviate the problem now and/or in the long term.
- Could limit practitioners in their ability to fully explore possible options and identify the most appropriate solution.

Completing a thorough problem assessment is therefore critical before proceeding to the options generation and assessment step.

4.2 Key dimensions in problem assessment

It is critical that practitioners develop a sound understanding of multifaceted transport problems. Figure 2 illustrates the dimensions of problems that need to be considered by practitioners in undertaking this stage of work.

Figure 2 Dimensions in problem assessment



Each of these dimensions is described in more detail below.

4.3 Causes of the problem

Once the problem statements have been developed, identifying and validating the causes of the problem is required. Effective action can only be taken once the underlying causes of a problem has been diagnosed.

The critical element at this stage is to understand the cause: that is, to probe the causes or explanations behind the observed problem and to identify the fundamental causes rather than the symptoms of the problems. Assessing a problem in terms of its symptoms obscures the real cause and leads to solutions that fail to correct the basic issues and conditions. For example, a symptom may be crowding on trains. The underlying cause is demand growth driven by employment growth in the CBD, which cannot be met by operating additional services on the existing infrastructure (IA 2018, B1.3)

Practitioners should be able to demonstrate an understanding of why the problem has arisen or will occur and directly link this understanding to the subsequent identification of potential solutions in the next step of the framework.

Possible causes for transport-related problems may include a market failure of some kind, a government failure in terms of planning, incorrect pricing, a lack of investment signals or poor governance arrangements.

It is important to identify the fundamental causes of the problem with as much precision as possible. For example:

- The root cause of road congestion should not be identified broadly as a ‘lack of capacity’. Further investigation is needed to determine what has caused the lack of capacity. It may be a demand/supply mismatch caused by incorrect pricing and excess demand or a lack of supply side investment due to the absence of price signals or targeted revenue streams.

- When shop owners in a suburban shopping centre complain about inadequate parking for their customers, the root causes may be broader than insufficient parking supply. The problem may also be defined as too many vehicles at certain times of the day, inefficient management of available spaces, land use planning that has permitted too many car-dependent businesses to locate together or a lack of adequate public transport or active transport offerings.

Accurate identification of the cause of the problem is crucial to developing well-targeted solutions.

Consideration should also be given to the nature of the cause of the problem and whether, on balance, it is a positive or negative development. This will affect the way in which a problem is addressed. For example, economic growth — generally a positive development — may have caused an increased demand for freight movements along a transport corridor, placing road and rail links under unexpected pressure. In this instance, the solution is unlikely to involve limiting economic growth; rather, the emphasis will be on managing the transport system to respond to the growth.

Considering the cause of problems will also often lead to identifying interdependencies between problems. More guidance on interdependencies is considered in F3.

4.4 Scale, extent and cost of the problem

Once the cause has been identified, systematic assessment is required to understand the scale, extent and cost (social, economic and environmental) of the problem. In effect, this analysis aims to answer the question: how much does the problem matter?

Assessing the scale, extent and cost of the problem should be an objective, data-rich and transparent exercise. Many specific datasets are available to support this exercise. For example:

- Transport for NSW provides comprehensive statistics and datasets for a range of topics, including Journey to Work data, travel and population forecasts, and information about rail, bus and ferry modes.
- The ABS provides nationwide statistics and data on travel to work or study, number of registered vehicles, road traffic accidents and motor vehicle use.
- BITRE produces monthly and annual statistics related to road deaths, road trauma, heavy vehicle crashes and international road safety comparisons.
- State and Territory agencies collect and publish road statistics in their respective jurisdictions.

4.5 Monetised, quantified and qualitative evidence

Wherever possible, problems should be quantified and monetised. Where neither of these are possible, due to a lack of quality information and data, they should be expressed in qualitative terms.

Infrastructure Australia (2018, section B1.3) outlines three tiers of information as indicators of evidence for problems, using the example of train crowding to illustrate:

- **Qualitative:** For example, the statement that there are trains crowded to capacity. This provides the weakest strength of evidence.
- **Quantified:** For example, the number of trains and passenger hours at different levels of crowding now and expected in the future. This evidence is stronger than qualitative but weaker than monetised.
- **Monetised:** For example, the cost to passengers in dollar terms associated with train crowding and reduced reliability.

Where available, monetised information, supported by estimated quantities and qualitative descriptions, provide the strongest value in an assessment. Notwithstanding this, where a benefit or cost cannot be monetised or quantified, but is considered large or significant in terms of affecting a decision, it is critical that they be fully accounted for in the assessment. (IA 2018, B1.3).

IA (2018) Section B1.3 Box 4 (reproduced in Box 2 below) provides a simple worked example showing how the monetised costs of congestion and rail crowding over time can assist in preliminary considerations of the size and timing of options to address these problems.

Monetisation of problems also creates a direct link to the cost-benefit analysis that follows in step 3 (see F3 and T2). The monetised costs in the base case (the situation *without* a solution to the problem) and the project case (the situation *with* a solution to the problem) provides the basis for the discounted cash flow analysis underpinning the cost-benefit analysis.

Appendix A provides a guide to problem costing.

4.6 Current and future problems

Problems should be considered in short, medium and long term times frames. There are no precise definitions of these time frames, but may typically be: short term 0-5 years; medium term 5-10 years; long term more than 10 years. Consideration of problems over even longer time frames also play an important role. For example, global warming is a problem with timeframes in excess of 50 years.

Current problems and their context should be described accurately. This requires the systematic mapping and quantification of problems. It should include an objective identification of deficiencies in the condition and operation of transport infrastructure networks and the services they support (see F10.1 Policy Choices and System Planning for discussion of network deficiency assessment). Generally, this will involve analysing and explaining data obtained through studies on development trends, demographic forecasts, land use requirements, infrastructure systems, feasibility studies and other aspects.

Given the scale and long asset life of many transport investments, it is important to consider whether in future:

- A problem today will persist, become larger, or diminish
- Any new problems will arise.

This means that the full range of factors (or 'drivers') that may shape the future should be considered. Failure to explore these drivers may lead to poorly considered transport decisions and investments that do not stand the test of time.

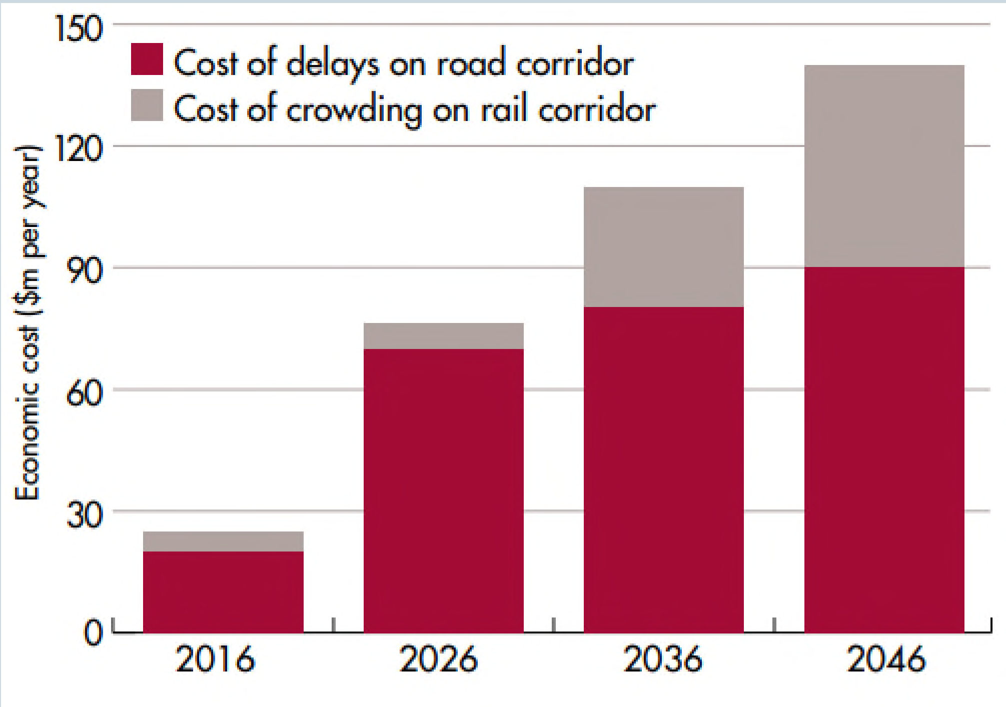
Box 2 Worked example of monetizing the cost of a problem

Suppose that a strategic planning exercise has been undertaken for a major city transport system. Using this information, a proponent can show the size and pattern of costs for a particular corridor or for a number of corridors:

- To measure the cost of delays on the road network, the proponent could estimate the economic cost of additional time and vehicle operating costs for road users relative to free flow conditions
- To measure the cost of crowding on the rail network, the proponent could measure the cost to users of travelling in more crowded conditions relative to non-crowded trains and/or stations.

Considering this over time, such as in the chart below, shows the relative size of the problem and how it changes. In this example, road congestion costs increase rapidly from 2016 to 2026, while rail crowding costs are smaller but increase rapidly from 2026 to 2036.

This would then allow for comparison with other problems in terms of size and timing, and for the scope and phasing of options to be considered relative to the monetised problem. In this example, a proposed road project that costs $1 billion to address the problem would likely cost more than the benefits it would provide, and smaller scale options should be considered.



Source: IAAF (2018), section B1.3, Box 4

Best practice planning requires these future drivers — and the links and interplay between them — to be identified and analysed to understand their influence on longer term objectives and problems.

While the drivers that influence transport problems will be unique to each problem, some potential drivers to consider are:

- Socio-demographic change — total population, population mix (especially age profile), population distribution, values, and behaviour change (e.g. increased work from home, larger night-time economy)
- Economic change — size and mix of the economy, growth, globalisation, labour markets
- Land use planning — the allocation of growth across the city/region will influence transport demand
- Energy prices — particularly the potential mix and cost of energy sources for various sectors of the economy
- Climate change — the impact of change in climate patterns such as temperature, run-off projections, sea level rise and storm surge probabilities on the demand for infrastructure and the maintenance of existing infrastructure networks
- Technological change — whether change in technology will reduce or increase the demand for certain transport systems, create entirely new demands and/or change the way infrastructure systems are built, managed and operated
- Governance change — changes in the wider system of government that may shape the demand for services and/or the way in which government responds to those demands
- Major unprecedented events — such as pandemics and catastrophic scale bushfires.

4.7 Analytical tools

A number of analytical tools are available to support practitioners in problem identification and assessment. Some of these are shown below.

Figure 3 Analytical tools for use in problem assessment

Deficiency analysis	Data and modelling	Gap analysis	Scenario analysis
This analysis compares a network and its components with specified benchmarks such as average vehicle speed, level of service, track availability, transit times and crash rates. Examples of sources of data for deficiency analysis include:	Transport modelling may yield useful data (such as travel times, origins and destinations of trips, vehicle operating costs and choice of travel mode).	Gap analysis may be a helpful tool to establish the degree to which actual outcomes (measured by performance indicators) fall short of desired outcomes (measured by performance targets).	Scenario analysis considers a number of potential different futures, and how the nature of the problem varies between those futures. Sources on scenario analysis include:

• State/Territory transport agencies • ABS • BITRE • OECD	Modelling tools include surveys, the conventional four step trip generation model, meso and micro simulation models, and integrated land use and transport modelling. Example transport models that may be used include: • aSIDRA • TRANSYT • AIMSUN • EMME • TRANSCAD	This gap comparison can be undertaken for the present year, and for any future year.	• US Federal Highway Administration, *Scenario Planning Guidebook* • Oregon Sustainable Transportation Initiative (OSTI), *Scenario Planning Guidelines* • Infrastructure Australia, *Assessment Framework* Box 2 provides further discussion.

4.8 Future uncertainties

Assessments of the future will involve uncertainties, and these need to be taken into account. Infrastructure Australia (2018) notes that policy and investment decisions should be made having regard to potential views of the future and that scenario analysis provides a strong platform for robust decision making. Infrastructure Australia asks to the proponents of initiatives to assess whether the problems identified are likely to be enduring and significant under a range of scenarios. Infrastructure Australia expects proponents to present some scenario analysis at the problem identification and assessment stage. Box 3 below provides a brief discussion of scenario analysis.

ATAP Part O7 provides further discussion of the assessment of risk and uncertainty in the ATAP Guidelines. As noted in O7, sensitivity analysis is another form of assessment that can be used to test robustness of a problem assessment. It can be used where a quantitative model is used to estimate the scale of the problem. The models input variables can be varied individually, or in combination, to test the impact on the scale of the problem.

Box 3 Scenario analysis

Although there are limited precedents for the use of this tool in Australia, scenario analysis is an important tool that can help to identify transport problems and assess their implications.

What is scenario analysis? - Scenario analysis is a structured way to think about the future. It has been described as 'stories that can help us to recognise and adapt to changing aspects of our environment'. It provides an assessment of the links and interactions between various drivers of change and the future impacts on transport infrastructure and networks.

How is it achieved? - Usually, the drivers of change are applied to establish three or four alternate views (scenarios) of the future. Using data-rich information about forecasts, these drivers are clustered and ranked to identify those that are most important for the goals and objectives defined during Step 1. A range of 'shocks' (scenario attributes) is set against these drivers to test the scenarios through quantitative and qualitative approaches that look for 'tipping points', which can then be compared with the defined goals and objectives.

What scenarios should be explored? - Scenarios should be plausible and varied. Importantly, they should not be restricted to minor variations to a central 'business as usual' scenario: futures where the drivers of change operate in a materially different way to that used for the 'most likely' or 'business as usual' scenario should also be explored.

What timeframes should be used? - Strategic planning should take a long term view. In developing scenarios, the time horizon for analysis should reflect the nature of the problems and challenges likely to prevent the achievement of the defined goals and objectives. For example, some challenges, such as those associated with climate change and the availability and cost of various energy sources, have long-term implications that extend beyond 25 years. Transport networks also tend to have long lives. For these reasons, scenario analysis frequently involves an assessment of the future beyond the next 20, 30 or 40 years. However, it should be noted that medium term horizons (of five to 10 years) are generally considered more plausible and certain than longer term horizons.

What are the limitations of scenario analysis? - The most significant practical limitation in undertaking scenario analysis is likely to be the resource implications of testing numerous quantitative scenarios. Where resources are constrained, practitioners may need to very carefully consider the number, nature and scope of scenarios to be tested. There may also be difficulties in establishing a planning baseline against which alternative scenarios can be tested: in some instances, this may render scenarios analysis a largely pointless exercise and make other forms of data collection more useful.

4.9 Bases for comparison

As noted by IA (IA 2018), when estimating the scale of a problem, the bases of comparison need to be clearly stated. Figure 4 provides the suggested bases of comparison for various other key transport problems. It shows that the comparison can be related to the current service level, or a higher service level. Either can be used, provided one approach is applied consistently throughout an assessment.

Figure 4 Bases of comparison for problem estimation

Case	Compared to current	Compared to higher level of service
Congestion	Future congestion vs current congestion	Current and future congestion relative to uncongested conditions
Pavement condition	Future pavement condition vs current condition	Current and future pavement condition relative to very high strength pavement
Travel time reliability	Future reliability vs current reliability	Current and future reliability relative to full reliability
Safety	Future crash risk vs current risk	Current and future crash risk relative to zero risk or very low risk
Emissions	Future emissions vs current emissions	Current and future emissions relative to zero emissions or very low emissions
Network resilience	Future network availability vs current network availability	Current and future network availability relative to full network availability

5. Stage 3: Problem prioritisation

This stage allocates priority to the identified problems. This determines which problems should be tackled first.

With resources being limited, governments and society cannot afford to address all identified problems at the same time. Setting priorities is therefore important.

A range of factors may be considered in prioritising problems, including:

- The goals and objectives identified in Step 1. For example:
  - The problem that presents the greatest obstacle to achieving the goals and objectives may be given priority
  - If objectives have also been prioritised, the problem preventing achievement of the most important objective may be given priority
  - Consideration of the overall strategic alignment of problems with goals and objectives.
- Current or forecast levels of demand
- The scale or extent of the problem (quantified and monetised), and hence the potential benefits of addressing the problem.
- Robustness of existence of the problems to alternative future scenarios.

As with problem assessment, a sound evidence-base is important in problem prioritisation. A comparison of information gathered during the problem assessment stage across problems will help to identify the most urgent or most significant problem. However, it is important to appreciate that this may not be an entirely objective process for two reasons:

- Input from stakeholders will be largely subjective
- Weighing up significant qualitative information alongside quantitative and monetised information can be challenging.

Problem prioritisation may require further problem assessment beyond the stage, to support evidence-based priority setting.

6. Engaging stakeholders

Transport planning is conducted in a complex environment in which the views of government and community stakeholders need to be understood. Engaging stakeholders and listening to their views and concerns is a key component of best practice transport planning.

Engaging stakeholders and the community in problem identification, assessment and prioritisation leads to a more comprehensive process. It may identify new problems or cast new light on known problems. It can improve access to data and information and help to fill gaps in knowledge regarding community views, concerns and expectations.

A planning process that does not engage more broadly with stakeholders runs the risk of identifying only the best known or most acute problems. It is also more likely to address problems in isolation rather than within a broader strategic and practical context.

The purpose of engagement during this step of the Framework is to ensure that all potential problems are identified and understood, across all planning levels. For example, a government department or agency may have a broad perspective on the problems that are impeding transport, such as regulatory barriers or funding constraints. Local residents may be much more focused in their assessment, nominating very specific problems on a particular stretch of road or intersection as compromising safety.

Where appropriate and practical, community engagement around problem identification and prioritisation can also help to develop trust in the early stages of a transport plan or initiative and create networks and structures to identify, prevent and solve problems on an ongoing basis.

Box 4 Tools for engagement

Many tools can be used to identify and engage stakeholders, and ensure their views and experiences are considered in identifying and assessing problems. These include:

- *Stakeholder mapping* — to identify all key stakeholders with an interest in a particular problem and the data or information they may hold
- *Strategic workshops with government stakeholders* — to identify problems in a broader strategic context and understand government preferences and priorities
- *Scenario analysis with stakehol*ders — to identify future drivers for change and develop best and worst case scenarios that consider the interests of community, private and public sector stakeholders
- ***Investment Logic Mapping and Benefit Dependency Mapping with stakeholders*** — to identify and explore problems (see section 3.1)
- *Real time feedback from transport system users* — to identify current problems and constraints that reflect the experiences and concerns of users
- *Surveys, community forums, online engagement and social media* — to better understand how the broader community views particular problems and issues
- *Value management stakeholder workshops* — to explore a specific problem or issue, involving people from different representatives and community groups, government agencies like local councils, and subject matter experts.

The extent to which any engagement tool is used will depend on many factors, including the requirements of government, the nature of the particular problems being assessed and the time allocated to this step.

Box 5 Checklist for practitioners

Checklist
What is the current or future problem?
How is the problem preventing achievement of the goals/transport system objectives?
Can the effects of the problem be measured?
What are the drivers that influence the problem?
How will the drivers of the problem change over time?
Will the problem increase gradually or will there be a step change increase?
What are the symptoms of the problem?
What are the causes of the problem?
Are there dependencies between this problem and others? Are there any other initiatives (including land use planning) under development that influence the problem?
Consider whether mapping techniques such as Investment Logic Mapping and Benefit Dependency Mapping processes may be helpful in the process of understanding the problem?

Appendix A Problem costing guide[2]

This report (F3) has provided guidance for Step 2 of the ATAP Framework — problem identification and assessment. This appendix provides a process for monetising the cost of a problem as part of the overall Step 2. It outlines the problem costing process, illustrating with application to roads, including two road based worked examples. It is critical for readers to note that the identification of a road problem does not necessarily mean using a road solution. In Step 3 of the Framework — options generation and assessment — a wide range of options, including non-transport options, and non-road options, need to be identified, and the overall best solution found.

Problem costing guidance beyond the road setting will be considered for future ATAP work programs.

A.1 Process

Problem costing is the process in which identified problems are monetised, that is expressed in dollar units. It involves three steps:

- Describe the problem in the Base Case
- Define the Reference Case — the comparison benchmark
- Monetise the problem cost.

A.1.1 Describe the problem in the Base Case

Identifying and documenting the base case lays a foundation for estimating the problem cost. Section 1.6 of ATAP Part T2 Cost-benefit analysis outlines how the Base Case should be identified. It should be the 'do minimum' option.

Once the Base Case has been agreed, the problem in the Base Case should be identified and documented following Chapter 2 above.

A.1.2 Define the Reference Case

In estimating the problem cost, it is important to define a 'reference traffic condition' to estimate the incremental problem cost. The problem cost is the difference between the base case and the reference case. The reference case is a level of service which is desirable and optimal. It would be considered a problem if the network performance falls below this level. The Reference Case coincides with column three of Figure 4, that is a comparison with a higher level of service.

[2] The Appendix A is based on "Estimating the Problem Cost" developed by Transport for NSW's Investment Branch in 2019. ATAP acknowledges Martin Oaten, Head of Investment Branch, and Baojin Wang, and author of the document for their permission to use its original material and analysis.

Austroads (2007) defines the road network performance in terms of efficiency (travel speed variation from posted speed limit), as well as reliability and productivity (speed and throughput). Generally, the road performance is measured by a Level of Service (LOS), where the LOS 'A' represents excellent driving condition and the LOS 'F' represents very poor performance. Austroads considers LOS 'D' as the limit of stable traffic flow approaching unstable traffic flow where user journey times become unreliable and subject to unplanned or unforeseen delays. At LOS 'D', drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. At this point small increases in traffic volume will generally cause a flow breakdown. More detailed description of LOS for urban and rural roads are shown in Table 1 and Table 2. The problem is identified if the performance is poorer than the predefined thresholds for the Level of Service, road safety and other performance standards.

Table 1 Urban and suburban arterial roads with interrupted flow conditions

LOS	Meaning
A	Describes free-flow operation. Vehicles are completely unimpeded in their ability to manoeuvre w the traffic stream. Control delay at the boundary intersections is minimal. The travel speed exceed 80% of the Base Condition Free Flow Speed (BFFS)
B	Describes reasonably unimpeded operation. The ability to manoeuvre within the traffic stream is (slightly restricted and control delay at the boundary intersections is not significant. The travel spee between 67% and 85% of the BFFS
C	Describes stable operation. The ability to manoeuvre and change lanes at mid- segment locations may be more restricted than at LOS B. Longer queues at the boundary intersections may contribu to lower travel speeds. The travel speed is between 50% and 67% of the BFFS.
D	Indicates a less stable condition in which small increases in flow may cause substantial increases delay and decreases in travel speed. This operation may be due to adverse signal progression, h volume, or inappropriate signal timing at the boundary intersections. The travel speed is between 40% and 50% of the BFFS.
E	Is characterised by unstable operation and significant delay. Such operations may be due to some combination of adverse progression, high volume, and inappropriate signal timing at the boundary intersections. The travel speed is between 30% and 40% of the BFFS.
F	Is characterised by flow at extremely low speed. Congestion is likely occurring at the boundary intersections, as indicated by high delay and extensive queuing. The travel speed is 30% or less (the BFFS.

Table 2 Two lane two way highway with uninterrupted flow conditions

LOS	Meaning
A	Motorists experience high operating speeds on arterial roads and little difficulty in passing. Platoo of three or more vehicles are rare. On sub-arterial roads, speed would be controlled primarily by roadway conditions. A small amoun platooning would be expected.
B	Passing demand and passing capacity are balanced. The degree of platooning becomes noticeat Some speed reductions are present on arterial roads. On sub-arterial roads, it becomes difficult to maintain Free-Flow Speed (FFS) operation, but the speed reduction is still relatively small.
C	Most vehicles are travelling in platoons. Speeds are noticeably curtailed on all three classes of highway.
D	Platooning increases significantly. Passing demand is high, but passing capacity approaches zerc high percentage of vehicles are now travelling in platoons, and Percent Time Spent Following (PT is quite noticeable.
E	Demand is approaching capacity. Passing is virtually impossible, and PTSF is more than 80%. Speeds are seriously curtailed which is less than two-thirds the FFS. The lower limit of this LOS represents capacity.
F	Whenever arrival flow in one or both directions exceeds the capacity of the segment. Operating conditions are unstable, and heavy congestion exists on all classes of two-lane highway.

Level of Service

To define the problem cost, the reference case is set at the road performance of LOS A or B, equivalent to the free-flow operation. Table 3 provides indicative free flow speed, and intersection delays for further adjusting the free flow speed for a route. The traffic speed dropping below the free-speed speed is considered as a “problem” and its associated costs should be included in the problem cost.

Table 3 Indicative road capacity, estimated free-flow speed and typical intersection delays

Road / intersection type	Indicative capacity (Veh/h/ln)	Assumed speed limit (km/h)	Estimated free-flow speed at LOS A/B (km/h)	Typical Intersection delays per vehicle at LOS B (Seconds)
Regional freeway	2000	110	110	
Regional highway	2000	90	90	
Urban motorway	1800	90	90	
Urban arterial road	1000	70	66^	
Urban sub-arterial road	800	60	55&	
Signalised Intersection				10 - 20
Stop / Give Way Control				10 - 15
Roundabout				10 - 20

** Flee flow speed at LOS A and B is almost the same.*

^ Free-flow speed is estimated based on 8 road access points form roadside

& Free-flow speed is estimated based on 12 road access points form roadside

The following problem costs should be included if the network performance is below LOS B:

- Congestion cost: Additional travel time due to the operational speed slower than free flow speed
- Intersection delay cost: Additional travel time due to extra delays above the typical intersection delays
- Travel time variability: Day to day travel time variability due to less than free-flow speed
- Additional vehicle operating cost: If the total vehicle operating cost (VOC) is more than the VOC at the free-flow speed, the additional cost is included as the problem cost
- Additional environmental externality: If the total environmental externality cost in the current and forecast traffic condition is more than at the free-flow speed, the additional cost is included as the problem cost.

Road Safety

From a social perspective, any road casualty is a ‘problem’. From an operational point of view, there is always a certain level of road crash that represents the random and inherent risk of the traffic system. The reference case on road safety can be set in line with a strategy. For example, the NSW Road Safety Strategy 2012-2021 targets a 30% reduction of fatalities and serious injuries as shown in Table 4.

Table 4 Example road safety target in reference case

	Actual from 2012-2016	Possible reference case
Road fatality rate (Number of fatalities per 100 MVKT)	0.50	0.35
Serious injury rate (Number of serious injuries per 100 MVKT)	9.53	6.67

The following problem costs should be included if the road crash rate is higher than the target set out in the strategy:

- Road crash cost: Include the crash cost for the crash rate above the target. If the crash rate in question is below the rate set out in the target, this item is excluded.
- IA suggests also referencing the cost of the problem in relation to average crash rates. The Infrastructure Australia Assessment Framework does not specify which comparison to use, but both are helpful in understanding the problem. It would also depend on whether the targets are highly aspirational (e.g. zero fatalities) or more easily achievable.

- Traffic delay and travel time variability caused by additional road crashes.

Other road performance problems

In addition to the problem costs estimated for traffic performance and road safety, other problem costs should be included if they are considered as a 'problem'. For example:

- Road noise beyond acceptable standard
- Higher than average maintenance cost
- Road flood and community isolation.

A.1.3 Monetising the problem cost

In general, the problem cost should be estimated for the following three time points:

- Near term (0-5 years)
- Medium term (5-10 years)
- Longer term (10-15 years)

This will facilitate an assessment of the scale of the problem both now and into the future. For an appraisal of a project option, the problem cost needs to estimated over the entire appraisal period. In problem costing, costs are presented in undiscounted dollar units. Discounting occurs later in the appraisal process.

Further details, including formulae, for estimating the problem cost is summarised in section A.5 for the worked examples provided below.

A.1.4 Problem cost in the Project Case

The above approach allows problem costing in Step 2 of the ATAP Framework — problem identification and assessment. The approach is then also used in Step 3 of the Framework — options generation and assessment. For a given option being assessed — the Project Case — the problem cost is estimated. The reduction in problem cost between the Base Case and the Project Case measures the benefit of an option.

A.1.5 Presenting the problem cost

The outputs of problem costing should be clearly presented for review and validation. The basic information included in the presentation should cover:

- Base case
- Reference case
- Problem costs in near, medium and longer-terms

- Values by the problem type
- Operating assumptions
- Patronage and traffic inputs
- Key assumptions

Table 5 provides a summary of an illustrative set of results. The problem cost represents the envelope of costing for all problems. In this illustrative example, the problem cost is estimated at $60m (i.e. $80m - $20m) in the current year and increases to $80m and $95m respectively at years 2026 and 2036, with the total problem cost estimated at $2,730m over 30-year period.

Table 5 Illustrative example of presenting problem costing results (undiscounted)

Generalised road user costs	2019	2026	2036	2049
Base case ($m)	$80	$100	$115	$120
Reference case ($m)	$20	$20	$20	$20
Proposed solution ($m)	$50	$70	$85	$90
Problem cost	$60	$80	$95	$100

A.2 Sourcing useful data for estimating the problem cost

Quantifying and monetising the problem cost should occur at an early stage of project development before traffic modelling and other detailed analysis have been undertaken. Ideally, jurisdictions would be regularly identifying, assessing then prioritising problems. Monetised problem costs are a key piece of information in problem prioritisation and also later in appraisal of options. The analyst will need to use existing data sources that are available as much as possible. Table 6 provides a summary of useful data sources that can be used in estimating the problem cost, illustrating with specific reference to NSW.

Table 6 Data sources for estimating the problem cost

Data source	Note
Traffic volume and speed In Advanced Analytics and Insights (AAI) data.	The AAI data contains TfNSW road performance analytics, traffic volume, travel time and Journey to Work (JTW) data. It is the most comprehensive data available on current traffic performance within RMS.
Traffic volume. RMS Traffic Volume Viewer.	View traffic volume data for RMS permanent traffic stations, sample stations and heavy vehicle checking stations. Includes traffic by direction, vehicle type and historical traffic volumes.
Traffic volume and intersection delay. SCATS.	Sydney Coordinated Adaptive Traffic System (SCATS). A reliable data source for intersection performance.
Traffic volume and speed. WIM (Weigh-In-Motion).	Weigh-In-Motion (WIM) Data systems are used to collect road usage information on the State road network. It includes 14 stations in Sydney and 24 stations in regional NSW. Data availability includes • Traffic count by vehicle class • Vehicle speed
Traffic volume and speed. Tube counts.	Traffic count by class. Can be set up on any road.
Traffic volume and speed. Camera counts.	Can be set up on any road that provides data for: • Volume by vehicle class • Vehicle speed.
Speed. RMS speed surveys.	RMS manages surveys of more than 170 such routes in the Sydney metropolitan area.
Speed. Speed probe data.	Data sources: • Google • TomTom, Garmin • iPhone App.
Bus speed. PTIPS.	Public Transport Information and Priority Systems. Data includes: • Bus speed • Bus passenger travel time
Bus speed. Opal.	Data includes: • Bus speed. • Bus passenger travel time.
Road crash. CrashLink.	A detailed database containing road crash data

A.3 Example 1: Princes Highway, Nowra Bridge

Within NSW, the Princes Highway provides the main north south connection between the M1 Princes Motorway at Yallah and the NSW border south of Eden. The highway links Sydney with the Illawarra and Shoalhaven Regions and provides the principal route connecting the communities along the South Coast of NSW. The highway carries a mix of freight, local, long distance, and tourist traffic. Upgrading the highway has progressed to the final section of dual carriageway between Sydney and Bomaderry (due for construction start in early 2020). The highway south of Nowra is largely a single carriageway.

The Princes Highway crossing the Shoalhaven River linking Bomaderry to Nowra is provided by two bridges:

- The southbound 'Whipple' truss bridge opened in 1881 is a mixed cast iron and wrought iron structure. This bridge provides two narrow 2.75-metre wide lanes for southbound traffic with a "clip on" pathway for pedestrians and cyclists on the downstream (eastern) side.
- The existing northbound bridge, opened in 1981, is a concrete box girder structure. This bridge has 3-metre wide lanes for northbound traffic, one of which provides a dedicated left turn into Illaroo Road. A footpath on the upstream side caters for pedestrians and cyclists.

This is the only crossing of the Shoalhaven River on the coastal plain with the next upstream crossing being at Oallen Ford on the tablelands near Nerriga with no other crossing downstream.

A.3.1 Describe problem in Base Case

The Princes Highway Corridor Strategy measured the performance of the highway for four criteria: road safety, traffic and transport, road design and geometry and road pavement; and compared the performance against desired performance targets for the criteria. The corridor strategy confirmed the deficiencies of the 1881 Nowra Bridge and the adjacent intersections as follows:

- Prevents operation of Higher Mass Limit B-Double vehicles southbound
- Is narrow at 5.5-metres between kerbs for accommodating two traffic lanes
- Has a 'poor' Bridge Health Index (BHI) and limited remaining life
- Prevents passage of loads over 4.6 metres high
- Vehicle configurations with heights between 4.3m and 4.6m are required to cross the lane separation line to negotiate the southbound bridge
- Forms a critical crossing which requires long detours of hundreds of kilometres if the crossing closes
- The intersections with Bolong Road, Illaroo Road, Bridge Road and Pleasant Way are congested and generate excessive delays.
- There are crash rates greater than the State average annual crash-rates on the Princes Highway between Bolong Road and Bridge Road for the same class of road, caused by the mixed traffic in the urban area.
- High traffic volumes during peak times leading to congestion between Bolong Road and Bridge Road and the wider network
- There is a need to ensure that the road network supports higher productivity vehicles (HPV), which includes removing height and weight restrictions on the southbound bridge.

A.3.2 Define the Reference Case

The reference case for Shoalhaven River Crossing at Nowra has been defined for each of the four performance criteria as detailed in Table 7.

Table 7 Performance of Shoalhaven River Crossing for current situation and in Reference Case

Criteria	Current situation	Reference case
Congestion and delay.	The average speed in PM peak hour is 14.7 km/h by 2026.	Network average speed is 66 km/h at LOS B, compared with a speed limit of 70 km/h.
Road safety.	The average crash rate was 8.13 crashes per-km in the Nowra bridge Project Area between 80 metres north of Bolong Rd and 75 metres north of Moss Street, well above the state average.	2.84 crashes per-km is the average NSW road crash rate for the same class of road.
PBS accessibility.	Vehicles with heights exceeding 4.6m or at HML loads are not permitted to use the southbound bridge, and are instead escorted across the adjacent and newer northbound bridge under a contra-flow arrangement which requires support from police or traffic controllers.	PBS vehicles are allowed for Shoalhaven River crossing at Nowra.
Bridge closure and traffic diversion.	If the Southbound Bridge (built in 1881) was closed due to its approaching to its end of the useful life, a diversion of hundreds of kilometres would be required or a contra-flow arrangement should be in place on the 2-lane Northbound Bridge (built in 1981). The contra-flow will cause excessive congestion in peak hours.	Additional 2-lane capacity is added to prevent the Bridge closure.

A.3.3 Monetise the problem cost

The problems of the base case are road congestion, high road crash rates, a low rate of freight efficiency and relatively high maintenance costs for the existing bridge, due to the heritage significance of the old southbound bridge and Roads and Maritime obligations under the Heritage Act. The problem cost has been assessed by monetising the difference between the Base Case and the Reference Case. Results are summarised in Table 8.

Congestion cost

Traffic modelling indicates that, by 2026, the average travel speed will reduce to 17.2 km/hr in AM peak and 14.7 km/hour in PM peak. Travel delays will impose economic cost to local businesses, commuters, freight vehicles and other private trips. The congestion cost was estimated as the difference in travel time cost between the existing congested road condition and the average speed defined in the reference case (i.e., 66 km/h at LOS A/B). In the Nowra Bridge area, a free-flow condition of 70 km/hr is achievable. This estimate has taken a conservative approach by assuming a lower average speed.

Crash cost

The congested road network in the vicinity of the crossing causes more start-stop traffic flow conditions. The crash rate is 8.13 crashes per km per year in the Nowra bridge Project Area between 80 metres north of Bolong Rd and 75 metres north of Moss Street, higher than the reference case of NSW average of 2.84 crashes per km per year for similar traffic and road conditions. Converting these crash rates to crash costs using unit crash cost, the crash problem cost is the difference in cost between the Base Case and the Reference Case.

Additional freight cost

The existing southbound bridge, built in 1881, is unable to accommodate Higher Mass Limit (HML) trucks. Improved freight efficiency can be achieved if PBS3A vehicles are permitted in the corridor. In the Nowra Bridge analysis, the freight cost was conservatively estimated within the "local area" instead of the Princes Highway corridor level as there are other constraints in achieving corridor PBS3A access. Narrow lane and shoulder widths along the Princes Highway restrict access to Higher Productivity Vehicles. As a result, the 26m B-Double Approved Route is limited to the northern and southern extents of the Princes Highway. In addition, vehicles longer than 19 metres are not permitted on some sections of the highway due to poor alignment issues on the Highway near Narooma and around Brogo.

Other constraints to Higher Productivity Vehicles include:

- Height constraints at Narooma Bridge
- Mass Limits at Batemans Bay, Tuross River, Narooma and Brogo River Bridges
- Narrow bridges or culverts at multiple locations along the corridor.

Additional maintenance cost

Due to the heritage significance of the old southbound bridge and Roads and Maritime obligations under the Heritage Act, maintenance cost for the old southbound bridge is significantly higher than the average maintenance cost of non-heritage bridges in similar size. An engineering study has estimated that the additional maintenance cost for the 1881 Bridge was $79.3m in a 50-year period, equivalent to $1.6m per annum.

Table 8 Problem cost in the base case by 2026

Problem	Cost of problem if existing Southbound Bridge remains open to traffic
Congestion cost	
• Delay cost ($m)	$64.0
• VOC cost ($m)	$6.4
Crash cost ($m)	$4.3
Freight inefficiency ($m)	$0.9
Additional maintenance cost ($m)	$1.6
Diversion ($m)	
Total cost ($m)	$77.3

A.4 Example 2: Prospect Highway, Western Sydney

The Prospect Highway is an arterial north-south corridor approximately 25-kilometres west of the Sydney CBD. The corridor connects Blacktown CBD with a number of commercial centres, Prospect, the Great Western Highway, the M4 Motorway and the Western Sydney Employment Lands via Reconciliation Road.

A.4.1 Describe problem in Base Case

The 3.6-kilometre section of the Prospect Highway between Reservoir Road, Prospect and St Martins Crescent, Blacktown, currently exhibits a number of operational deficiencies and constraints, as discussed below.

Road capacity

The corridor currently has an Average Annual Daily Traffic (AADT) volume of 36,000 (observed in 2018). The speed of traffic flow is limited by:

- The sections of single lane carriageway
- The intersections along the corridor do not operate above LOS 'D' during peak periods, resulting in extended queue lengths and travel times. The dual lane carriageway sections of the corridor are irregular and relatively ineffective. This is largely due to queuing at adjacent intersections which limits utilisation of the additional lanes.

The eight priority (un-signalised) intersections operate with poor levels of service and reliability. The use of proven traffic flow management practices to optimise flow is not possible given the self-regulated nature of the intersections. Existing travel speeds average around 30km/h during peak periods (in 2012), less than half of the sign-posted speed limit.

The traffic modelling undertaken in 2013 calculated a volume to capacity ratio of 1, indicating that the corridor operates at its maximum lane capacity in some sections during peak periods. This is insufficient to cope with the existing 3,000 to 3,500 vehicles per hour.

The situation will worsen in future, as traffic volumes are forecast to reach an AADT of approximately 75,000 within the next 25-years, which would double the existing peak hour volumes.

Speed zoning

Design standards require developing arterial road corridors to enable operations at least 10 km/h above the sign-posted speed limit. This is to provide a factor of safety on the basis that drivers may exceed speed limits. This phenomenon has been confirmed by traffic surveys in some project developments. The existing geometric design of the Prospect Highway does not meet the requirements for a 70 km/h design speed for an arterial road.

Structural and operational deficiencies

There are a number of pinch points along the route. For example, the capacity of the two-lane bridge at the Great Western Highway limits the ability of Prospect Highway to service M4 Motorway bound traffic, which is a major trip distributor for the corridor. The traffic modelling identified the bridge as a major constraint to traffic flow. The reduction to single lane carriageway on approaches to the bridge funnels and slows traffic flow, and this section was identified as the slowest flowing section in the corridor.

High crash rate

The Prospect Highway between Reconciliation Road and St Martins Crescent was the location of 232 reported crashes from 2009 to 2013. The current crash rate is 2.3 times the NSW State average.

A.4.2 Define the Reference Case

In estimating the problem cost, it is important to define a ‘reference traffic condition’ to estimate the incremental problem cost. At the best case scenario, the reference traffic condition can be defined as “free-flow” condition. However, the free-flow is rarely achieved in real traffic conditions given the level of demand on the Sydney road network, particularly in peak periods. Accordingly, in the Prospect Highway case, a conservative reference traffic condition has been defined as:

- Traffic and road asset would be operated at the LOS ‘B’ measurement
- The road crash rate at the reference condition would be the same as the average crash rate of similar road classes in Sydney and other urban roads.

In order to estimate the problem cost, the reference case for the Prospect Highway has been defined on the four criteria as detailed in Table 9.

Table 9 Reference case for the Prospect Highway

Criteria	Current situation	Reference case
Congestion and delay.	The average speed in the PM peak hour is 13 km/h in 2017/18.	To achieve the average speed of 66 km/h for the LOS ‘B’ for the proposed speed limit of 70 km/h.
Journey Time Reliability.	Unreliable journey time.	100% of journeys completed within 117% of the expected journey time for a particular period.
Vehicle operating cost (VOC).	Slow speed incurs additional VOC.	More regular speed will reduce VOC.
Road safety.	The average crash rate was 101 per 100 MVKT.	To achieve 69 crashes per 100 MVKT, the NSW average crash rate on urban roads.

A.4.3 Monetise the problem cost

The Prospect Highway Corridor is currently experiencing a high-level of road congestion. The corridor and intersections currently operates at levels of service 'E-F' during peak periods, resulting in extended queue lengths, some exceeding 200-metres.

The problem cost was estimated based on the incremental cost between the actual traffic condition and the reference traffic condition. Analysis was based on Q Link data in 2017 and 2018 to derive the problem cost in 2018. In addition, a long-term problem cost was projected by assuming a traffic growth rate of 0.9% per annum estimated from the 2012 traffic modelling output.

Congestion caused vehicle delay

The average speed in the four-hour AM peak (i.e. 6:00 AM to 10:00 AM) was 25.3 km/hr in 2017/18, compared to the posted speed limit of 70 km/hr. The average speed in the four-hour PM peak was even lower, at 19.7 km/h. The average speed had dropped to as low as 13 km/hr during the 5:00AM to 6:00 PM period, representing the most heavily congested time of the day. Travel conditions during congested periods are shown in Figure 5.

The expected speed is 66 km/hr at the reference traffic condition (LOS 'B') . The congestion delay was estimated based on the actual travel speed by the time of day (AM and PM peak periods only) and the expected speed at LOS 'B'. The congestion delay was estimated at $30.1m in 2018, and $42.1m by 2028.

Figure 5 Prospect Highway traffic (Source: google map on 23 Oct 2018)

Unreliable travel time due to congestion and intersection performance

In TfNSW's Advanced Analytics and Insights (AAI) data, Journey Time Reliability (JTR) is the percentage of journeys completed within 117% of the expected journey time for a particular period. In 2018, the JTR for the Prospect Highway was 90% in AM and PM peak periods, which means that 10% of trips in peak hours were unreliable with a travel time 17% longer than the expected travel time.

When there is variability in travel time, some drivers might change behaviour by departing home earlier to arrive at the destination on time. This 'buffer" time is a resource cost resulting from the unreliability. For this segment of road, the travel time unreliability problem cost was estimated at $3.4m in 2018, increasing to $4.8m in 2028.

Additional vehicle operating cost (VOC) due to stop-start traffic condition

When traffic flow has deteriorated into start-stop conditions, VOC per-km increases. The additional VOC was estimated from the difference between the actual traffic condition and the expected flow condition at LOS 'B'. The additional VOC was estimated at $11.9m in 2018, increasing to $19.2m in 2028.

Additional road crash cost

The congested road condition has led to a higher crash rate along the Prospect Highway as a result of start-stop traffic flow conditions and more interactions between vehicles. In a five-year period from 2009-2013, there were 232 road crashes in this road section. That is equivalent to 101 crashes per 100 MVKT. This is higher than the average crash rate for similar roads of 69 crashes per 100 MVKT (Austroads (2010) p.50). The additional road crash cost was estimated at $2.3m in 2018, increasing to $2.5m in 2028.

The problem cost of the Prospect Highway is summarised in Table 10, which indicates that the largest problem was the congestion caused vehicle delay that represented 63% of the total problem cost. The additional VOC from start-stop traffic flow represented 25% of the total problem cost, followed by unreliable travel time (7%) and additional crash cost (5%).

Table 10 Problem Cost of Prospect Highway

Problem item	Problem cost as at 2018 ($m)	Medium to long term problem cost in 2028 ($m)	Proportion of problem cost in 2018
Congestion caused delay	$30.1	$42.1	63%
Unreliable travel time	$3.4	$4.8	7%
Additional vehicle operating cost	$11.9	$19.2	25%
Additional road crash cost	$2.3	$2.5	5%
Total problem cost	$47.7	$68.6	100%

Source: TfNSW Analysis, using Advanced Analytics and Insights' Data in 2018

The problem cost was only estimated for the 3.6 km length of the Prospect Highway and the related intersections. It did not include the local network. In fact, the Prospect Highway is causing congestion problems for other surrounding roads. Based on the traffic modelling, the problem cost of the local network, including the Prospect Highway and other surrounding roads, was as high as $131m in 2028. Thus, the problem cost in the Prospect Highway is around 53% of the total problem cost of the local network.

A.5 Supporting details for examples

The methodology used to estimate the problem cost elements in the above examples are outlined in Table 11.

Table 11 Methodology of estimating problem cost

Category	Cost component	Factors affecting cost	Estimation method
Congestion and delay.	Value of person time, value of freight.	Speed, distance travelled, vehicle type.	*Travel time value * hours travelled.* *VTTS = ∆ VHT Vehicle Type × Expansion Factor ×V Vehicle Type*
Unreliable travel time.	Day to day travel time variation and unpredictability.	Traffic volume, congestion.	$STD = S_0 + \frac{(S - S_0)}{1 + e^{b(VCR - a)}}$ $TTV = \sqrt{STD_1^2 + STD_2^2 + \ \ldots \ldots + STD_n^2}$ *Buffer Time = TTV x PAT AR.* *VTTR = ∆ Buffer Time × Expansion Factor × VOT Ve Type × Reliability ratio.*
Freight efficiency and Vehicle operating costs.	Fuel, oil, tyre wear, repair and maintenance, depreciation and interest.	Vehicle type and mass, gradient, curvature, roughness, condition, speed	VOC unit value * VKT. VOC = C0 + C1*V + C2*V2.
Road crash rates.	Fatality, serious injury, other injury, property damage.	Austroads' crash reduction factors, model road state	*Crash rate per VKT * average crash value * VKT.* *Benefit of Road Crash Reduction = ∆ Crash × Crash*
Transport externality and environmental impact.	Air pollution, greenhouse gases, noise, water, nature and landscape, upstream and downstream costs.	Vehicle type and weight	*Externality unit value * VKT* *Benefit to Road Externality Reduction = ∆VKT × Externality Unit Cost*

Notes for Table 6-1, Column 4 formulae and models:

- Line 1: Value of Travel Time Savings (VTTS):

- The product of vehicle hours, value of time and expansion factor. The expansion factor is used to estimate the result of the modelling period (some combination of peak hour and off-peak hour) to annual. VHT is from traffic modelling. Expansion Factor and VOT can be sourced from ATAP M2 and PV2.

- Line 2: Value of Travel Time Reliability (VTTR) (NSW approach):
  - STD denotes the Standard Deviation of travel time for the same route for the same time period due to day to day traffic volume and traffic condition variations
  - S, S_0 and b are equation parameters estimated for different road types, provided in "TfNSW Economic Guidelines" (pg.119, Table 7.1)
  - VCR = volume capacity ratio
  - STD1, 2,….,n are the travel time standard deviations on different road sections
  - PAT AR is the Preferred Arrival Time Applicability Ratio, provided in "TfNSW Economic Guidelines" (pg.121, Table 7.2).
- Line 3 – Vehicle Operating Cost:
  - VOC model can be found ATAP PV2
  - V represents journey speed (km/h)
  - A, B, C0, C1 and C2 are model coefficients (see ATAP PV2 for values)
  - Coefficient A represents the constant fixed cost
  - Coefficient B represents the relationship between speed and VOC for the urban stop-start model
  - The coefficients C1 and C2 represent the relationship between speed and VOC for the freeway model, and vary by vehicle type (see ATAP PV2 for values)
- Line 4 – Crash Cost:
  - VKT is can be calculated from traffic volume and road length, or from the output of traffic modelling if available at the problem definition stage
  - Crash cost is provided in ATAP PV2
- Line 5 – Transport externality and environmental impact:
  - VKT is the output of traffic modelling
  - Unit cost of environmental externality values are provided in ATAP PV5.

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