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Cost overruns in transport infrastructure

Marion Terrill



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This report was written by Marion Terrill, Transport Program Director, and Lucille Danks, Associate, Grattan Institute. Brendan Coates, Owain Emslie, Hugh Parsonage and James Button made substantial contributions to the report.

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Overview

Over the past 15 years, Australian governments have spent \$28 billion more on transport infrastructure than they told taxpayers they would. The cost overruns amounted to nearly a quarter of total project budgets. Both Western Australia's Forrest Highway between Perth and Bunbury and New South Wales' Hunter Expressway cost over five times the amounts initially promised. Yet despite their sometimes staggering size, cost overruns attract little public attention. There is little interest in understanding and fixing the underlying causes.

For the first time in Australia, this report investigates the cost outcomes of all 836 projects valued at \$20 million or more and planned or built since 2001. It finds that most problems are caused by a relatively small number of projects. Ninety per cent of Australia's cost overrun problem is explained by 17 per cent of projects that exceed their promised cost by more than half.

Premature announcement – when a politician promises to build a road or rail line at a particular cost, often in the lead-up to an election – is the biggest culprit. Although only 32 per cent of projects were announced early, these projects led to 74 per cent of the value of cost overruns over the past 15 years. Prematurely announced projects need larger cost upgrades not just early on, but throughout their funding approval and construction phases.

Analysing cost overruns from the first funding promise is not common practice, but it should be. Once politicians have announced a project, they and the public treat that announcement as a commitment. They are right to do so: two thirds of projects end up being built.

Promising to build infrastructure for less than it finally costs makes infrastructure projects seem more attractive than they really are. Understating costs also makes it impossible for decision-makers to differentiate good projects from bad ones. With more accurate numbers, we would often spend the money on other priorities.

All main political parties have committed to sound analysis and planning of infrastructure, to avoiding waste, and to making decisions with broad social benefit. But in practice they continue to announce projects before they have been properly assessed.

Governments should have to table business cases in parliament when committing to projects. Stand-alone legislation should be used for big projects to encourage bipartisanship when risk and complexity are high. Once a project is completed, governments should report to the public on how it performed against the cost-benefit estimates behind the original investment decision.

Producing more reliable cost estimates is vital. Current cost estimation guidance is inconsistent, omits valuable tools, and can't draw on previous projects because we don't collect the data. Governments set aside large contingency funds for every project, and on many projects this is ultimately spent on add-ons that are poor value for money.

Even today, multi-billion dollar projects such as Melbourne's Western Distributor, Sydney's WestConnex and the Inland Rail from Melbourne to Brisbane have much less provision for the worst case than experience would suggest is prudent. We must start to learn from history. Our infrastructure systems should promise what is worth having, and then deliver what is promised.

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Recommendations

Recommendation 1: Evaluate before spending

Governments should not be able to commit public money to transport infrastructure until a rigorous, independent like-for-like evaluation and the underlying business case have been tabled in the state or federal parliament.

Recommendation 2: Publish evaluations of new infrastructure commitments

The Commonwealth should enable and facilitate better public understanding of infrastructure commitments by:

- a) requiring Infrastructure Australia to publish
 - (i) summaries of *all* transport infrastructure projects funded by the Commonwealth within the previous quarter, completed to the extent that Infrastructure Australia has the information to do so and otherwise left blank; and
 - (ii) business cases and cost benefit analyses for all transport infrastructure proposals receiving Commonwealth funding during the previous quarter, if these have not already been published by a state government; and
- b) requiring the Productivity Commission to publish reliability ratings of all transport infrastructure business cases within one month of Infrastructure Australia publishing them.

Recommendation 3: Publish post-completion data

To enable learning from past experience, and to improve accountability:

- a) The Commonwealth Department of Infrastructure should be required to publish to data.gov.au the post-completion report it already requires from state governments as a condition of providing final milestone payments for transport infrastructure projects. Reports should detail any scope changes and their justification, agreed and actual construction start and finish dates, actual project costs, reasons for overruns or under-runs, and progress against performance indicators.
- b) Infrastructure Australia should be asked to provide the Joint Committee of Public Accounts and Audit with a post-completion appraisal of the benefits and costs of each infrastructure project that received Commonwealth funding of \$50 million or more.
- c) The Council of Australian Governments should add a new category of infrastructure services to the terms of reference for the annual Report on Government Services, produced by the Productivity Commission.

Recommendation 4: Special arrangements for big projects

When the estimated construction cost to a jurisdiction is \$1 billion or more, Commonwealth, state or territory governments should be required to introduce standalone legislation for that transport infrastructure.

Recommendation 5: Improve risk measurement guidance

The Commonwealth should provide model guidelines that states and territories may adopt or adapt, that recommend a consistent approach to measuring and managing project risk, including a statement of seniority where specific guidelines would otherwise conflict with one another.

Recommendation 6: Compile Australian database of completed projects

The Commonwealth should seek cooperation from the states to create new benchmarking data to improve risk measurement in new project proposals and public accountability. They should do so using data collected through mechanisms described in Recommendation 3.

Recommendation 7: Hold the project contingency in a portfolio pool

Central agencies should hold project contingency funds at arm's length from project management, and formalise the conditions governing contingency drawdown.

1 The extent of cost overruns

The Peel deviation is a stretch of the Forrest Highway running between Perth and Bunbury. It was first promised during the 2001 state election campaign at a cost of \$136 million. Many twists and turns later, in 2010, the road was completed at a cost of \$688 million – over 400 per cent more than its originally promised cost.¹

Such budget blowouts like this are disturbing but they do not hit the media or public eye very often. People could therefore be forgiven for thinking they are rare.

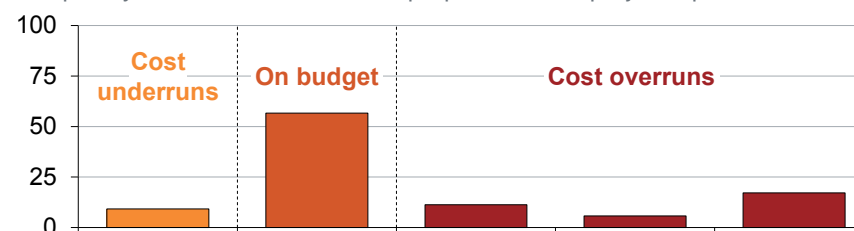
Unfortunately, they are not rare enough. This report finds that the transport infrastructure projects valued at \$20 million or more and planned or built in Australia in the past 15 years cost \$28 billion more than their promised costs. This is 24 per cent more than the costs that were announced.²

The 24 per cent over and above the original cost promise does not stem from the accumulation of small cost overruns on most projects. Rather, most projects come in reasonably close to their promised cost, as Figure 1.1 shows. The problem is that when projects do exceed their promised costs, the overruns can be spectacular: 90 per cent of Australia's cost overruns problem is explained by the 17 per cent of projects that overran their cost promise by more than 50 per cent.³

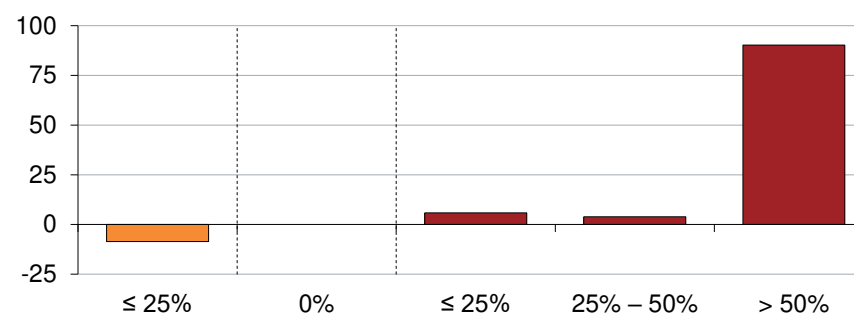
Overruns are not matched by underruns. Only 9 per cent of projects finished under their announced cost, and these cost underruns were,

1. As detailed in Box 1 on page 15.
2. This result and others not separately referenced in this report are based on Grattan analysis described in Appendix B on page 62.
3. 90 per cent of cost overruns are attributable to projects with cost overruns greater than 50 per cent of initial project value. It should be noted that these cost overruns explain 98 per cent of total cost differences, as illustrated in Figure 1.1 as small cost overruns are almost entirely offset by cost underruns.

Figure 1.1: Large cost overruns are uncommon, but expensive
Frequency of cost differences as a proportion of all projects, per cent



Value of cost differences as a proportion of total cost overruns, per cent



Notes: Australian transport projects completed between 2001 and 2015. Cost differences is defined to refer to cost underruns and cost overruns collectively.

Source: Investment Monitor; Grattan analysis.

on average, only a quarter of the size of the average cost overrun, amounting to a total of \$41 million. The majority of projects come in close to their announced costs, and underruns do little to offset overruns.

1.1 This is the first comprehensive Australian analysis of transport project cost overruns

This report is the first comprehensive Australian analysis of cost overruns on transport infrastructure projects. It is comprehensive in two ways: it includes the entire portfolio of transport infrastructure projects valued at \$20 million or more and built or planned in Australia since 2001; and it examines the entire project lifecycle, from first announcement through to completion of construction. This section explains why each of these features of the report matter.

1.1.1 We analyse the entire portfolio of projects since 2001

This report is the first study of cost overruns in Australia that includes all 836 transport infrastructure projects valued at \$20 million or more planned or built in the past 15 years.

A small number of researchers and state auditors-general have analysed aspects of this problem in recent years, but they have studied small numbers of projects (Figure 1.2). The drawback of small samples is that their findings may be less representative, and so policymakers cannot rely upon their findings as much as they can with larger or more comprehensive studies.

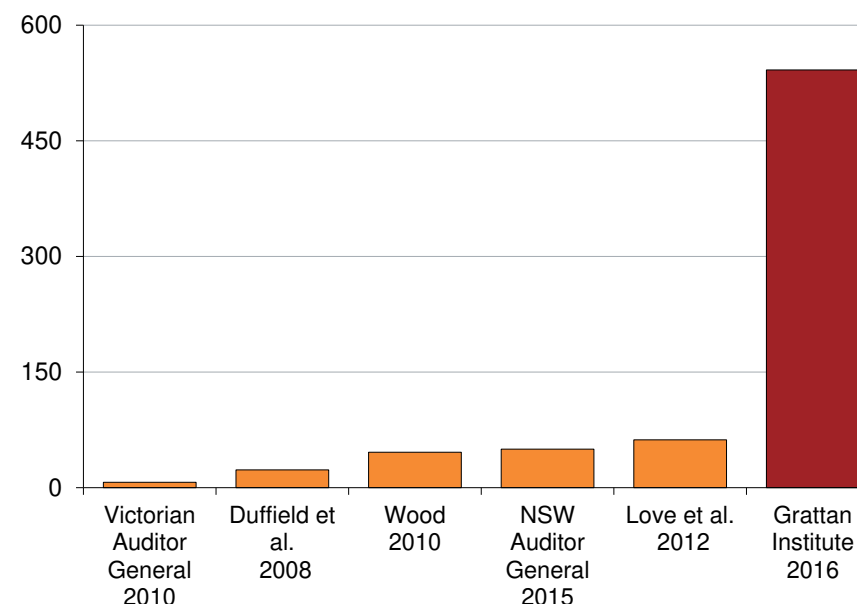
The findings of these small studies present a mixed view. Two key studies in 2007 and 2008 of infrastructure projects valued at more than \$20 million found overruns ranging from 12 to 35 per cent⁴ from formal funding commitment to completion and 24 to 52 per cent⁵ over the

4. Allen Consulting Group et al. (2007, p. 5).

5. Duffield et al. (2008, p. 15). Costs over the full project life mean originally announced to actual final costs.

Figure 1.2: This report analyses over nine times more Australian projects than previous studies

Sample sizes of studies into cost overruns on completed Australian transport infrastructure projects



Source: Cited studies and Investment Monitor; Grattan analysis.

full project life. Another study of 58 projects found an average 13 per cent overrun.⁶ A further study of 46 projects found overruns of 5 to 11 per cent of project costs.⁷ A 2015 study of 44 projects each valued at \$1 billion or more found cost overruns of 14 per cent on the \$44 billion budget.⁸

While not seeking to be representative, an investigation by the Victorian Auditor-General found a 5 per cent cost overrun across seven road and rail projects valued at more than \$40 million.⁹ The New South Wales Auditor-General reported a 7 per cent cost overrun across 50 transport and other infrastructure projects valued above \$50 million.¹⁰ These two studies did not consider scope changes or overruns between project announcement and formal contract.

The variation in the average size of overruns observed across these small sample studies illustrates the value of a large sample when analysing extreme events.

1.1.2 We analyse the entire project lifecycle

This report considers the entire project lifecycle from when ministers or opposition politicians first announce a project to when they make a formal funding commitment; from the formal funding commitment to the start of construction; and from the start to the end of construction (Figure 1.3).

We define a cost overrun as the amount by which the actual cost at the end of a particular phase exceeded the estimated cost at the start of that phase, expressed as a percentage of each project's first cost.

6. Love et al. (2012, p. 157).

7. P. Wood (2010).

8. Australian Constructors Association (2015, p. 7).

9. Victorian Auditor-General (2010, p. 22); and Victorian Auditor-General (2011, p. 12).

10. NSW Auditor-General (2015, p. 5).

Figure 1.3: Project lifecycle begins when the project is announced



Source: Grattan analysis.

Some argue that cost overruns should only be measured from the point that a formal cost benefit analysis is completed or a funding commitment made.¹¹ But this ignores the realpolitik of infrastructure funding. Politicians often promise to pursue infrastructure projects before a detailed cost benefit study is completed. Indeed, the vast majority of project commitments made in the last federal election were in this category.¹² Once an elected government has made such a commitment, it is unusual for the project not to proceed. Indeed, it appears that cost benefit analyses are sometimes retrofitted to justify such commitments.¹³

This report takes politicians' commitments seriously. We treat a promise to build a particular project for a particular cost as a real promise. Even when politicians promise infrastructure that is at a very early stage of development, the politician and the public both regard the promise as binding.

1.2 Cost overruns may be even bigger than we claim

This finding and others in this report may well be understated. For the 68 per cent of projects where data on their early costs is missing in our dataset, we have made the assumption that no early cost overruns occurred.¹⁴

11. Love et al. (2014, pp. 493-494); Love et al. (2016, p. 185); and Seimiatycki (2009, pp. 144-145).

12. Terrill (2016).

13. Australian Constructors Association (2015, p. 20).

14. Early cost data is not wholly missing for all of these projects. Only 41 per cent of projects have no cost estimates recorded prior to construction commencing.

This assumption appears to be extremely conservative. Detailed analysis of a subset of the projects which are missing early cost data indicates that these projects experience cost overruns at approximately the same rate as projects which are not missing data on projects' early costs.¹⁵ Consequently, the rate of overruns presented as the upper bound of Figure 1.4 appears to be more likely than the lower bound that underpins this report's analysis.

The analysis in this report relies upon public sources of data, such as publicly available government documents, company, media and other reports and announcements. This information is imperfect. Only governments can provide full information for all public infrastructure projects. It would be a big step forward if they did.

1.3 Common explanations for cost overruns are myths

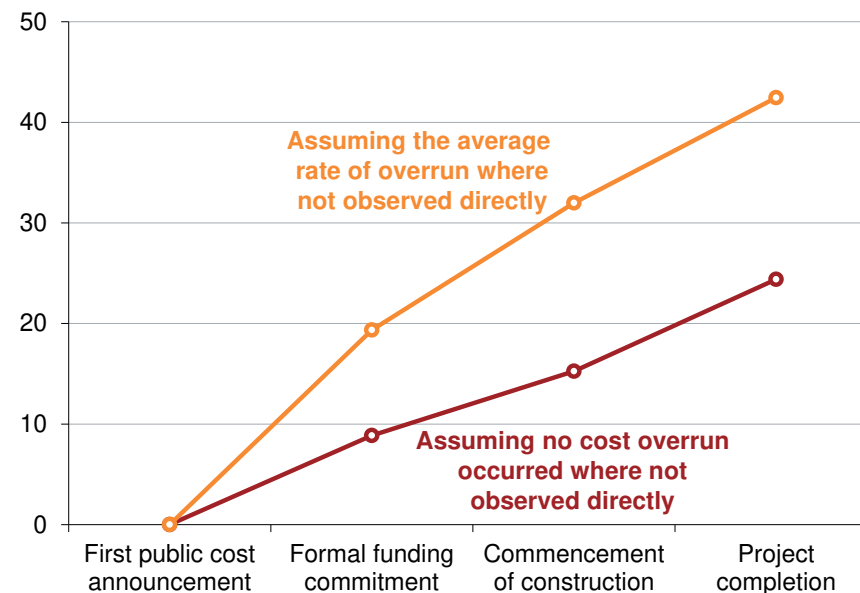
This report's large scale analysis of cost overruns on Australian projects debunks myths about infrastructure in this country. Two prominent myths are that scope changes are the main reason for cost overruns, and that Australian projects are less prone to overruns than those in other countries. This section explains the challenge to these two views.

1.3.1 Scope changes actually explain only a small share of overruns

The early period of a project's lifecycle, from its first announcement by a government or potential government until a formal funding commitment, is the best time to settle its scope – that is, exactly what infrastructure is planned, where it will be and at what quality.

15. Of the 51 projects investigated, 19 were missing early cost data and 37 per cent were identified to have experienced cost overruns in this early period. This prevalence rate is comparable to the 51 per cent observed across the 32 per cent of projects which are not missing early cost data.

Figure 1.4: Cost overruns are likely to be even higher than we report
Average cost overrun rates as a proportion of initial costs by project stage, per cent of initial project cost



Notes: Australian transport projects completed between 2001 and 2015. All cost overrun estimates contained elsewhere in this report have been estimated under the assumption that no overrun occurred where not observed directly – that is, the bottom line on this graph. Please see Appendix B on page 62 for further details.

Source: Investment Monitor; Grattan analysis.

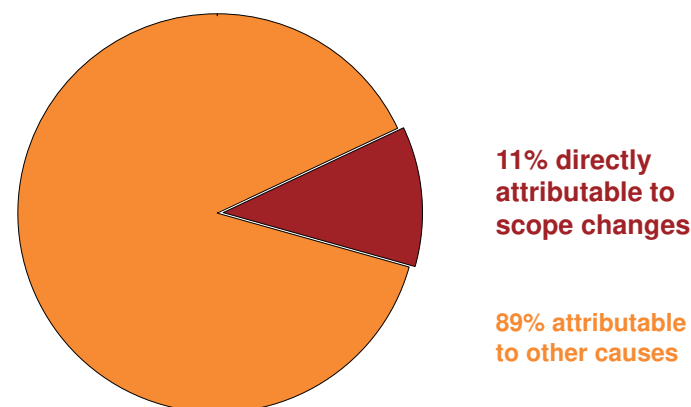
Scope changes might add extra length to a road, or an extra station to a rail line. This report defines scope changes as additions to functionality, such as additional road length, but not quality improvements, such as higher sound barriers to a new highway. We take this approach to differentiate genuinely additional infrastructure from refinements.

Changes to scope are only a problem if they are not appraised on their merits as to whether they are worth the money and are better than alternative ways to solve a problem or to spend public funds.

This report finds that scope changes only account for about 11 per cent of cost overruns on transport infrastructure projects (Figure 1.5). This conclusion is counter to what appears to be the prevailing wisdom on the causes of cost overruns on Australian transport projects, and the Productivity Commission's conclusion that "cost overruns during delivery mainly stem from government clients changing the scope of the project."¹⁶

The Productivity Commission's finding was based upon the Western Australian Auditor-General's report on major capital projects, which found that scope changes explained the majority of cost overruns observed across 20 major projects.¹⁷ The Western Australian Auditor-General's finding differs from our finding in that focused on cost overruns incurred only during the construction phase, and was largely driven by the substantial scope changes observed on non-transport projects, such as hospitals, schools and prisons. The finding does not appear to be readily generalisable to cost overruns incurred on transport infrastructure projects over the full project life, from first cost announcement to project completion.

Figure 1.5: Most cost overruns are not attributable to scope changes
Proportion of cost overruns attributable to scope change, per cent



Notes: Based upon detailed investigation of 51 Australian transport infrastructure projects completed between 2008 and 2013, using publicly available data sources. For projects where the percentage change in the scope of the project was known, the cost attributable to scope change is this known size multiplied by the project cost. For projects where the size of the scope change was unknown, the proportion of cost overrun attributable to scope change is the proportion of the project's cost overrun that occurred when the scope changed.

Source: Grattan analysis of 51 projects valued above \$100 million.

16. Productivity Commission (2014, p. 29).

17. Western Australian Auditor General (2012).

1.3.2 Australia actually does not compare especially well internationally

The scarcity of Australian studies of cost overruns has fed a misperception that this country does well at avoiding or minimising cost overruns compared to other countries.

The best-known international studies of ‘megaprojects’ have found road projects overrunning by 24 per cent and rail by 40 per cent. These findings emerge from a study of infrastructure project cost overruns on 1603 road and rail projects of all sizes, each valued at between US\$1.5 million and US\$8.5 billion, in 20 countries between 1927 and 2013.¹⁸ The findings led the leader of the study, Danish economic geographer Bent Flyvbjerg, to invent what he called “the iron law of megaprojects: over budget, over time, over and over again.”¹⁹

Yet Flyvbjerg’s findings, while credible, cannot be generalised. His overrun estimates are markedly higher than the average overrun of 14 per cent reported across the next four biggest academic studies, or the 15 per cent reported across the four largest studies completed by auditors of road projects.²⁰

Other studies emphasise the importance of not assuming that Flyvbjerg’s international studies are representative of each of the countries included in the sample. For instance, a study of the Dutch projects in the Flyvbjerg sample shows an average cost overrun of 16.5 per cent.²¹ Many other studies have demonstrated variations in the size of overruns across different countries.²²

When cost overruns around the world are compared from the time of the formal funding commitment or contract, Australia generally ranks in, or slightly worse than, the mid range. Most studies of cost overruns focus on contract compliance and engineering, which are most relevant from the time of the contract, rather than the time a government or would-be government first announces the project. Our public finance perspective takes the starting point of a project as the initial cost announcement, as this is the point at which a government becomes de facto committed.

The following chapter shows that premature announcement is in fact the key underlying cause of ongoing cost overruns.

18. Flyvbjerg (2016b), methodology described in Flyvbjerg and Rothengatter (2003).

19. Flyvbjerg (2014, pp. 9–11).

20. Seimiatycki (2009).

21. Cantarelli et al. (2012).

22. Jenpanitsub (2011); and Berechman and Wu (2006).

Box 1: Case study – Forrest Highway (Peel deviation) – 406 per cent cost overrun

Poorly scoped election promises end badly

The Western Australian Liberal government promised to build the Peel deviation from Perth to Bunbury during the 2001 election campaign. The project was priced at \$136 million.^a Yet in an indication of the lack of clarity surrounding the cost, it was shortly afterwards included in a \$100 million package of works, along with other works in the package estimated to cost \$87 million in total.^b

Before building began, estimated project costs skyrocketed: to \$337 million in May 2005, then to \$370 million in August 2005, \$511 million in 2006 and \$631 million in 2007.^c During construction, the price increased further to \$705 million,^d before finishing at \$688 million.^e

What caused these cost changes?

The initial funding commitments (\$136 million, \$337 million, and \$370 million) were for a road 20 per cent shorter.^f By the time the road was contracted in 2006, an enhancement of a section of the existing Kwinana Highway between Baldavis and Karnup was included.^g

Official documents reveal little about the reasons for the cost increases. There were design enhancements, including an extra \$40 million to fund a change in materials from those specified in the business case.^h

a. Criddle and Court (2000).

b. Parliament of Western Australia (2001, p. 285).

c. For the May 2005 estimate, see Government of Western Australia (2005a, p. 662). For August 2005, Government of Western Australia (2005b, p. 40). For 2006, see GHD (2007). For 2007, see Government of Western Australia (2007, p. 794).

d. Department of Infrastructure and Transport (2012, p. 85).

e. Government of Western Australia (2010, p. 13).

f. Government of Western Australia (2005b, p. 40).

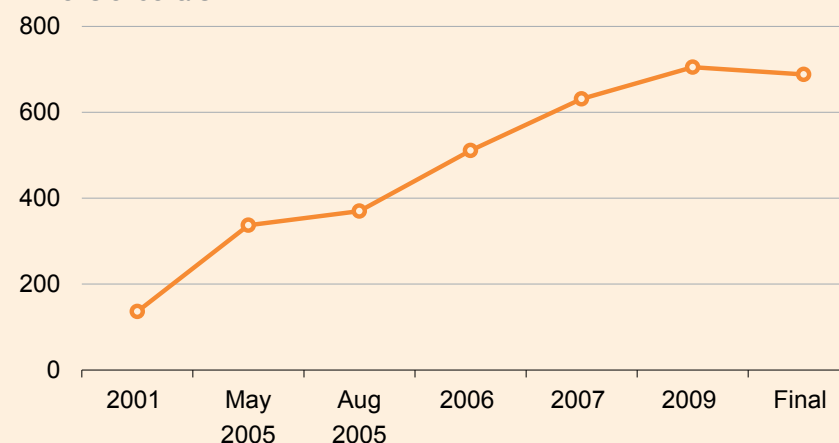
g. GHD (2007); and Department of Infrastructure and Transport (2012, p. 87).

h. Department of Infrastructure and Transport (2012, p. 92).

But even reducing the final cost by 20 per cent (to account for the extended road length) and subtracting \$40 million from the final estimate (to exclude the additions) leaves a cost of around \$500 million to build the originally specified road – 368 per cent higher than the initial cost estimate.

Figure 1.6: Forrest Highway cost estimates

Millions of dollars



2 Premature announcements cause larger and more persistent cost overruns

Ministers and opposition spokespeople often promise to build a road or bridge or rail line, for a particular cost. They are especially prone to doing so in the lead-up to elections (see Box 1 on page 15 on the Forrest Highway).

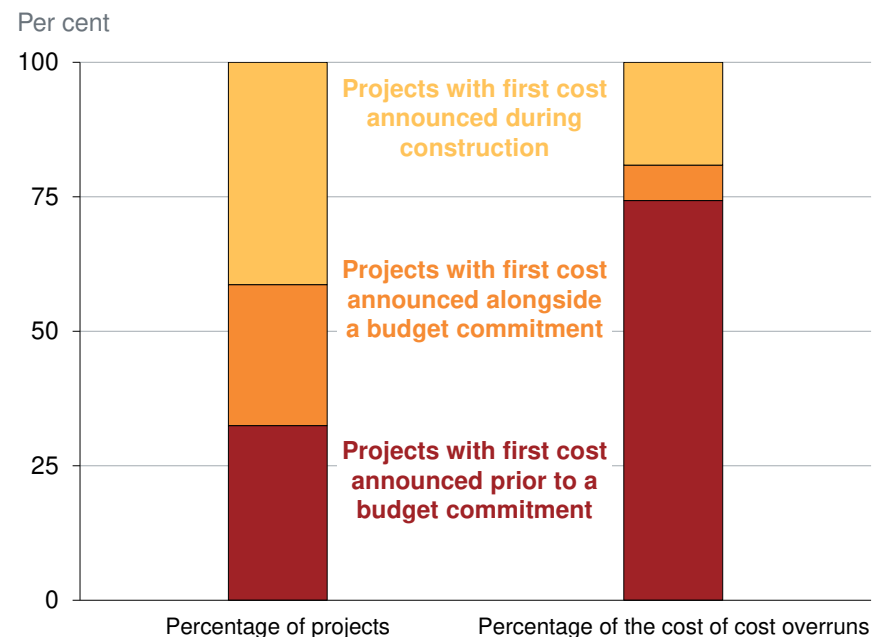
It is normally premature and unwise to announce project costs this early in the planning process. History shows that projects with costs announced prior to a formal budget commitment experience far larger cost overruns than projects with later cost announcements. Over the past 15 years, 74 per cent of the total value of cost overruns is explained by the 32 per cent of projects with early cost announcements (see Figure 2.1).

It comes as no surprise that ad hoc announcements prior to formal budget commitments tend to be extremely optimistic. Once such announcements are scrutinised as part of the budget process, their early cost estimates need to be upwardly revised by an average of 25 per cent.

The poor cost performance of projects with early cost announcements is not just a warning to mistrust politicians' infrastructure promises. Rather, premature cost announcements appear to haunt projects throughout their lives.

Figure 2.2 on the next page shows that projects announced early tend to perform worse than average against their cost estimates, not only in the early stages but also later in the project's life. After formal budget commitments, the costs of projects with early cost announcements project typically increase by a further 26 per cent (see Figure 2.2). This suggests that overly optimistic initial cost estimates are rarely adequately adjusted straight away – reliable project cost estimates may only even-tuate half way through construction.

Figure 2.1: The projects with early initial cost announcements account for most of the value of cost overruns



Notes: Australian transport projects completed between 2001 and 2015.

Source: Investment Monitor; Grattan analysis.

Another reason why projects with premature cost announcements repeatedly have large overruns is that these low quality cost estimates are often imposed on the highest risk projects. Figure 2.2 shows that projects with early cost estimates are substantially bigger, on average, than projects with later cost announcements. Section 4.1.1 of this report confirms that large projects are more prone to cost overruns than smaller projects in Australia, as is consistently the case internationally.

This chapter argues that premature announcements are often made for electoral gain (see Box 2 on the following page on the Alstonville bypass). To counteract this problem, there needs to be better accountability at the time that promises are made and after projects are completed.

2.1 Premature announcements are made for electoral gain

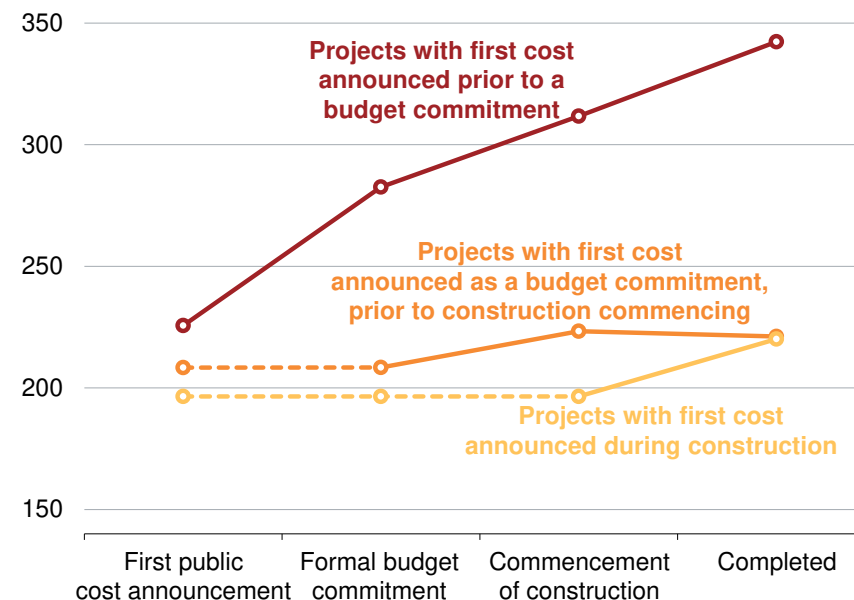
Governments and would-be governments are very fond of promising infrastructure. But while these promises might give them political advantage, politicised announcements that ignore proper process have particularly poor outcomes. Cost overruns are 23 per cent higher on average for projects announced close to a state or federal election than for similar projects announced at other times. Previous Grattan work shows how politicians commit to poor quality projects for political benefit.²³

Politicians continue to make infrastructure promises for political advantage even though their parties have made strong statements recognising the need to spend infrastructure money better. For example:

- The current Commonwealth Government maintains that:
it is critical to base project selection on rigorous analysis and sound planning to avoid wasteful investment . . . [t]he advice provided by Infrastructure Australia will be a key input in guiding

Figure 2.2: Projects announced prematurely have larger cost overruns at all stages of the project lifecycle

Average project size of each cohort, by project stage, \$2016 millions



Notes: Australian transport projects, completed between 2001 and 2015. Projects' maturities at the time of initial cost announcements are inferred from each project's stated maturity when the project entered the Investment Monitor. Where initial cost announcements were very low profile, it is possible that the Investment Monitor may have missed the announcement and erroneously recorded the first cost announcement as having occurred when the project reached a more mature stage. Given this data collection methodology, it should be noted late initial cost announcements may in fact reflect that earlier cost announcements were of a particularly low profile.

Source: Investment Monitor; Grattan analysis.

23. Terrill et al. (2016); and Terrill (2016).

Box 2: Case study – Alstonville bypass – 162 per cent cost overrun

An under-cooked election promise

In 2002, the Federal Coalition Government committed \$12 million to the \$36 million cost of an upgrade to the Bruxner Highway in Northern New South Wales, to bypass Alstonville.^a The following year, the then Labor Premier, Bob Carr, promised in a New South Wales election campaign to build the bypass by the end of 2006, at a cost of \$36 million.^b

Yet the project was not confirmed until 2009, when a contract was awarded for \$101 million.^c

Savings of \$6.7 million were made during the construction period, and the project was declared to have come in “under budget”^d when it was completed in 2011,^e six months after the contracted completion date,^f five years after the promised completion date, and nine years after the first commitment.

a. Parliament of New South Wales (2002).

b. ABC News (2003).

c. ABC News (2009); and Government of New South Wales (2009).

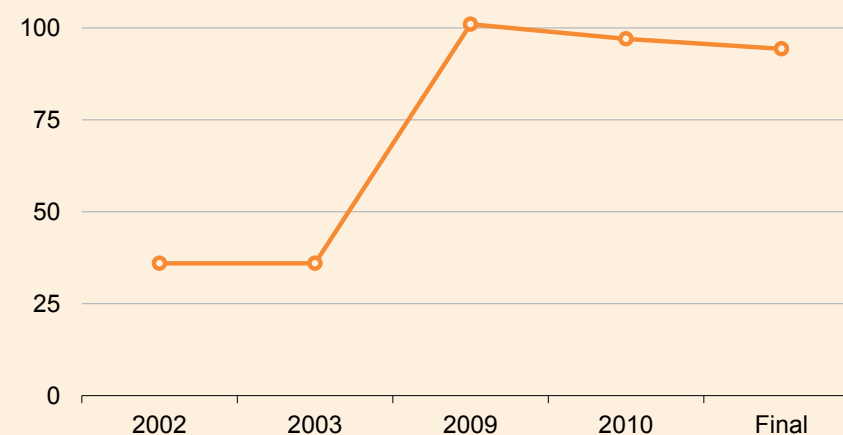
d. Rural & Regional Affairs and Transport Legislation Committee (2014).

e. Lollback (2011).

f. ABC News (2009).

Figure 2.3: Alstonville bypass cost estimates

Millions of dollars



the Australian, state and territory governments when making major investment decisions.²⁴

- The Federal Labor Opposition, which established Infrastructure Australia when it was in office in 2008, promises to take the politics out of infrastructure by ensuring that:

Infrastructure Australia independently assesses all major infrastructure projects on the basis of the benefits they provide to the economy and society as a whole, their commercial viability and their capacity to enhance national productivity.²⁵

- The Greens contend that:

[t]oo often, major infrastructure decisions are made for short-term, politically expedient reasons, rather than in the long-term public interest.²⁶

They would like to see comprehensive cost-benefit analysis for large projects submitted to Infrastructure Australia for evaluation, and with the recommendation made public at the same time it is given to government.²⁷

But even though parties make such statements, the behaviour of politicians exposes the hollowness of their claims. In the 2016 federal election campaign, Labor, the Coalition and the Greens all promised to build a large number of projects that had not been properly assessed. Between a quarter and a half of their promises were for projects that had not been submitted to Infrastructure Australia for assessment, or had been assessed and judged as not worth doing.²⁸ Many others were only

24. Truss (2013); and Fletcher (2015).

25. Australian Labor Party (2016a).

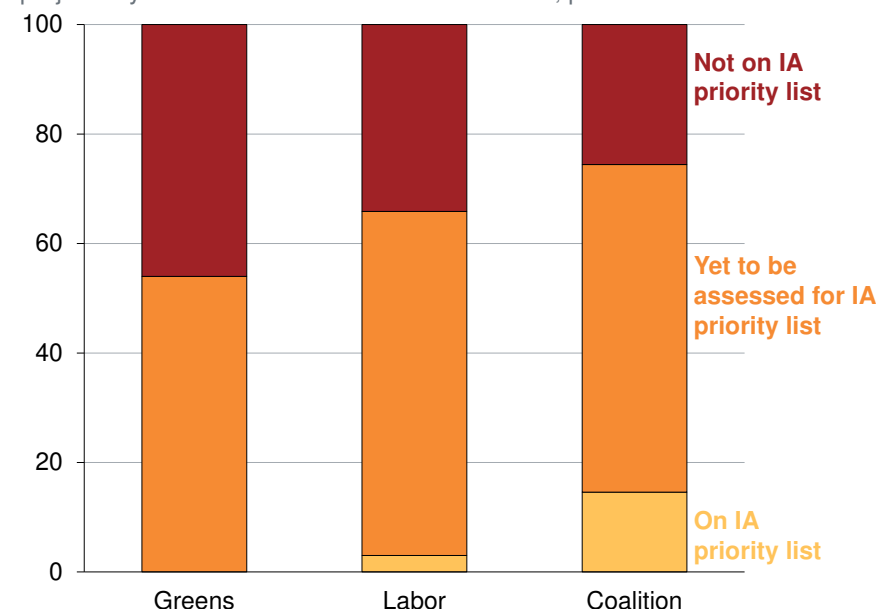
26. Australian Greens (2016b).

27. Ibid.

28. Terrill (2016).

Figure 2.4: The vast majority of committed money from all three major parties is for projects not endorsed by Infrastructure Australia

Proportion of 2016 federal election commitments to transport infrastructure projects by Infrastructure Australia review status, per cent



Notes: Includes projects where a specific dollar amount could be discerned from campaign material or, in the case of the Coalition, from the 2016–17 budget papers. Excludes projects for which construction had commenced by June 2016.

Source: Liberal Party (2016); Australian Labor Party (2016b); Australian Greens (2016a); Treasury (2016) Treasury (2014); Infrastructure Australia (2016d); Grattan analysis.

an “initiative” on Infrastructure Australia’s list; in other words, Infrastructure Australia was yet to be convinced that the project was worthwhile. The proportions of the promised money that were for projects that had been assessed as nationally significant and worth doing ranged from 15 per cent for the Coalition to none for the Greens (see Figure 2.4 on page 19).

This pattern of promising poor quality or under-developed project ideas in election campaigns is troubling because politicians find it very hard to back down from promises, even when it becomes apparent that the original assumptions about the project were not well founded (see Box 3 on the following page on the Hunter Expressway).

2.2 Premature cost claims cannot be disputed at the time

There is currently no effective curb on premature announcements. Politicians promise projects that have not been evaluated, or they promise projects with an evaluation that is not available to the public. Both of these shortcomings should be fixed.

Both Commonwealth and state governments commonly commit to infrastructure projects that have not been evaluated. If there is no evaluation, then politicians’ claims about a project’s costs and benefits – or even when it will open – cannot be scrutinised until much later if at all (see Box 4 on page 23 on Bulahdelah bypass).

While governments are responsible for investment decisions, they should not spend public money without due care for how the spending will benefit the community. Cost benefit analysis has limitations, but it remains the best way for making like-for-like comparisons of projects.²⁹

29. Eliasson and Fosgerau (2013).

Even when there is a cost benefit analysis, politicians will be tempted to pressure evaluators to massage assessments to fit political priorities. This is not just a theoretical concern. For example, the Victorian Auditor-General, in his audit of the East West Link project, highlighted several instances involving advice:

that gave too much emphasis to the benefits of approaches that were in line with the governments’ preferred outcome and too little to alternative options that could be argued were more aligned with the state’s best interests.³⁰

He further noted that:

[s]ome public officials involved in this audit indicated that providing frank and fearless advice when they believe a government does not want to receive it will negatively impact their influence or career opportunities.³¹

Other spheres of government spending offer far less scope for discretionary decisions. For example, payments to unemployed people have cost \$108 billion since 2000 – substantially less than the \$141 billion spent on transport infrastructure. The *Social Security Act 1991* lays out in exhaustive detail the conditions under which an unemployed person may qualify for Newstart or Youth Allowance, the rate at which they may be paid, and the arrangements for recovering incorrect payments. Politicians frequently bemoan waste in the welfare system and the need to reduce fraud, improve compliance and get better value for money. They rarely do the same for transport infrastructure.

The system would be improved if governments were not able to commit public money until the project evaluation and the business case had been tabled in parliament. Ministers would then be free to commit

30. Victorian Auditor-General (2015a, p. xiv).

31. Ibid. (p. xv).

Box 3: Case study – Hunter Expressway – more than 400 per cent over budget

Government reluctance to change course when facts change

A plan to build a Maitland bypass as part of the New England Highway in northern New South Wales was floated as early as 1983.^a The preferred route for what eventually became the Hunter Expressway was decided in 2001 and expected to cost “more than \$335 million” in 2002.^b

In 2007 the Federal Coalition Government increased its funding commitment to \$887 million as an election pledge.^c After winning the 2007 election, the new Labor Government cooled on the idea. In 2008, Joel Fitzgibbon, the then Labor Member for Hunter, observed that: “First, the F3 link was conceived in the mid 1980s and there have been big changes in traffic movements and residential and commercial settlement patterns since then. Second, the cost of the project is now \$1,700 million (\$1.7 billion) and it has a very low benefit to cost ratio (meaning it provides taxpayers with a low-value solution).”^d

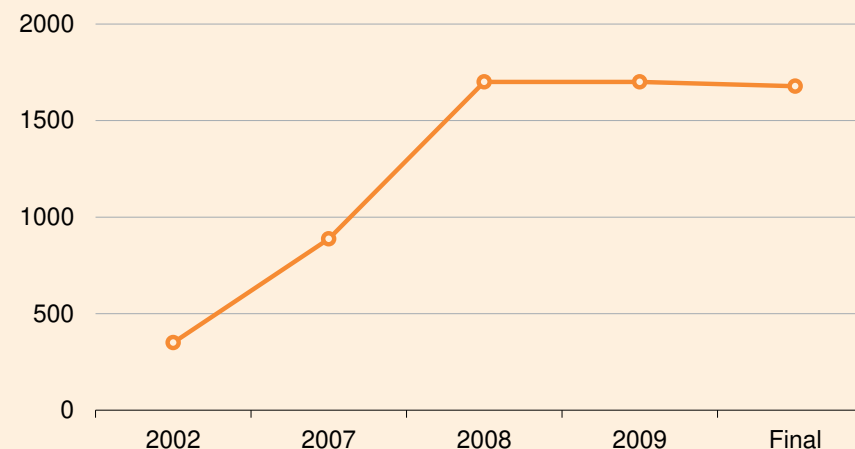
The Government commissioned a review in 2008,^e after which it committed \$1.7 billion in 2009.^f The Federal Liberal Member for nearby Paterson, Bob Baldwin, criticised the Government’s prevarication “because we [the Coalition] had committed to it as a government”.^g Mr Baldwin emphasised the persistence of Support the Link, a local lobby

group that pushed hard for the road.^h The project was completed in 2014 for \$1678 million.ⁱ

While the final benefit cost ratio has not been published, these comments from politicians reveal the difficulty governments experience in reneging on commitments made very early in a project’s life, even after the facts of the project change significantly.

Figure 2.5: Hunter Expressway cost estimates

Millions of dollars



a. Nation Building Program Amendment Bill (2009).

b. Department of Infrastructure and Regional Development (2002).

c. Nation Building Program Amendment Bill (2009).

d. Ibid.

e. Department of Infrastructure and Regional Development (2008).

f. Roads and Maritime Services (2010).

g. Nation Building Program Amendment Bill (2009).

h. Ibid.

i. Roads and Maritime Services (2016).

to the projects that best met their priorities, and to explain to the public any differences between their priorities and the findings of project assessments (see Recommendation 1).

Keeping an evaluation secret also protects cost claims from scrutiny and debate.

The best incentive for high quality disinterested project analysis is detailed, timely publication. Although some will be concerned that publication may reduce the competitiveness of tenders by anchoring expectations, the cost of poor project selection is likely to far outweigh a marginal reduction in tendering competitiveness.

Consequently, before a government decides to build infrastructure, the public should have access to the business case, cost benefit analysis and evaluation summary. The information should include disclosure of the key assumptions made in the cost benefit case, sensitivity analysis of these assumptions, and the evidence justifying them. Without this detail, there is no public check on the quality of assessments.

Where no business case or cost benefit analysis has been developed, or where these assessments are not reliable or robust, the public should know. We have found no evidence that governments are routinely offered a set of developed and feasible options to choose from. To the extent that this lack of evidence points to a gap in planning department processes, it is relevant for the public to understand the shortcomings in the basis of government infrastructure decisions. This would be most effective if done at a national level, with data published on a consistent and comparable basis. Recommendation 2 proposes mechanisms to do this.

Recommendation 1: Evaluate before spending

Governments should not be able to commit public money to transport infrastructure until a rigorous, independent like-for-like evaluation and the underlying business case have been tabled in the state or federal parliament.

Recommendation 2: Publish evaluations of new infrastructure commitments

The Commonwealth should enable and facilitate better public understanding of infrastructure commitments by:

- a) requiring Infrastructure Australia to publish
 - (i) summaries of *all* transport infrastructure projects funded by the Commonwealth within the previous quarter, completed to the extent that Infrastructure Australia has the information to do so and otherwise left blank; and
 - (ii) business cases and cost benefit analyses for all transport infrastructure proposals receiving Commonwealth funding during the previous quarter, if these have not already been published by a state government; and
- b) requiring the Productivity Commission to publish reliability ratings of all transport infrastructure business cases within one month of Infrastructure Australia publishing them.

2.3 Politicians are not held accountable for poorly founded cost promises once projects are finished

There is at present no systematic public reporting on the effectiveness of government spending on infrastructure projects. In particular, there is no public reporting on how well government-funded transport infrastructure projects perform against the costs and benefits, such as travel time savings, used to make the investment decision. This is a serious gap.

Infrastructure Australia, according to the law that establishes it, is supposed to evaluate whether projects met targets set before or during delivery, and to promote public awareness of its monitoring role, in part by publishing information on its website.³² This does not happen. Nor do state governments, including their infrastructure bodies, publish information about how well projects performed against their estimated costs and benefits. Post-implementation reviews seldom take place or are made public when they do.³³ For such reporting to be effective, it must be done in a standard way to allow like-for-like comparisons.

Other spheres of government investment require much stricter reporting on outcomes. For instance, the \$123 billion Future Fund,³⁴ is governed by the *Future Fund Act 2006* and overseen by a board of independent guardians. The Act ensures that investment decisions and activities are conducted at arm's length from government. It requires the tabling in Parliament of an annual report and audited financial statements. The Future Fund publishes quarterly portfolio updates to provide details of the investment activity and performance of the fund. Transport infrastructure investment by Australian governments is similarly large, and could be governed with similar scrutiny and assurance. But it is not.

32. Infrastructure Australia Act (2008).

33. Australian Constructors Association (2015, p. 26); Ellis (2015); and Victorian Auditor-General (2015b, pp. 10–11).

34. Future Fund (2016).

Box 4: Case study – Bulahdelah Bypass – 111 per cent cost overrun

Road opened before it was finished

In June 2013, New South Wales' Bulahdelah Bypass was running six months behind its revised schedule^a and still wasn't finished, so the state government decided to hold a ribbon cutting ceremony and announce its completion anyway.

Official sources say that construction finished in June 2013.^b Yet the road was closed for further construction immediately after the ceremony and opened properly a month later.^c

a. Rural Affairs and Transport Legislation Committee (2010).

b. Department of Infrastructure and Regional Development (2015).

c. Great Lakes Advocate (2013); Murphy (2013); and Prime7 (2013).

In the absence of such reporting for infrastructure projects, the public is not equipped to understand whether any particular infrastructure turned out to offer value for money in the terms in which it was originally promised. Ministers overseeing projects with significant cost overruns over time commonly end up claiming that the project came in under budget. Both Governments and oppositions feel free to make claims that the media and public cannot verify. Box 5 on the following page provides background on some extreme examples of overstated benefits that have come to light through legal action by shareholders.

The current opacity of investment planning processes means that the public cannot readily judge the success of projects. This means that there is little political cost associated with announcing project costs prematurely, even when this creates a significant risk of promising projects with poor payoffs.

Moreover, the absence of outcomes reporting limits the ability of project proponents and managers to learn from the experiences of other project managers around the country and over time. Like appraisals of new commitments, post-completion information is most useful when it enables comparisons of different projects. For this reason, the mechanisms proposed in Recommendation 3 are actions that Commonwealth entities should adopt.

Recommendation 3: Publish post-completion data

To enable learning from past experience, and to improve accountability:

- a) The Commonwealth Department of Infrastructure should be required to publish to data.gov.au the post-completion report it already requires from state governments as a condition of providing final milestone payments for transport infrastructure projects. Reports should detail any scope changes and their justification, agreed and actual construction start and finish dates, actual project costs, reasons for overruns or under-runs, and progress against performance indicators.
- b) Infrastructure Australia should be asked to provide the Joint Committee of Public Accounts and Audit with a post-completion appraisal of the benefits and costs of each infrastructure project that received Commonwealth funding of \$50 million or more.
- c) The Council of Australian Governments should add a new category of infrastructure services to the terms of reference for the annual Report on Government Services, produced by the Productivity Commission.

Box 5: Case study – overstated benefits

Several successful lawsuits show the most extreme cases of inaccurate forecasting of project benefits.

Brisbane's CLEM 7 tunnel was forecast to carry over 100,000 vehicles per day within 2 years of opening, but the reality was only around 22,000.^a A successful class action was brought against the forecaster, AECOM.^b The tunnel's owner, RiverCity Motorway, went into administration in 2011, as the traffic had not generated enough revenue for the company to pay its debts.^c

The traffic forecasts for Sydney's Lane Cove tunnel were in contention in a lawsuit brought against the companies, Parsons Brinckerhoff and Booz Allen, settled in 2014. The case concerned allegations that the forecasters "reverse engineered" the predictions, working backwards from commercial objectives in estimating traffic volumes.^d

The Brisbane Airport Link is another example of a road for which traffic volumes were far below expectations. This also resulted in litigation being launched, by toll road owners Brisconnections against forecaster Arup.^e This action was settled in 2015.^f

Until Australian governments routinely ascertain whether projects' promised benefits have been realised, they will not be in a position to hold experts accountable for their advice as the Brisconnections shareholders have done.

- a. Maurice Blackburn representing The Hopkins Superannuation Fund (2014, pp. 9–11).
- b. Maurice Blackburn (2016).
- c. Wiggins (2016).
- d. Papdakis (2014).
- e. Thompson et al. (2014).
- f. IMF Bentham (2013).

3 The costs of cost overruns

Reducing premature announcements would go a long way towards reducing cost overruns. But the risk of cost overruns is inherent in all infrastructure projects, not just those that are announced prematurely. This chapter discusses the rationale for intervening in projects that may be on a path towards substantial cost overruns.

In particular, close to two thirds of cost overruns occur before construction begins. These early and middle phase overruns could be used as a signal to actively reappraise projects, in order to determine whether they still appear to be good investments (Figure 3.1).

The following two sections identify why it is important that projects' investment merits are reappraised after early cost overruns, and the evidence that Australia's project appraisal processes could be better.

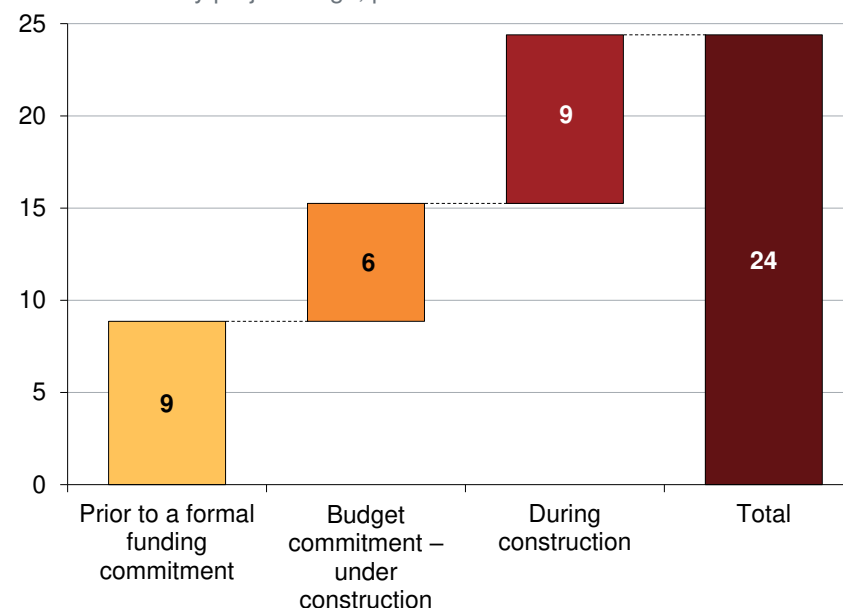
3.1 Failure to reappraise projects after early cost overruns is expensive

Over the last 15 years, the costs of transport infrastructure projects over and above what was promised have amounted to \$28 billion. There is insufficient data to determine how often these overruns were a consequence of announced costs that were unfeasibly low, and how often construction costs were excessively high. However, all of this \$28 billion is problematic because it has caused substantial distortions to investment planning processes. These distortions take three forms.

First, cost overruns distort decisions regarding how much to invest in transport infrastructure relative to other spending priorities, such as hospitals, schools and pensions. Transport infrastructure projects have been systematically represented as if they were more attractive and better value for money than they really are. At the portfolio level, this misrepresentation has amounted to a 20 per cent reduction in the

Figure 3.1: Two thirds of cost overruns occur prior to construction commencing

Cost overruns by project stage, per cent



Notes: Australian transport projects, completed between 2001 and 2015.

Source: Investment Monitor; Grattan analysis.

transport infrastructure portfolio's anticipated return on investment, that is, 20 per cent lower benefit cost ratio underpinned the original investment decision.

Second, cost overruns distort decisions regarding which transport infrastructure projects to invest in. At the project level, cost overruns have reduced projects' returns on investment by as much as 406 per cent. When returns on investments are distorted to this degree, it is impossible for decision-makers to choose the projects with the highest net benefits to the community.

In fact, as inaccurate cost estimates inflate benefit cost ratios, projects with inaccurate cost estimates are systematically advantaged in the project selection process. This phenomenon is known as the "winner's curse", meaning that the projects that are funded are more likely to be afflicted with the "curse" of poor quality cost estimates than those that are not.³⁵

Third, cost overruns distort decisions regarding the types of transport infrastructure to invest in. The most obvious case of this phenomenon is multi-billion dollar projects. As these projects are particularly prone to cost overruns, the benefit cost ratios for these projects are systematically more optimistic than those of smaller projects. Together with politicians' penchant for iconic and legacy projects, this distortion biases politicians towards funding large projects like the Dinmore to Goodna bypass (Box 6 on the next page), at the expense of smaller projects with more certain returns.

The reduction to the transport infrastructure portfolio's return on investment caused by these distortions to investment decisions is sizable. If even half this reduction was avoided by switching to alternative invest-

ments when project costs skyrocket prior to construction, the benefits to taxpayers would be as much as \$41 billion.³⁶

3.2 There is substantial scope for Australia to better reappraise projects after cost overruns

Cost overruns that occur early in a project's life should prompt a re-assessment of the project's costs relative to its benefits. The magnitude of some cost overruns suggests that not all projects will still be worth building.

Projects should be cancelled when their estimated benefits are found to be lower than their estimated costs. Given that benefits are probably overstated much of the time,³⁷ just as costs are understated, it is entirely fitting that projects be cancelled if their estimated benefits are only slightly more than their estimated costs (see Box 5 on page 24).

Fortunately, there is ample opportunity for Australian jurisdictions to identify these projects, as 63 per cent of cost overruns occur before construction begins, and 38 per cent before a formal budget commitment. However, such active reappraisals do not appear to be happening enough.

Over the last 15 years, two thirds of all announced projects have been completed. Even those announced before a formal government funding commitment are usually completed (Figure 3.3 on page 28).

This cancellation rate seems lower than it should be: the proportion of projects that are cancelled is less than the proportion of projects that would be expected to have benefit cost ratios less than one, given the

36. This conclusion is based on the observation of an average benefit cost ratio of 2.95 across the 39 business cases for transport infrastructure published by Infrastructure Australia by the 12th of February 2016. Please see Appendix B on page 62 for further details.

37. Elaurant and Louise (2015).

35. Eliasson and Fosgerau (2013).

Box 6: Case study – Ipswich Motorway Dinmore to Goodna upgrade – 196 per cent overrun

“Under budget”, and no return of contingency

An upgrade of the Ipswich Motorway between Dinmore and Goodna in Southern Queensland was announced in 2003, at a cost of \$594 million, based on a cost-benefit analysis.^a

In the 2007 federal election campaign, Labor promised to provide the upgrade for \$1.1 billion.^b Although this figure was far higher than the initial cost proposed, it turned out to be far lower than the 2008 contracted cost of \$1.95 billion.^c

On completion in 2012, the project came in 10 per cent lower than the contracted cost.^d Rather than being returned to the Commonwealth, the contingency was diverted to other Queensland roads, including the Bruce Highway.^e

a. Parliament of Australia (2006).

b. Roads Australia (2007).

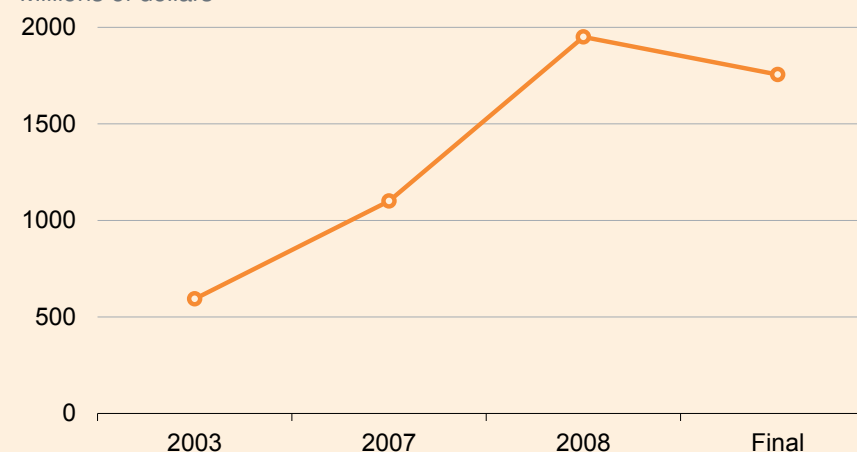
c. Australian Engineering Excellence Awards (2016).

d. Ibid.

e. Moore (2012).

Figure 3.2: Ipswich Motorway cost estimates

Millions of dollars

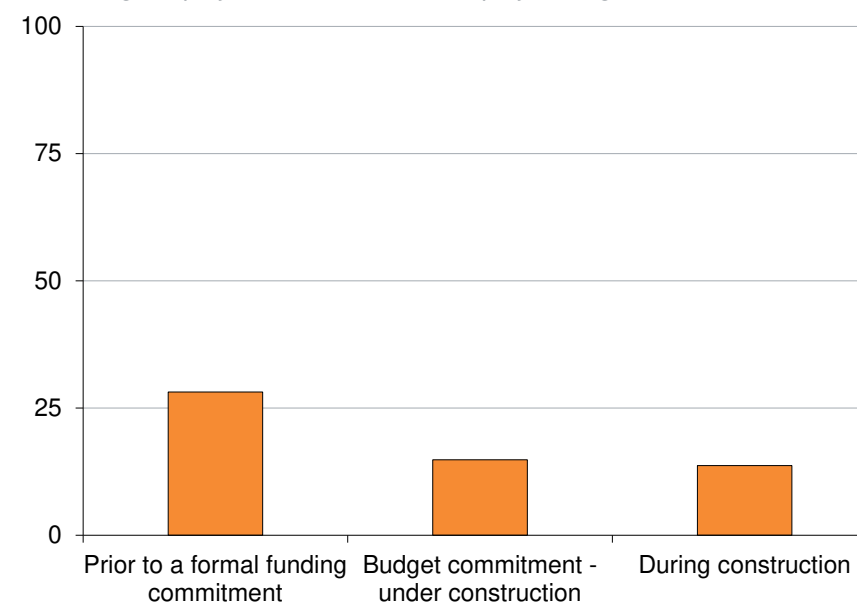


average magnitude of cost overruns (see Appendix B.2.4 on page 67 for details). Moreover, projects that did not incur cost overruns have been just as likely to be cancelled as those that did. This suggests that the project appraisal process may not be being used to cancel the right projects.³⁸ Together, these findings indicate that Australia's project appraisal process could be doing a much better job at cancelling projects when cost overruns push their costs above their benefits.

The early timing of Australia's cost overruns offers a substantial and unrealised opportunity to reduce cost overruns on transport infrastructure projects. If more projects were to be cancelled when cost overruns eroded the projects' investment merits, the costs associated with distortions to investment planning processes could be materially reduced.

A corollary of this conclusion is that, until the project appraisal process can be demonstrated to reliably cancel projects when it becomes apparent that they are poor investments, premature cost announcements remain a reckless practice. This is because, even though cost estimates announced prior to a budget commitment have been demonstrated to be of poor quality, in the absence of a robust mechanism for cancelling projects, such cost announcements constitute de facto commitments to build.

Figure 3.3: Few projects are cancelled once announced
Percentage of projects cancelled at each project stage



Notes: Australian transport projects completed between 2001 and 2015.

Source: Investment Monitor; Grattan analysis.

38. It could also be the case that projects are cancelled because of cost overruns that are anticipated but never publicly announced. However, this would mean that cost overruns are even higher than we observe, and hence, that even more projects should be being cancelled.

4 How to improve cost estimation

The previous chapter highlighted the costs to the community of cost overruns on transport infrastructure projects. While cost estimates for any given project are uncertain, cost estimates should, on average, correspond to cost outcomes.

But there is a substantial gap between estimated and actual costs on transport infrastructure projects over the past 15 years. In that period, cost estimators expected between 10 and 25 per cent of projects to exceed their budget. In fact, 34 per cent did so (Figure 4.1). Moreover, these overruns are not offset by underruns, as cost estimation guidelines optimistically imply.³⁹

Although it is not possible to perfectly predict the costs of any individual project, where cost estimates are wrong on average, there is clearly scope to improve.

This chapter identifies three concrete opportunities to improve cost estimation. First, cost estimates should reflect predictable patterns in the types of projects that overrun their budgets; second, project risks should be assessed comprehensively; and third, the assumptions employed in cost estimation should be aligned with historical experience.

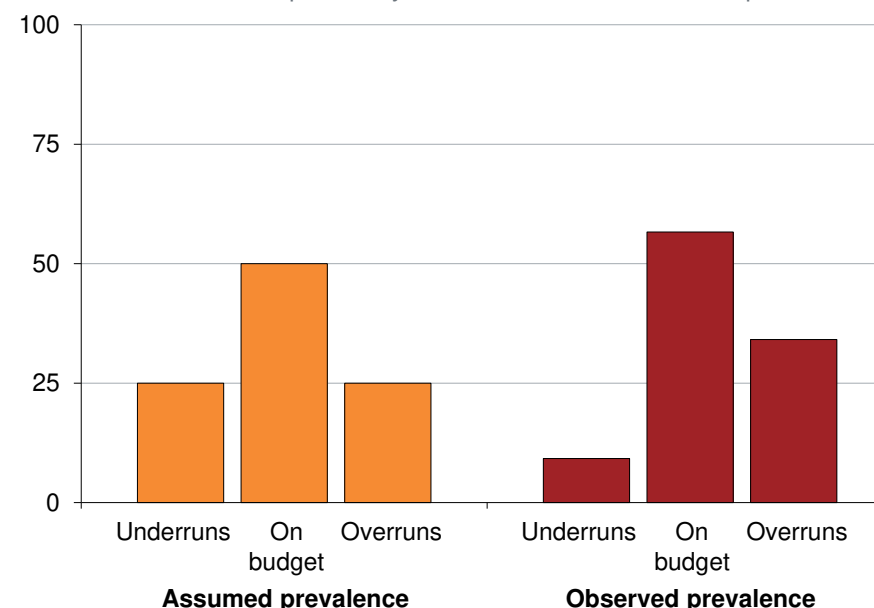
4.1 Cost estimates should reflect predictable patterns

There is an element of chance to any project finishing on budget. Yet the overall historical performance of Australian transport projects in aggregate suggests that we could be coming up with much better guesses of likely costs.

39. Please see Appendix B.2.6 on page 70 for further details and evidence of this claim.

Figure 4.1: Experts systematically underestimate the likelihood of cost overruns

Assumed and observed probability distributions of cost overruns, per cent



Notes: See Appendix B.2.6 on page 70 for the analysis of Australia's risk management guidelines which underpins the prevalence of cost overruns and underruns claimed here to be assumed by risk management guidelines.

Source: Australian risk management guidelines listed in Appendix A.4 on page 56 and Investment Monitor; Grattan analysis.

For example, large⁴⁰ road projects are more likely to come in over the cost initially announced than they are to finish on budget. Being a large road is not a subtle characteristic that could easily go unnoticed. Rather, it is an example of the tangible project characteristics that affect the likelihood of a project finishing on budget. The fact that projects with these characteristics are less likely to finish on budget than others indicates that their obvious risks are not adequately factored into project cost estimates.

This section discusses three tangible project characteristics associated with high risks:

1. project complexity,
2. project mode, and
3. contract type.

Properly accounting for their risk characteristics is a straightforward way to improve project cost estimates.

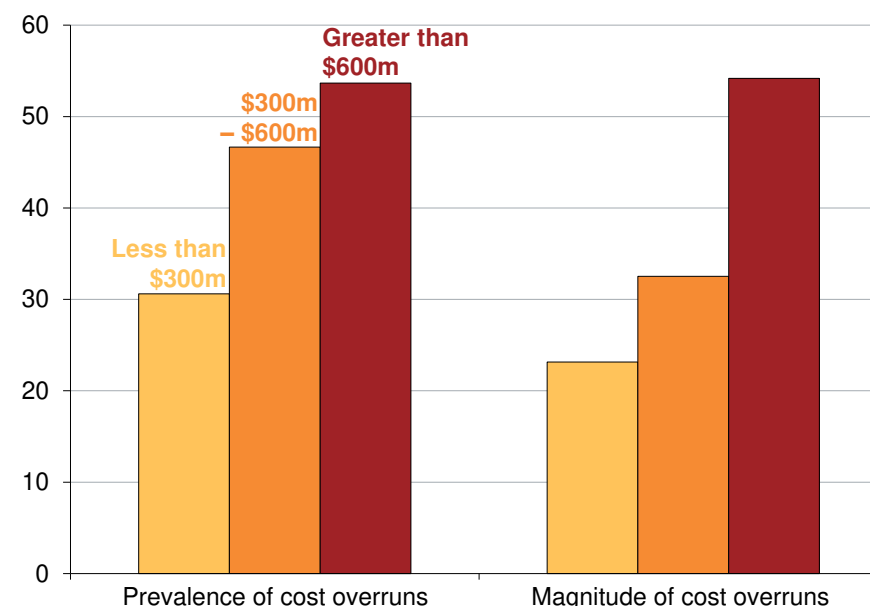
4.1.1 Large and complex projects are more prone to cost overruns

It is not surprising that complex projects are prone to cost overruns. Such projects tend to have many interdependent components that can be disrupted if one element falls behind time, and multiple interfaces with existing infrastructure. These risks are amplified when the existing infrastructure continues operating during construction.⁴¹

The most complex projects also tend to be large (Figure 4.2). Because of this, large projects are more likely to incur cost overruns, and these

Figure 4.2: Cost overruns are more common and larger, on average, among big projects

Prevalence and average magnitude of cost overruns as a percentage of initial project costs by project size, per cent



Notes: Australian transport projects completed between 2001 and 2015. Project size is defined by project value at the commencement of construction, \$2016.

Source: Investment Monitor; Grattan analysis.

40. Here we define "large" as valued above \$500 million at the commencement of construction.

41. For overseas examples, see Hinze et al. (1992) and Flyvbjerg (2014, pp. 9–11); for Australian examples, see Engineers Australia (2014, p. 3).

overruns are likely to be particularly big. In fact, a 10 per cent increase in a project's size (measured by cost estimate when first under construction) is associated with a 6 per cent higher chance of a cost overrun.

Given that project size is such a clear predictor of the size of cost overruns, cost overruns could be reduced by routinely amending the cost estimates of large projects so that they are more conservative. Some states have recently done this by instituting special cost estimation guidance for "high value, high risk" projects. However, in most jurisdictions, cost estimates are arrived at under the assumption that large projects face the same risk of cost overruns as small projects.

High-risk projects should be more closely scrutinised, and parties promoting them should seek to negotiate bipartisan support. Before they proceed, public infrastructure projects that are anticipated to cost \$1 billion or more should need the support of the parliament, not just the party in or seeking office (see Recommendation 4).

Recommendation 4: Special legislation for big projects

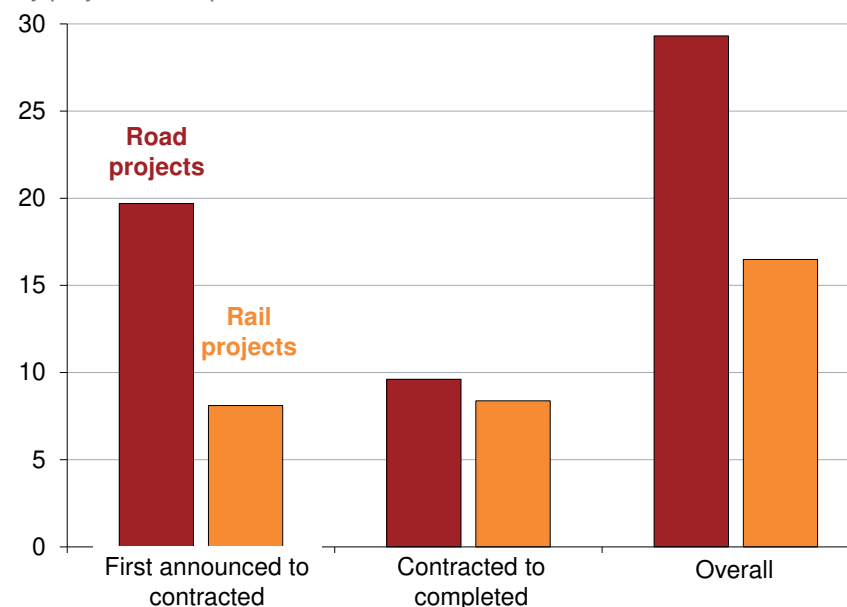
When the estimated construction cost to a jurisdiction is \$1 billion or more, Commonwealth, state or territory governments should be required to introduce standalone legislation for that transport infrastructure.

4.1.2 Road and rail projects overrun at different stages

It is not surprising that unusual projects are also more prone to cost overruns. This is because the more unusual a project is, the more difficult it is to estimate its cost and to build it to budget. Understanding when and where a project is unusual can help project proponents identify which projects are at particularly high risk of cost overruns.

Figure 4.3: Both road and rail projects suffer from cost overruns, but at different stages

Average magnitude of cost overruns as a proportion of initial project costs on Australian transport infrastructure projects completed between 2001 and 2015 by project mode, per cent



Notes: Australian transport projects completed between 2001 and 2015.

Source: Investment Monitor; Grattan analysis.

For example, rail projects tend to be relatively homogeneous during the planning stage, as many key components are standardised and can be purchased for a known price.⁴² However, these projects tend to incur disparate construction problems, because they are usually built on brownfield sites, around ongoing operations.

The inverse is true for roads. They often involve bespoke designs and complex interfaces with existing infrastructure. However, roads are less often constructed on brownfield sites with poor accessibility.

The timing of cost overruns on rail and road projects is aligned with the stages in which projects of these types are expected to be most bespoke. Cost overruns are larger for road projects during the planning stage, when road projects tend to be more bespoke than rail, and larger for rail projects during the construction period, when rail projects tend to be more bespoke (Figure 4.3 on page 31).⁴³

These differences in the size and timing of cost overruns by project mode illustrate another opportunity to improve cost estimates. Project proponents are always aware of their project's mode, and their project's mode provides substantial information about the project's likely cost risks. However, Australian risk management guidance does not currently advise project proponents to account for mode-specific differences in projects' cost risks.⁴⁴

42. Parliament of New South Wales (2012).

43. The observation that road projects experience larger overruns, on average, than rail projects runs counter to several key findings in the cost overruns literature (Merewitz (1973), Flyvbjerg et al. (2002) and Lee (2008)). However, it should be noted that these studies only investigate cost overruns during the construction phase, where we observe that the distinction between the average magnitude of cost overruns observed on road and rail projects is extremely modest.

44. The recently updated Australian Transport and Planning guidelines cite the importance of mode specific cost estimation differences, but only contain placeholder sections (Australian Transport Assessment and Planning (2016)). Placeholder sections cite the NGTSM guidelines which preceded the ATAP guidelines, but the

4.1.3 Contract type may affect the risk of cost overruns

A third characteristic that affects a project's cost risk is its contract type. Different types of contracts are used in order to allocate cost risks to the party best placed to manage them.

Traditionally, projects have been built under Design-Bid-Build and Design-Build contracts, where private companies have engaged with government in a typical contractor-client relationship. In order to improve the cost-efficiency of construction and management, the past generation has seen significant innovation in contract design for public infrastructure projects, resulting in increased use of public private partnerships and alliancing.

Public Private Partnerships, known as PPPs, have been used extensively to bring commercial discipline to infrastructure construction and operations. PPPs encourage integrated trade-offs between construction and maintenance. They also tend to require clearer definition in advance of construction.⁴⁵ Relative to traditional delivery models, PPPs can reduce costs if the additional commercial discipline is greater than the higher costs of private capital that PPPs incur.⁴⁶

A newer form of contract type, known as alliancing, creates a partnership between the government buyer and the contracting company or companies. Alliancing has become common over the past decade or so for projects in which it is particularly difficult to define risks prior to tendering, as this contract type allows for greater ongoing negotiation between the private contractor and government body.⁴⁷

relevant sections of this document do not note modal differences in cost risk, or how to accommodate them. Australian Transport Council (2006a) and Australian Transport Council (2006b).

45. Hodge and Greve (2009).

46. MacDonald (2002).

47. P. Wood and Duffield (2009).

Because different contract types are designed to allocate project risk in different ways, the average size of cost overruns is likely to vary by contract type. However, there is limited evidence on whether this is the case in practice.

A 2007 study of 54 projects and a 2008 study of 67 projects both concluded that PPPs are less prone to cost overruns than are traditionally procured projects.⁴⁸ Another study of 38 projects found no statistically significant difference in cost outcomes between PPP and non-PPP projects.⁴⁹ A 2010 study of 14 alliance projects found significantly greater cost overruns than in traditional delivery methods.⁵⁰

Given the small sample sizes and varying results of these studies, it is difficult to generalise about whether the average size of cost overruns is different under different types of contracts. However, this is an important field of research because it has the potential to identify more cost efficient ways to deliver infrastructure projects and to improve our ability to anticipate cost overruns.

4.2 Risk assessment should be comprehensive

Cost estimators are at present hampered by weaknesses in official guidance on cost estimation.

Every state produces its own guidance on how to estimate project costs. The Commonwealth produces guidance too. There are more than 50 current guideline documents and handbooks around the country. The adequacy of these guidelines is reviewed in detail in Appendix A.

Ultimately all cost estimates use some combination of four tools: expected value, sensitivity analysis, probability pricing, and reference

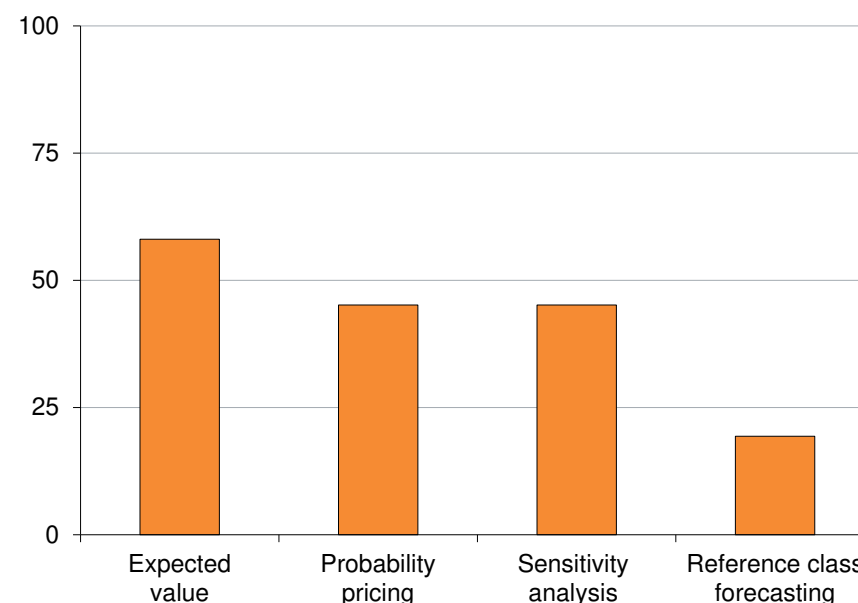
48. Allen Consulting Group et al. (2007); and Duffield et al. (2008).

49. Elaurant and Louise (2015).

50. P. Wood (2010).

Figure 4.4: Australia's various guidelines on transport risk measurement do not recommend any approach consistently

Proportion of guidelines recommending each key risk assessment tool, per cent



Notes: Prevalence rates were calculated over the subsample of Australian risk management guidance that provides quantitative risk measurement guidance.

Source: Australian risk management guidelines references in Appendix A.4 on page 56; Investment Monitor; Grattan analysis.

class forecasting (see Box 7 on page 35). The various guidance documents present the same basic tools in a wide variety of ways. Yet they are inconsistent in terms of which tools they recommend and in how they guide the user through the relationships among the various tools (see Figure 4.4).

A project's expected value is the most obvious gap in cost estimation guidance. Most thinking about risk measurement is predicated on some measure of expected value or expected cost, so expected value is an

important component of the risk manager's toolkit. It can be calculated using project information alone, or using historical information on completed projects. However, the expected value methodology, or a reasonable substitute is missing from the Commonwealth's "comprehensive"⁵¹ *Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction*. It is also missing from official guidelines for key gateways such as Infrastructure Australia's *Detailed Technical Guidance* and *Business Case Template*, and in some key state documents such as the South Australian *Estimating Manual* and Western Australian *Business Case Template*.

While there is more than one valid approach to measuring project risk, it is not obvious why different Australian jurisdictions need different approaches to the same basic tools. Different approaches make it difficult or impossible to collect data on a consistent basis so that project managers can draw on a large pool of past projects around Australia to improve their understanding of cost and risk.⁵² It would be better for all jurisdictions to adopt a standard approach, and for the Commonwealth to assist them to do so (see Recommendation 5).

4.3 Risk assessment should be based on actual Australian data on past projects

Cost estimates are produced from combining two types of information: one is building an estimate from adding up the costs of materials, equipment, labour and other inputs; the other is comparing a particular project to others like it. While information on the cost of inputs is widely available, the opposite is true when it comes to comparative information on projects.

51. Department of Infrastructure Transport Regional Development and Local Government (2008).

52. See Appendix A on page 44 for a comprehensive discussion.

Recommendation 5: Improve risk measurement guidance

The Commonwealth should provide model guidelines that states and territories may adopt or adapt, that recommend a consistent approach to measuring and managing project risk, including a statement of seniority where specific guidelines would otherwise conflict with one another.

The gap lies in the lack of actual Australian data on past projects. There is no consistent post-implementation review of projects, nor are data collected on how projects of various kinds performed against the original cost and benefit estimates.

This lack of data is concerning for two reasons. One is the poor accountability for project delivery and the unfortunate incentives it creates for governments to promise to build projects for unrealistic costs.

The second concern is that lack of data makes it impossible for those estimating project costs to do so properly. They can estimate the costs of inputs, but they lack the data to make robust comparisons with past projects - to use the cost estimation toolkit properly.

The cost estimation toolkit relies upon historical cost outcomes to calculate key aspects of a cost estimate. Probability pricing and reference class forecasting depend entirely on knowing the historical outcomes of similar projects. Not knowing these has three important consequences.

The first is that many guidelines suggest to cost estimators that overruns and underruns are equally likely.⁵³ They do so by recommending that symmetric probability distributions should underpin the typical approach to estimating probability prices, known as Monte Carlo simulation.

53. Please see Appendix B.2.6 on page 70 for further details.

Box 7: The risk manager's toolkit

The **expected value** of a project's cost is the average or mean cost of a project. It is calculated by assigning a single probability to each potential cost outcome, and multiplying this probability by the cost of that particular outcome if it did occur. This is the simplest approach to estimating the likely size of cost overruns. To be useful, the approach should include all of the risks involved in a project. Its main shortcoming is that it does not include the costs of any unknown risks.

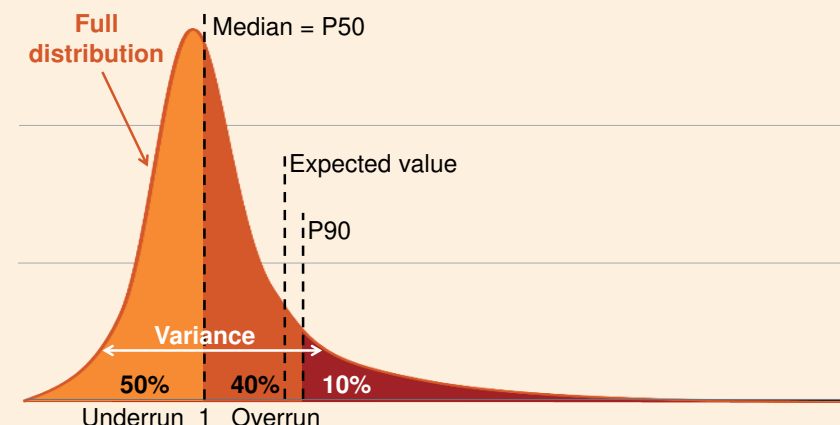
Sensitivity analysis assesses the range within which a cost estimate is likely to vary. It involves specifying the range of values that critical inputs to project cost estimates could take, and estimating how much the project would cost if the inputs were to take these values. Like the expected value methodology, it does not deal with unknown risks.

Probability pricing identifies how large a project budget needs to be in order to accommodate a specific probability that the project will be completed within budget. For instance, most projects have 'P50' and 'P90' cost estimates, which identify the prices for which it is expected that a project will meet or better its budget in 50 or 90 per cent of cases, respectively.

Reference class forecasting compares cost estimates for one project to those on similar projects that have already been built. The average size of cost overruns observed across the sample can be used as an estimate of the expected value of cost overruns; the variance of the outcomes on the comparison projects can be used to understand the range within which a cost estimate is likely to vary; and the different points within the observed distribution can be used to estimate probability prices.

Figure 4.5: Key risk measurement and management concepts

Illustrative probability distribution of cost outcomes on individual projects



Notes: The distribution of cost risk depicted is a stylized representation of the distribution of cost overruns observed in the Investment Monitor; see Appendix B.2.6 on page 70 for details. This graph's illustrative purpose is to depict the relative distances between key points of the distribution

Source: Investment Monitor; Grattan analysis.

The key advantages of reference class forecasting are that it incorporates the likely costs of unknown risks and does not suffer from optimism bias, as it relies on objective historical information. Its main shortcoming is that it does not account for the ways in which a project's risk profile is unique.

Figure 4.5 illustrates these tools for the costs of a group of completed projects: expected value (or mean); variance (assessed by sensitivity analysis) and probability pricing levels. The fourth tool, reference class forecasting, offers a way to improve the quality of expected value, sensitivity analysis and probability pricing by relying on historical experience.

This advice contradicts Australian experience (see Box 8 on current projects).

A second consequence of not knowing historical outcomes of similar projects is that it deprives cost estimators of an effective counter to known psychological biases. Just as trains or aeroplanes more often arrive late than early, so too do cost estimates tend to ramp upwards more often and to a greater degree than downwards. The psychological tendency to believe that project outcomes will be better than they turn out to be is known as ‘optimism bias’, and arises from the combined impacts of cost underestimation and benefits overestimation.⁵⁴ Unfortunately, optimism bias is especially acute when the most money is at stake, in the larger and more complex projects where the interdependence of risks is particularly hard for experts to judge accurately.

A third consequence of not knowing historical outcomes is that cost estimators lack an effective counter to ‘strategic misrepresentation’ – when proponents deliberately manipulate the cost estimates to make them look more favourable than they really are.⁵⁵ Project proponents have an incentive for strategic misrepresentation to the extent that they are judged more on how much they build rather than how well they manage their budget. Lack of historical outcomes data makes this behaviour hard to counter.⁵⁶

The discrepancy between expert expectations and historical experience shows that the reliability of risk assessments on Australian transport infrastructure projects would be substantially improved by equipping risk experts with better information. The Productivity Commission’s 2014 Public Infrastructure inquiry report highlights the need for an accurate database of historical cost outcomes for Australian projects.

54. Kahneman (2012); and Flyvbjerg (2014, p. 14).

55. Productivity Commission (2014, p. 102).

56. See Productivity Commission (*ibid.*, pp. 100–102) for a recent discussion.

Box 8: Failure to learn from history continues to affect current projects

The experience of the past 15 years has shown that the difference between the median cost, or “P50”, and the “worst case”, or “P90” cost, is 26 per cent on average, for transport infrastructure projects valued at \$20 million or more.

But cost estimates for current projects do not reflect this experience. Instead, the difference between median and “worst case” estimates is generally about half this size. Judging by recent history, this indicates that either the median cost estimate is too high, or – more likely – the “worst case” cost estimate is too low. If the latter is the case, more than the expected 10 per cent of these projects will be likely to experience overruns. This report has found that these will be larger, on average, than expected.

Table 4.1 on the following page shows that the difference between median and “worst case” estimates appears to be too small for projects currently under way. They show a “worst case” cost estimate far lower than 26 per cent above the median estimate that history should have led us to expect.

Table 4.1: Large projects currently under development or construction

Project	State	Cost estimate (nominal, \$millions)		Difference
		Median (or “P50”)	“Worst case” (or “P90”)	
Inland Rail	National	9 890	10 660	7.8%
WestConnex	NSW	16 800	n/a	6.0%
Melbourne Metro	Vic	10 154	10 837	6.7%
Western Distributor	Vic	5 226	5 548	6.2%
Princes Highway West Duplication	Vic	334	363	8.7%
Main Road, St Albans Level Crossing Removal Project	Vic	222	231	3.9%
Bruce Highway Upgrade	Qld	841	929	10.5%
M1 Pacific Motorway – Gateway M’way Merge Upgrade	Qld	197	207	5.2%
Mitchell Freeway extension	WA	297	322	8.3%
Great Northern Highway	WA	301	361	19.7%
North West Coastal Highway	WA	148	179	20.9%
Canberra Light Rail	ACT	759	806	6.5%
Average difference of above estimates				9.2%
Average actual difference across all projects completed in the past 15 years				26.0%

Notes: See Appendix B.2.7 on page 73.

Source: Victorian State Government (2016), Victorian State Government (2015), SGS Economics & Planning (2016), Nation Building Program Amendment Bill (2009), Infrastructure Australia (2016f), Australian Capital Territory Government (nodate), Infrastructure Australia (2015b), Infrastructure Australia (2015a), Infrastructure Australia (2016e), Infrastructure Australia (2016g), Infrastructure Australia (2016h) and Infrastructure Australia (2013)

The Commonwealth, which supports this recommendation,⁵⁷ should create such a database, using the information on completed projects from all states on a consistent basis. The change would help cost estimation experts to create better quality estimates.

Recommendation 6: Compile Australian database of completed projects

The Commonwealth should seek cooperation from the states to create new benchmarking data to improve risk measurement in new project proposals and public accountability. They should do so using data collected through mechanisms described in Recommendation 3.

57. Productivity Commission (2014, Volume 1, Recommendation 9.2) and Department of Infrastructure and Regional Development (2014, p. 19). The focus of the Government's response is on cost benchmarking data, not on cost risk benchmarking data.

5 How to manage exceptional circumstances cost-effectively

Once risks have been quantified as accurately as possible, the task is to manage them. Most of a project's risks materialise during construction and on completion. These are key times for managing risks.

5.1 Not all risks are avoidable

Some risks materialise through changes in the economy. Because the growth rate of the economy fluctuates, the costs of public infrastructure will always be uncertain. This is because a project's input costs may be higher than anticipated if private sector demand for resources such as equipment, materials and workforce is higher than anticipated.

This type of unavoidable cost risk may explain the higher rate of cost overruns experienced in Western Australia during the resources boom. With many construction companies deployed on mining projects, there were often few or even only one bid for public sector works projects. Not surprisingly, Western Australia experienced larger overruns on average than those in New South Wales, Victoria and Queensland (details in Appendix B on page 62).

By contrast, current economic conditions have led to more competition within the construction industry to build public infrastructure. Anecdotal evidence suggests that constructors may make unfeasibly low bids when the number of available projects shrinks, as is the case in some parts of Australia at present. This practice would only be a concern for government if contractors pursued contract changes that were in effect claims to recoup the revenue forgone by a low bid, and if governments were unable in practice to deny these changes because of political lock-in.⁵⁸ While this may occur on some projects, we do not find significant evidence of low initial bids leading to later overruns.

58. Love et al. (2014, p. 500); and Hinze et al. (1992, pp. 87–88).

Constrained budgetary environments also affect cost overruns by causing a general tightening of incentives to deliver projects within budget. This appears to have been the case in Australia since the global financial crisis, when the focus swung sharply from getting projects shovel-ready to balancing the budget. During this period, there have been substantial changes to the culture and practice of governments, and the probability of cost overruns during construction has approximately halved (although the same cannot be said of cost overruns before a formal funding commitment).

There are numerous other unavoidable risks that are a part of major construction projects, like unexpected weather, ground conditions and industrial relation events. Each project also has its own idiosyncratic risks that cannot be avoided. These risks mean that it is impossible to eliminate cost risk entirely. Consequently, it is important that budgeting, reporting and contingency management practices are designed to minimise the cost of cost overruns when they occur.

5.2 We could better manage the risks that cannot be avoided

Currently, unavoidable cost risks on transport infrastructure projects are more costly than they need be. This is because budgeting and reporting practices are targeting the wrong outcome and contingency funds are managed in an unnecessarily expensive manner. The following sections identify how these practices could be improved.

5.2.1 Manage budgets not reputations

Currently, reporting and budgeting process are designed to minimise the number of cost overruns that occur, rather than the cost of cost overruns. Politicians often announce whether a project finished on or

under budget, but they rarely talk about how much over budget it ran unless they want to blame a rival from another party. Similarly, projects are costed to reflect a low probability of going over budget rather than a zero net cost of cost overruns.

This is problematic because whether or not a project runs over budget is only a small part of the story. What governments should really worry about is the cost of such overruns. All projects overrunning by a tiny amount is much less troubling than a few blowing out by vast sums.

The lack of data on project outcomes encourages this focus on the rate of cost overruns. This is because it is easy to count how many projects came in on budget when there is not much data, but hard to uncover the average amount by which projects overran their budgets.

A more technical way of putting this is that current practice has encouraged the folly of managing the *median* cost overrun rather than the *mean*. While the median and mean are often one and the same, this is not the case for cost outcomes because the distribution of cost outcomes is extremely asymmetric – that is, overruns are much more likely and much bigger than underruns.

Over the past 15 years, Australia has delivered a median cost overrun of zero per cent, but a mean cost overrun of 24 per cent. The mean value is the figure that matters because it summarises how much more we spent on infrastructure than we intended. The median or “P50” outcome represents a less relevant statistic: the worst outcome observed among the 50 per cent of projects with the best cost performance.

Reducing the size of cost overruns is much more important than reducing their rate. Collecting and aggregating project performance data is essential to reducing the size of overruns. Governments should aggregate data across jurisdictions to make this possible.

5.2.2 Contingencies should be used cost efficiently

The costs of cost overruns could be reduced by managing contingency funds in a more cost efficient way.

A project’s contingency fund is a sum of money from the project’s operating budget that is set aside for exceptional circumstances. The idea is that the contingency is there to be called upon if needed, but if it is not needed, it should be kept separate and used at some point on another infrastructure project that does need it. Most projects should not need to use their contingencies, but, inevitably, some will.

In most jurisdictions, some or all of a project’s contingency funds are held within the managing agency, often by the project manager. But managing contingency funds at the project level in this way is far more expensive than managing them at the portfolio level.

This is because a larger amount needs to be put aside for exceptional circumstances if managers cannot also call upon unused contingency funds from other projects when risks eventuate. By contrast, pooling contingencies from a portfolio of projects is cheaper, for the same level of protection, because the same funds provide protection for multiple projects at the same time.

Figure 5.1 on the next page illustrates the difference between the contingency funds that would have been needed on average for projects valued at \$20 million or more and planned or built over the past 15 years, according to whether the contingency was set for an individual project or for a whole portfolio. The difference is substantial: contingency funds can achieve the same level of certainty for a third of the cost when managed at the portfolio level.

A second reason why it is more expensive to hold most or all of the contingency at the individual project level is the risk that the money is used on other things (see Box 9 on the Pacific Motorway).

While holding the contingency against an individual project allows a more nimble response to unexpected events, this very nimbleness is also a disadvantage. It makes it easier for contingency funds to be spent on scope extensions, quality upgrades, or even on completely different purposes. The practice of holding the contingency in the department responsible for managing the project risks poor discipline in managing costs, and encourages project enhancements that have not been justified through a business case. In fact, project managers arguably waste an opportunity when they *do not* use the contingency funds on project enhancements.

It is in the project manager's interest to have the contingency accessible at the project level rather than held against a portfolio. Individual project managers may face reputational damage, however unfairly, if they preside over a project that runs over budget, even when it has been costed at, say, the P75 level, where by definition an overrun is expected to occur 25 per cent of the time at the P75 price estimate.

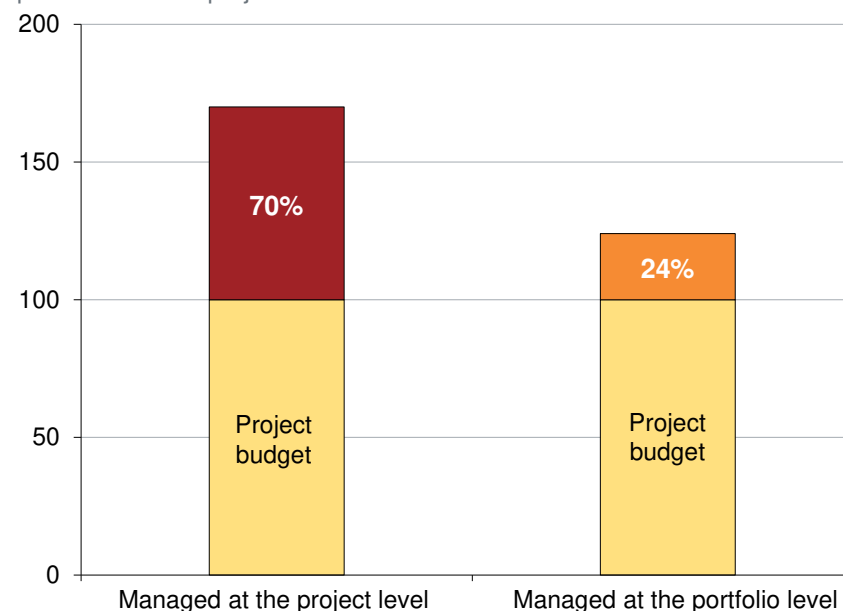
For these reasons, managing all risk at the project level is unnecessarily expensive. Australian governments would do well to introduce more explicit requirements for contingency funds to be managed by state departments of treasury or finance. Even managing a substantial portion of contingencies at the project level could deliver substantial savings, while maintaining the same level of risk coverage (Recommendation 7).

Recommendation 7: Hold the project contingency in a portfolio pool

Central agencies should hold project contingency funds at arm's length from project management, and formalise the conditions governing contingency drawdown.

Figure 5.1: Small contingencies can achieve a lot when they are managed at the portfolio level

Value of the contingencies required to ensure that individual projects are expected to finish within initial budget commitments with 90 per cent probability, and that 90 per cent of projects finish within initial budget commitments, as a per cent of initial project costs



Notes: Australian transport projects completed between 2001 and 2015.

Source: Investment Monitor; Grattan analysis.

Box 9: Case study – Pacific Motorway – 14 per cent under-run

Unused contingencies are often funnelled into scope increases and other projects

The Pacific Motorway (Springwood South to Daisy Hill) upgrade project in southern Brisbane finished under budget. Then Federal Infrastructure Minister Anthony Albanese announced that the “savings achieved on the Springwood South to Daisy Hill upgrade will be used to construct an auxiliary lane between Fitzgerald Avenue and Aranda Street in Springwood as well as undertake the land acquisitions and planning work associated with the future widening of the Motorway between Daisy Hill and the Logan Motorway.”^a

^a. Albanese (2013).

6 Conclusion

Taxpayers have paid \$28 billion more on transport infrastructure in the past 15 years than they were told they would pay. This is 24 per cent above the promised cost.

Premature announcements are the main causes of these cost overruns. Projects that are announced prematurely have larger and more frequent cost overruns than those announced at a more mature stage of development. This is true not just in the run-up to a formal cost assessment but throughout the project lifecycle. Limiting premature announcements could substantially reduce cost overruns.

If premature announcements were reduced or eliminated, further overruns could be addressed through more comprehensive risk measurement. More accurate cost estimates would give governments realistic information that they could use to establish the size of the infrastructure building program and the priorities within it.

They cannot do this until they collect information on past projects. Cost estimation and risk management must allow for unforeseen as well as known risks, and the best way to prepare for unforeseen events is to learn from history. It is essential to collect and publish Australian data on historical project outcomes, to allow better risk measurement and account to the public for decisions made.

There are no grounds for believing that the problem has been fixed. On the contrary, projects currently in the planning and delivery stages have cost estimates that do not take account of the experience of the past 15 years, and many may well be at risk of significant cost overruns.

With actual Australian data on past projects, we would no longer need to be surprised by what is predictable. Instead, our infrastructure systems could promise what is worth having, and then deliver what is promised.

A Risk appendix

Construction projects inevitably involve a host of cost risks. The objective of risk management is to minimise the costs of these risks. This involves:

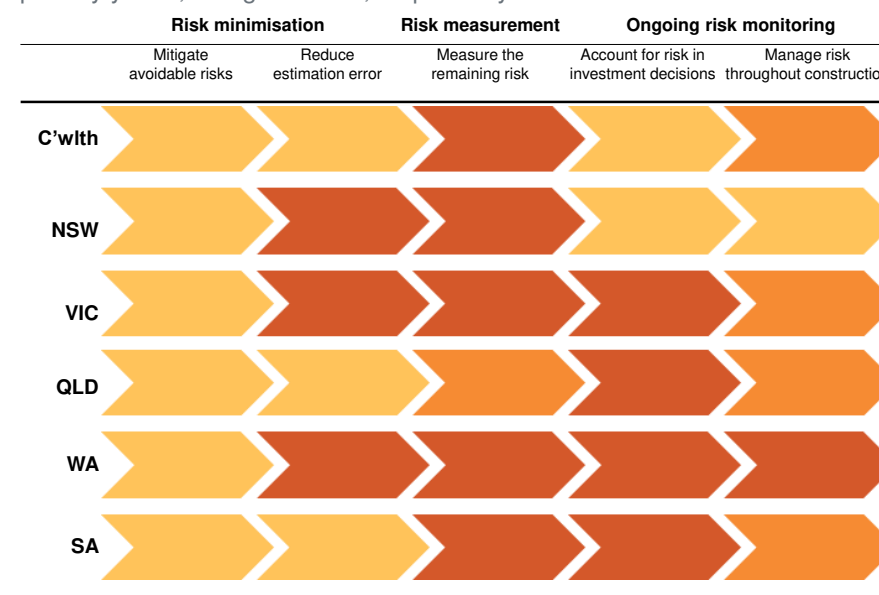
1. Risk minimisation
 - a) Identifying and mitigating avoidable risks
 - b) Reducing estimation error as appropriate
2. Risk measurement
 - a) Measuring the remaining risk
3. Ongoing risk monitoring
 - a) Accounting for the remaining risk in investment decisions
 - b) Managing the remaining risk in a cost efficient manner

There are over fifty sets of guidelines outlining required approaches to risk management across Australian jurisdictions.⁵⁹ In general, these documents are very detailed and well written. However, there are substantial blind spots in the guidance provided in each jurisdiction. This has resulted in risk management guidance that varies in quality across the components of risk management.

Figure A.1 provides a high level summary of the quality of risk guidance across Australian jurisdictions for each of the aforementioned components of risk measurement. It identifies that the guidance provided regarding risk minimisation is generally of a far higher standard than

Figure A.1: The quality of risk management guidance varies

Guidance quality by jurisdiction and topic ranked as sufficient, incomplete and poor by yellow, orange and red, respectively.



Notes: See Table A.4 on page 60 for the guidelines rated and Table A.5 on page 61 for the criteria used to rate them.

Source: Guidelines listed in Table A.3 on page 57; Grattan analysis.

59. As listed in Table A.3 on page 57.

that of risk measurement and ongoing risk monitoring. This is aligned with the nature of Australia's problem with cost overruns: most projects finish on budget, but the huge costs of uncommon events are poorly anticipated and accounted for.

In this appendix we review the current practices of each state for each of these components of risk management, and highlight the opportunities for improvement. Full details of the Australian risk management guidelines analysed in this appendix are provided in Appendix A.4.

A.1 Risk minimisation

The most critical component of risk management is the reduction of project risks⁶⁰ where possible. This can be achieved by identifying and mitigating avoidable risks and reducing estimation error, as far as it is financially worthwhile to do so.

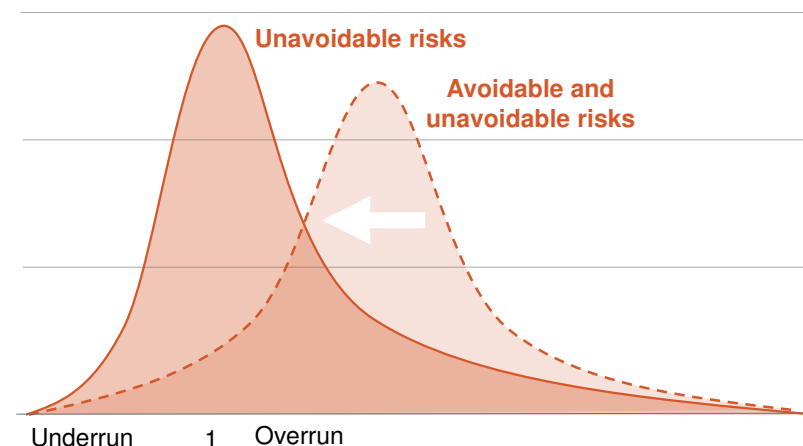
While there is scope to improve estimation error in many jurisdictions, the general quality of guidance provided on risk minimisation on transport infrastructure projects is high. This is a necessary component of a high quality risk management process, but risk minimisation alone is not sufficient.

This section provides a conceptual overview of Australia's risk minimisation practices with the objective of identifying both what risk minimisation can achieve, and highlighting the risk management tasks that remain after risks have effectively been minimised.

60. Project risks include external factors, such as market conditions and industrial relations, as well as project-specific factors, such as geotechnical conditions, cost estimation error and scope variation.

Figure A.2: Some avoidable risks can be mitigated

Stylized representation of the probability of cost overruns of each size, per cent



Notes: The distribution of unavoidable risks depicted is a stylized representation of the distribution of cost overruns observed in the Investment Monitor; see Appendix B on page 62 for details. The distribution of avoidable risks relative to unavoidable risks has been inferred by assuming that cost overruns would be larger if no effort was made to mitigate avoidable risks. This graph's illustrative purpose is to graphically present the common wisdom that cost risks can be reduced, but not eliminated, by mitigating avoidable risks.

Source: Investment Monitor; Grattan analysis.

A.1.1 Identify and mitigate avoidable risks

Consistent use of risk matrices or like tools to identify and mitigate avoidable risks on construction projects is extremely important. This is because active mitigation of cost risks can reduce the frequency with which large cost overruns occur, as illustrated in Figure A.2.

At least one set of risk management guidelines in each of Australia's state and Commonwealth government jurisdictions recommends the use of risk matrices and provides high level advice on how to mitigate

common risks.⁶¹ For this reason, the guidance on risk identification and mitigation provided in every jurisdiction appears to be sufficient.

A.1.2 Reduce estimation error

Some states also provide comprehensive guidance on the level of detail required for risk estimation at each stage of a project's development.

For example, the South Australian Department of Planning, Transport and Infrastructure *Estimating Manual* sets out:

- the **detail with which costs should be estimated**, in terms of whether global benchmark, unit rate or first principles approaches should be used to price project inputs;
- the **detail with which projects should be broken down** into their components, defined relative to the Work Breakdown Schedule; and
- the **size of the contingency margin** which should be added to estimates at each stage.

It is important that every jurisdiction provides this level of guidance for two reasons. Firstly, the expense of arriving at more detailed cost estimates means that, where there are not clear requirements regarding the appropriate level of detail, incentives to produce insufficiently detailed cost estimates will prevail.

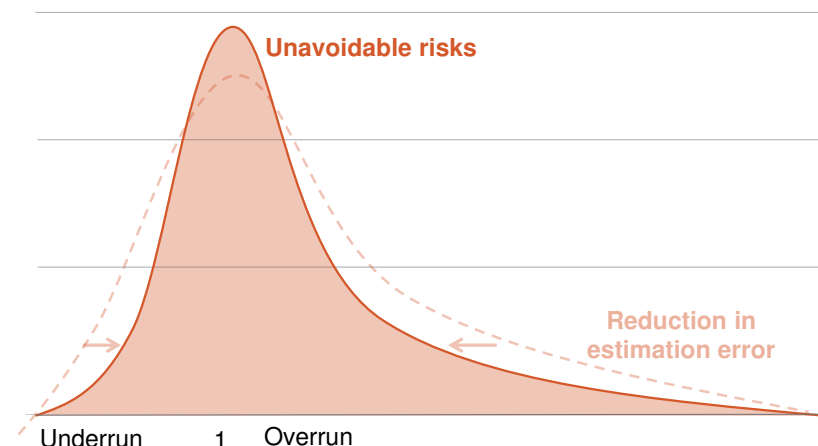
Secondly, the different margins of error associated with different cost estimation methodologies mean that cost estimates derived using different estimation methodologies are not directly comparable.

Providing detailed guidance on how project costs should be estimated for each level of project maturity allows governments to increase their confidence that projects will come in on budget, as illustrated in Figure A.3.

61. See Table A.3 on page 57.

Figure A.3: More projects will finish on budget when estimation error has been minimised

Stylized representation of the probability of cost overruns of each size, per cent



Notes: The distribution of unavoidable risks depicted is a stylized representation of the distribution of cost overruns observed in the Investment Monitor; see Appendix B on page 62 for details. The distribution of cost overruns before estimation error has been minimised has been inferred by assuming that cost estimates will be incorrect more often under less detailed cost estimation methodologies. This graph's illustrative purpose is to graphically present the common wisdom that cost risks can be reduced, but not eliminated, by mitigating avoidable risks.

Source: Investment Monitor; Grattan analysis.

Such increased cost certainty should be pursued insofar as the benefits outweigh the costs.

A.2 Risk measurement

Australia's guidance on risk minimisation is generally of a high standard. However, risk minimisation alone is not sufficient, as it is inevitable that some cost risks will be impossible, or prohibitively expensive, to eliminate. These remaining risks need to be accurately measured,

so that they can be factored into investment decisions and efficiently managed throughout a project's life.

As discussed in Section 4.2 on page 33, the critical shortcoming of risk management on Australia's transport infrastructure projects is that the guidance regarding the measurement of unavoidable project risks is uniformly poor. This is because the guidance on how to quantify project risks is:

- inconsistent within and across jurisdictions,
- incomplete, as most guidance does not provide advice on how to assess unknown risks or extreme and unlikely events, and
- often contains insufficient information for the recommended risk measurement methodologies to be properly implemented.

This section reviews each of these shortcomings in detail and provides state-specific examples of opportunities for improvement.

A.2.1 Guidance is inconsistent, within and across levels of government

Guidelines which apply to the same jurisdiction often recommend different approaches to risk measurement. For instance, probability pricing is required for Commonwealth funding, yet only half the risk measurement guidance provided by the Commonwealth Government discuss probability pricing. Although it may seem sufficient that some guidance material discusses probability pricing even if not all do, in practice, such fragmentation makes guidance hard to follow properly.

For example, the *National Partnerships Agreement on Land Transport Infrastructure Projects*,⁶² the Australian Transport Council's *National Guidelines for Transport System Management in Australia*,⁶³ Infrastruc-

62. Council of Australian Governments (2014).

63. Australian Transport Council (2006a).

ture Australia's *Business Case Template*,⁶⁴ the Department of Infrastructure and Regional Development's *Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction*⁶⁵ and the Bureau of Infrastructure, Transport and Regional Economics's *Overview of Project Appraisal for Land Transport*⁶⁶ require or discuss probability pricing. However, Infrastructure Australia's *Assessment Framework*⁶⁷, the *HB 158:2010 Handbook on delivering assurance based on ISO 31000:2009*⁶⁸ and BITRE's *Risk in Benefit Cost Analysis*⁶⁹ do not.

The Victorian guidelines on risk measurement are similarly fragmented. For example, three key guidelines on risk measurement each recommend only part of the toolkit, and a different part in each case:

- the Victorian Insurance Management Authority's *Practice Guide*⁷⁰ requires only the calculation of the expected value of project risks;
- the Department of Treasury and Finance's *Technical Guidelines on Economic Evaluation of Business Cases*⁷¹ requires only sensitivity analysis; and
- the Department of Treasury and Finance's *Business Case Template*⁷² and *Gateway Review Process*⁷³ only requires reference class forecasting.

64. Infrastructure Australia (2016c).

65. Department of Infrastructure Transport Regional Development and Local Government (2008).

66. Bureau of Infrastructure, Transport and Regional Economics (2014).

67. Infrastructure Australia (2016b).

68. Standards Australia (2010).

69. Bureau of Transport and Regional Economics (2005).

70. Victorian Managed Insurance Authority (2016).

71. Victorian Department of Treasury and Finance (2013).

72. Victorian Department of Treasury and Finance (2016a).

73. Victorian Department of Treasury and Finance (2016b).

Such fragmentation of guidance within jurisdictions obfuscates proper process and makes the conceptual dependencies between tools unclear.

In some instances, inconsistencies also introduce contradictions within jurisdictions. For example, the Australian Transport Council's *National Guidelines on Transport System Management* and Department of Infrastructure and Regional Development's *Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction* guidelines both apply federally, but recommend that contingency margins of substantially different sizes are added to project budgets.⁷⁴

Risk measurement guidance should also be consistent between the Commonwealth and each individual state. This is because each state must comply with both its own guidelines and the Commonwealth's whenever it seeks project funding from the Commonwealth to supplement its own funding of a project. Where state and commonwealth guidance differs, multiple versions of the same analysis are required.

For example, Victoria's business case on the Western Distributor has two sets of benefit cost ratios in order to conform to different requirements of the two levels of government.⁷⁵ Neither of these benefit cost ratios is necessarily more correct than the other. Rather, they are two imperfect estimates of the same concept. As cost estimates are expensive to produce, Australia's project appraisal processes could be made more cost efficient by aligning the analysis required across each jurisdiction.

The inconsistencies observed across Australian risk measurement guidelines could be resolved by removing old guidance when new processes are implemented, consolidating existing guidelines and

writing new guidance so that it replaces, rather than accretes to, older guidance.

For example, many of the inconsistencies within Commonwealth, COAG and Austroads guidance were addressed through the 2016 release of the *Australian Transport Assessment and Planning Guidelines*.⁷⁶ These guidelines replaced *Austroads' Guide to Project Evaluation*⁷⁷ and the *National Guidelines for Transport System Management in Australia*,⁷⁸ and were written to be aligned with Infrastructure Australia's guidelines, the *National Guidance on Public Private Partnership Projects* and the *National Charter of Integrated Land Use and Transport Planning*. A similar exercise should be undertaken within each state, which should aim to align guidance with these federal guidelines.

Where different institutions within jurisdictions require different levels of risk analysis, guidance should be comprehensively reviewed so that the hierarchy of guidance documents is clear and, where possible, analytical requirements are aligned.⁷⁹

A.2.2 Guidance is incomplete

Even if project proponents were to follow the guidance on risk measurement to the book, cost overruns would be underestimated. This is because the recommended approaches to risk measurement are incomplete.

There is no single "right" way to measure risk, but for an approach to risk measurement to be considered complete, it must be both reliable and comprehensive. Assessments of project risks can be considered:

74. The *National Guidelines on Transport System Management* recommend that New Zealand's narrow contingency margins are added to project budgets, whereas the *Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction* recommends that the UK's extremely wide contingency margins are added to project budgets.

75. Victorian State Government (2015).

76. Australian Transport Assessment and Planning (2016).

77. Austroads (2014).

78. Australian Transport Council (2006a).

79. Page 11 of Transport NSW's *Principles and Guidelines for Economic Appraisal of Transport Initiatives* provides a useful example of how this can be done.

- **reliable** if expert opinion is used to tailor risk estimates to projects' specific characteristics, and objective information is used to counter the challenges of optimism bias and strategic misrepresentation; and
- **comprehensive** if known, unknown, moderate and extreme risks are all accounted for.

No single risk measurement tool achieves all these objectives, which means that a combination of tools is required. Table A.1 on the following page summarises how each risk measurement tool can, if used properly, contribute to a complete approach to risk measurement.

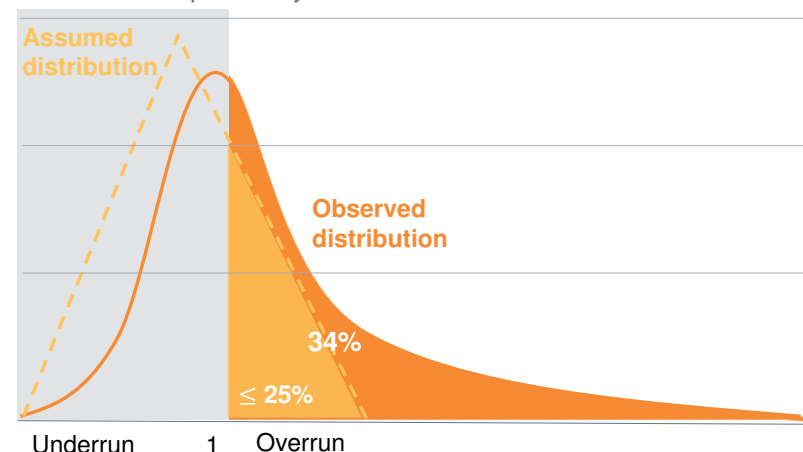
As summarised in Table A.2 on page 51, most key guidelines recommend approaches to risk measurement that only go part way towards incorporating objective information and accounting for extreme and unknown risks.

Unknown risks are the most poorly accounted for. None of the reviewed guidelines require project teams to draw on analysis of the outcomes that have been observed historically across a reference class of projects. Guidelines which recommend the use of Monte Carlo simulation do a better job at accounting for unknown unknowns than those that rely purely on expert judgement. This is because structured processes somewhat dampen the effects of innate overconfidence biases. However, the effects of overconfidence could be fully protected against through routine use reference class forecasting.

Figure A.4 on page 52 compares the distribution of cost risks recommended for use in Monte Carlo analysis in most risk management guidelines with the realised distribution of cost outcomes. It illustrates that probabilistic risk analysis is also compromised by overconfidence bias, as far more than the anticipated 25 per cent of projects overran

Figure A.4: The probability of extreme cost overruns is systematically underestimated

Assumed and observed distributions of the average project cost risk, represented as the probability distribution of cost overruns



Notes: The distribution of cost risks depicted is a stylized representation of the distribution of cost overruns observed in the Investment Monitor. Please see Appendix B.2.6 on page 70 for details and a discussion of the sources underpinning the typical risk management guidelines' assumed distribution of cost overruns. This graph's illustrative purpose is to graphically present that a symmetric distribution with a lower bound of zero and 25 per cent probability of cost overruns drastically underestimates the probability and magnitude of extreme cost risks.

Source: Investment Monitor; Grattan analysis.

their budgets⁸⁰. Moreover, the extreme risks underpinning the extreme cost overruns that are responsible for Australia's cost overruns problem⁸¹ do not appear to be anticipated at all.

80. See Appendix B.2.6 for the analysis of Australia's risk management guidelines underpinning the claim that no more than 25 per cent of projects were expected to overrun their budgets

81. As discussed in Chapter 1, the 17 per cent of projects with cost overruns greater than 50 per cent of their initial project budgets account for 90 per cent of cost overruns by value.

Table A.1: Complete approaches to risk measurement satisfy all the conditions for reliability and comprehensiveness by using a combination of tools

Attributes of each risk management tool, where ✓ indicates that a tool can be used satisfy the criteria, ✓ indicates that a tool can be used to get part way towards the criteria and ✗ indicates that a tool cannot be used to achieve the criteria.

			Reliable		Comprehensive			
			Tailored	Objective	Moderate	Extreme	Known	Unknown
Expert judgement	Expected value		✓	✗	✓	✓	✓	✗
	Probability pricing	Moderate (e.g. P50)	✓	✗	✓	✗	✓	✗
		High (e.g. P90)	✓	✗	✗	✓	✓	✗
	Sensitivity analysis		✓	✓	✗	✗	✓	✗
Monte Carlo simulation	Expected value		✓	✓	✓	✓	✓	✗
	Probability pricing	Moderate (e.g. P50)	✓	✓	✓	✗	✓	✗
		High (e.g. P90)	✓	✓	✓	✓	✓	✗
	Value at Risk		✓	✓	✓	✓	✓	✗
Reference class forecasting	Expected value		✗	✓	✓	✓	✓	✓
	Probability pricing	Moderate (e.g. P50)	✗	✓	✓	✗	✓	✓
		High (e.g. P90)	✗	✓	✗	✓	✓	✓
	Value at Risk		✗	✓	✗	✓	✓	✓
Characteristics of complete risk measurement			✓	✓	✓	✓	✓	✓

Source: Grattan analysis.

Table A.2: Completeness analysis of prominent guidelines

		Reliable		Comprehensive			
		Tailored	Objective	Moderate	Extreme	Known	Unknown
C'wlth	Australian Transport Assessment and Planning [†]	✓	✓	✓	✓	✓	*
NSW	Principles and Guidelines for Economic Appraisal of Transport Investment Initiatives [‡]	✓	✓	✓	✓	✓	✓
Vic	High value high risk guidelines [‡]	✓	✓	✓	✓	✓	✓
Qld	Project Cost Estimating Manual [¶]	✓	✓	✓	✓	✓	✓
SA	Estimating Manual [§]	✓	✗	✓	✓	✓	✗

Notes: * indicates that the recommended use of Monte Carlo simulation to estimate P50 and P90 costs for full business cases of large projects gets part way towards accounting for unknown risks, meriting the ✓ status. However, this criterion is not satisfied for small initiatives or rapid CBAs, where deterministic probability pricing is recommended.

† recommend that expert judgement is used to estimate the expected value of cost risks, P50 and P90 costs for rapid CBAs and small initiatives, and to conduct sensitivity analysis. If the project is deemed significant enough, full business cases should use Monte Carlo simulation to estimation P50 and P90 costs.

‡ recommend expert judgement be used to calculate the expected value of cost risk and conduct sensitivity analysis. Monte Carlo simulation is also recommended for estimating P50 and P90 costs.

¶ recommend that expert judgement is used to conduct sensitivity analysis, and that Monte Carlo simulation is used to estimate P50 and P90 costs.

§ recommend that expert judgement is used to estimate P50 and P90 costs.

Source: Australian risk management guidelines; Grattan analysis

Even if unknown risks were accounted for and extreme risks were anticipated, the current approaches employed to measure risk do not consistently evaluate **extreme risks**. Over the last 15 years, the expected value of cost overruns was 24 per cent of initial project costs – a figure which is approximately equivalent to the 26 per cent average difference observed between P50 and P90 costs. This extreme asymmetry in the distribution of cost outcomes is in line with previous conclusions of the transport cost overruns literature.⁸² It also makes clear that measures of the costs of extreme outcomes cannot be inferred from extreme quantiles like P90 estimates. This is because the worst ten percent of cost overruns take a huge range of values, which means that the expected value of cost overruns could readily be above or below P90 costs.

Risk management guidelines need to account for the likely costs of extreme risks, not just their likely prevalence. Although the expected value doesn't assess extreme risks exclusively, it is a critical component of risk measurement because it is the only common tool which accounts for the likely cost of these risks. In other sectors like finance, Value at Risk (VaR) – the expected value of extreme risks above a particular threshold – is used to measure the costs of extreme risks. Given that 90 per cent of the value of Australia's cost overruns over the last 15 years has been attributable to extreme cost overruns, adopting such a rigorous treatment of extreme risks seems warranted.

Finally, most of the guidelines summarised in Table A.2 on page 51 rely on sensitivity analysis and Monte Carlo simulation to incorporate **objective information** into cost estimates. However, these approaches only satisfy these objectives if they employ high quality objective information. The following section reviews the information provided for the execution of these approaches, and identifies that the quality of the objective data provided for implementing these tools is generally very poor. There is substantial scope for the accuracy of existing risk measurement practices

82. Love et al. (2013); and Flyvbjerg (2016a).

Figure A.5: No state consistently provides sufficient information for high quality risk measurement

Yellow = approach is recommended

Orange = approach is recommended, but with insufficient information to be properly implemented

Red = approach is not recommended

	Commonwealth	NSW	VIC	QLD	WA	SA
Expected value	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Sensitivity analysis	Yellow	Yellow	Orange	Yellow	Orange	Orange
Probability pricing	Orange	Orange	Red	Yellow	Red	Orange
Reference class forecasting	Orange	Orange	Orange	Orange	Red	Yellow

Source: See Table A.3 on page 57; Grattan analysis.

to be improved through the use of high quality data on historical cost outcomes.

A.2.3 Insufficient information is provided

Perhaps the most troubling shortcoming of Australia's current risk measurement guidelines is that they commonly do not provide sufficient information to realise the advantages of the methodologies that they recommend.

Figure A.5 on the following page shows that expected value is the only approach which is consistently recommended with sufficient information

to be implemented, and this is largely because calculation of the expected value of project risks is typically entirely based on project-specific information. The quality of risk measurements obtained using the other key risk measurement tools are significantly impeded by the lack of data.

For example, **sensitivity analysis** is a valuable tool for understanding the external drivers of cost uncertainty. However, only 43 per cent of guidelines which recommend sensitivity analysis specify the variables that should be subjected to sensitivity analysis and the range of values these variables should be expected to take. In the absence of this information, there is opportunity for project proponents to retrofit their choices of variables and ranges of variation in order to achieve an acceptable level of cost uncertainty. Because of this, guidelines should suggest ranges for sensitivity analysis, or recommend that the sensitivity ranges specified in another set of guidelines are used.⁸³

Even more problematic is that some guidelines recommend that **reference class forecasting** be employed, but do not provide data or key statistics on any reference classes. Reference class forecasting is the practice of incorporating the rate of cost overruns observed historically on like projects into a project's cost estimate. Consequently, reference class forecasting cannot be implemented to any degree without high quality data on historical cost outcomes.

Yet this is what some of Australia's risk management guidelines demand of project proponents. For example, the cost benefit analysis guidelines of Queensland Treasury's *Project Assessment Framework* recommend that cost estimates are adjusted for optimism bias using empirical evidence that is relevant to the project's type.⁸⁴ However, they

do not provide any such evidence and, to the best of our knowledge, such empirical evidence is not readily available.

Similarly, the Commonwealth Department of Infrastructure and Regional Development's *Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction* identifies that reference class forecasting should be used to counteract optimism bias, and refer to the United Kingdom's reference class forecasting uplift rates.⁸⁵ However, these uplift rates are not appropriate for use on Australian cost estimates because they are designed to offset the average magnitude of cost overruns observed on British projects, relative to British cost estimation practices.

A similar circumstance befalls **probability pricing**. Probability pricing is the practice of identifying the cost under which a project is expected to be completed with a given probability. Accordingly, probability pricing requires knowledge of the distribution of a project's cost risks. Probability pricing can be conducted either:

- *probabilistically*, which involves estimating the distribution of risks on a specific project from estimates of its component parts,⁸⁶ or
- *deterministically*, which involves applying standard uplift rates that are – like reference class forecasting – derived from historical analysis of completed projects.⁸⁷

More than 80 per cent of guidelines on probability pricing recommend that the probabilistic approach to probability pricing is employed, as the validity of the deterministic approach under active debate.⁸⁸

83. The Australian Transport Assessment Planning Guidelines provide a set of sensitivity ranges that could serve as a common point of reference, as the Austroads sensitivity ranges have done in the past. See Queensland Department of Transport and Main Roads (2011, p. 27).

84. Queensland Treasury (2015, p. 25).

85. Department of Infrastructure Transport Regional Development and Local Government (2008, Appendix 7).

86. For example, Queensland Department of Transport and Main Roads (2015).

87. For example, South Australian Department of Treasury and Finance (2014).

88. Currently, institutions like Infrastructure Australia (Infrastructure Australia (2016a, p. 36)) and Queensland's Department of Main Roads (Queensland Department

However, there appears little grounds to claim that the probabilistic approach, as currently practiced, is any more scientific. This is because very few guidelines⁸⁹ provide any guidance to project proponents on the expected distribution of project risks, and these guidelines commonly overlook the most critical characteristic of the distribution of cost risk on transport infrastructure projects: that cost overruns are more likely and larger on average than cost underruns.⁹⁰

The observed distributions of construction project risks are actively being researched in academic circles.⁹¹ This research is important, as the specific probability prices estimated through Monte Carlo simulation are only as reliable as the assumptions on which they are based. In order to obtain reliable probability prices using a probabilistic methodology, the distributions of key project risks need to be reliably estimated and clearly communicated in probability pricing guidelines.

A.3 Risk management

While Australian jurisdictions appear to have good guidance on risk mitigation and ample, though flawed, guidance on risk measurement, there is a dearth of guidance on how remaining risks should be managed. This is problematic because the consequences of cost overruns can be moderated through good cost risk management.

of Transport and Main Roads (2015, p. 79)) assert that deterministic approaches to probability pricing are “invalid” and “inaccurate” while others still recommend its practice. For example, South Australian Department of Planning, Transport and Infrastructure (2015)).

89. Queensland Department of Transport and Main Roads (2015), Department of Infrastructure and Regional Development (2013) and Victorian Department of Treasury and Finance (2015) are honourable exceptions.

90. For further discussion and evidence, please see Appendix B.2.6 on page 70.

91. For example Love et al. (2012).

The following sections contrast the existing guidance and best practice on how to include risk when making investment decisions and how to manage contingencies.

A.3.1 Account for the remaining risk in investment decisions

Cost overruns are most problematic when they result in projects with benefits less than the costs being built at the expense of projects which promise higher returns.

It is true that project costs, and hence projects’ returns on their investments, will always be uncertain. However, when project risks are not priced into benefit cost ratios, returns on investments will routinely be lower than expected. This increases the probability that cost overruns will distort project selection.

The impact of cost overruns on project selection can be minimised by including the expected value of project risks in the cost estimates used for cost benefit analysis.⁹² While benefit cost ratios will still be more uncertain for risky projects than routine projects after this adjustment is made, the benefit cost ratios of risky projects will no longer be systematically biased in a way that makes projects appear more attractive than they really are. For this reason, it is critical that the costs used in cost benefit analyses include the expected value of project risks.⁹³

Only the Commonwealth and NSW’s risk management guidelines⁹⁴ clearly recommend that the expected value of projects risks should be incorporated in the costs estimates used for benefit cost analysis.

It is not reasonable to assume that incorporation of the expected value of risks into cost estimates is implicitly expected by guidelines which do not

92. Bureau of Transport and Regional Economics (2005).

93. Ibid.

94. Australian Transport Assessment and Planning (2016); and Transport for New South Wales (2013).

comment on the type of costs that should be employed in cost benefit analysis. This is because previous Australian research regarding the treatment of risk in cost benefit analysis has found that there is substantial confusion on this matter.⁹⁵

The various guidance documents provided on cost benefit analysis for transport infrastructure projects in Australia should be amended to clearly recommend that the expected value of project risks be included in the costs employed in cost benefit analysis.

A.3.2 Manage project risks in a cost efficient manner

Cost overruns are also problematic when they inflict unanticipated shocks on government budgets. In order to protect against this, it is routinely advised that project budgets are accompanied by contingency funds.

However, this important component of risk management appears to be largely governed by rules of thumb.⁹⁶ This conclusion is supported by the observations that the recommended size of contingencies varies widely across guidelines (Figure A.6 on the following page), and that the data underpinning guidelines' recommended contingency ranges is not routinely cited.

Even more problematic is the frequent absence of strict requirements for contingency funds to be held at the portfolio level. New South Wales is the only jurisdiction which provides clear, strategic advice on how contingency funds should be managed,⁹⁷ and Queensland appears to be the only state where there is a strict requirement for contingency funds to be managed at the portfolio level.⁹⁸

95. Bureau of Transport and Regional Economics (2005).

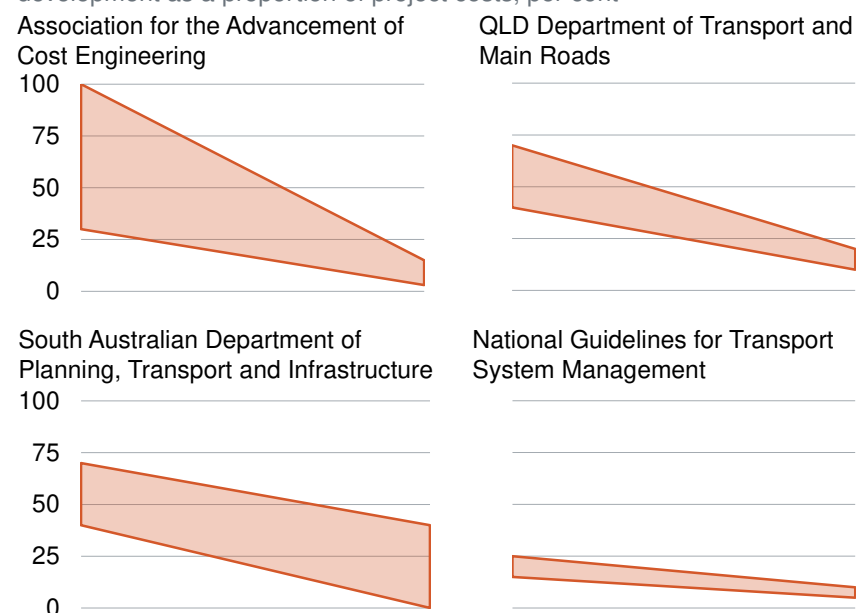
96. Love et al. (2014, p. 494).

97. Infrastructure New South Wales (2014).

98. Queensland Treasury (2015); and Government of Queensland (2015).

Figure A.6: The recommended size of contingency funds varies substantially across guidelines

Recommended contingency ranges at early and late stages of project development as a proportion of project costs, per cent



Notes: The contingency ranges cited in the National Guidelines for Transport System Management refer specifically to road projects specifically, and are anticipated to be too conservative for projects which are one-off in nature.

Source: Advancement of Cost Engineering (2016), Queensland Department of Transport and Main Roads (2015), South Australian Department of Planning, Transport and Infrastructure (2015), Australian Transport Council (2006c); Grattan analysis.

It should be noted that in the absence of such protocols, there are clear incentives for contingencies to be managed at the project level. This is because changes to project budgets that involve state treasuries increasing projects' budget allocations are open to public scrutiny. Consequently, project management teams are subject to lower reputational risk when contingency funds are included within initial budget allocations and managed at the project level.

Section 5.2.2 on page 40 identified that contingency funds can be three times more cost effective when managed at the portfolio level. For this reason, it would be desirable for all states to adopt a stringent practice of managing contingency funds at the portfolio.

A.4 Reviewed Australian risk management guidelines

This appendix, and the conclusions of the report that are founded upon its analysis, are based upon a thorough review of all the key documentation on cost estimation and risk management which we could identify as publicly available. Table A.3 on the following page lists the guidelines reviewed.

The high level review of the quality of risk management guidelines presented as Figure A.1 is based on the criteria listed in Table A.5 on page 61. The guidelines which had most bearing on the rating allocated for each component of risk management by state are listed in Table A.4 on page 60. These guidelines are those that were perceived to go the furthest towards satisfying the ratings' criteria, or were the most conspicuous examples of the failure of a jurisdictions' guidelines to do so.

Table A.3: List of guidelines

Coverage	Agency	Guideline
Commonwealth / national	Australian Transport Council	The National Guidelines for Transport System Management in Australia (NGTSM)
	Austroads	Guide to Project Evaluation
	Bureau of Infrastructure, Transport and Regional Economics	Overview of project appraisal for land transport Report 110: Risk in Benefit Cost Analysis
	Comcover	AS/NZS ISO 31000:2009 Risk Management - Principles and Guidelines
	Council of Australian Governments	National Partnership Agreement on Land Transport Infrastructure Projects
	Department of Finance and Administration	Handbook of Cost Benefit Analysis
	Department of Infrastructure and Regional Development	Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction National Framework for Traditional Contracting
	Infrastructure Australia	Better Infrastructure Decision Making: Guidelines for Making Submissions to Infrastructure Australia's Infrastructure Planning Process Assessment Framework Business Case Assessment Template
	Standards Australia	HB 158:2010 Handbook: Delivering assurance based on ISO 31000:2009 Risk management - Principles and guidelines HB 327:2010 Handbook. Communicating and consulting about risk
NSW	Infrastructure New South Wales	Infrastructure NSW Contingency Management Guidebook
	New South Wales Treasury	Guidelines for Economic Appraisal: Policy and Guidelines Paper Guidelines for Financial Appraisal: Policy and Guidelines Paper Risk management toolkit Online risk assessment tool Gateway toolkit Gateway workbooks
	Transport for New South Wales	Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives 30-ST-164 Transport Enterprise Risk Management (TERM) Standard

Continued on next page

Table A.3: List of guidelines (continued)

Coverage	Agency	Guideline
Queensland	Building Queensland	Business case development framework: Cost benefit analysis guide
	Government of Queensland	Financial and Performance Management Standard 2009
		Queensland Procurement Policy
	Queensland Department of Housing and Public Works	Capital Works Management Framework
	Queensland Department of Transport and Main Roads	Cost-benefit analysis manual: Road projects
		Project Assurance Framework
		Project Cost Estimating Manual
		OnQ Business Case Template
	Queensland Treasury	A guide to risk management
		Financial Accountability Handbook
Victoria		Gateway review processes
		Project Assessment Framework: Policy overview
		Project Assessment Framework: Business Case Development
		Project Assessment Framework: Cost-Benefit Analysis
		Project Assessment Framework: Deliver Service
	VicRoads	Investment Evaluation Framework
	Victorian Department of Treasury and Finance	Victorian Government risk management framework
		Economic Evaluation for Business Cases :Technical guidelines
		Business Case Template
		High value high risk guidelines
South Australia		Gateway review process - guidance materials
	Victorian Managed Insurance Authority	Practice Guide
	Victorian Transport Policy Institute	Transport Cost Benefit Analysis: Techniques Estimates and Implications.
	Government of South Australia	Risk management policy statement
		Construction Procurement Policy Project Implementation Process
	SA Department of Planning Transport and Infrastructure	Estimating Manual: Road and rail projects
	SA Department of Treasury and Finance	Guidelines for the Evaluation of Public Sector Initiatives
	SA State Procurement Board	Risk Management Guideline

Continued on next page

Table A.3: List of guidelines (continued)

Coverage	Agency	Guideline
Western Australia	WA Department of Education	RiskBase
	WA Department of Finance	Risk workbook template, Goods and Services Templates, Business Case Template, Guides and Conditions of Contract
	WA Department of Finance Government Procurement	Procurement practice guide Gateway business case workbook Gateway: Helping your projects succeed
	WA Treasury	Options Analysis Model Strategic Asset management Framework: Business Case

Table A.4: Key risk management guidelines underpinning the ratings allocated in Figure A.1 on page 44

	Risk minimisation		Risk measurement	Ongoing risk monitoring	
	Mitigate avoidable risks	Reduce estimation error	Measure the remaining risk	Account for the remaining risk	Manage the remaining risk
C'th	Infrastructure Australia Business Case Template	Best Practice Cost estimation Standard for Publicly Funded Road and Rail Construction	Australian Transport Assessment and Planning Guidelines	Australian Transport Assessment and Planning Guidelines	Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction
NSW	Risk Management Toolkit	N/A	Transport for NSW Principles and Guidelines for Economic Appraisal of Transport Investment Initiatives	Transport for NSW Principles and Guidelines for Economic Appraisal of Transport Investment Initiatives	Contingency management Guidebook
Vic	Victorian Managed Insurance Authority Practice Guide	N/A	Economic Evaluation for Business Cases: Technical guidelines	Department of Treasury and Finance Business Case Template	High Value High Risk Gateway Review Process
Qld	Project Cost Estimating Manual	Project Cost Estimating Manual	Project Cost Estimating Manual	Project Assessment Framework Business case development	Project Cost Estimating Manual
WA	Gateway business case workbook	N/A	RiskBase	Strategic Asset Management Framework	Gateway business case workbook
SA	Procurement risk management plans	South Australian Department of Planning Transport and Infrastructure Estimating Manual	South Australian Department of Planning Transport and Infrastructure Estimating Manual	South Australian Department of Planning Transport and Infrastructure Estimating Manual	South Australian Department of Treasury and Finance Guidelines for the Evaluation of Public Sector Initiatives

Source: See full list of guidelines in Table A.3 on page 57.

Table A.5: Criteria underpinning the ratings of jurisdictions' risk management guidelines presented in Figure A.1 on page 44

Topic	Rating	Criteria
Mitigate avoidable risks	Sufficient	At least one set of guidance recommends the use of risk matrices to identify and log preventative measures by risk. It would be ideal, but not necessary, for some guidelines to also identify key risks which should be mitigated and provide recommendations of how to do so.
	Incomplete	N/A. No external information is required to implement the risk measurement strategies deemed to be sufficient.
	Poor	No guidelines. Recommends the use of risk matrices to identify and log preventative measures by risk.
Reduce estimation error	Sufficient	At least one set of guidelines specifies the amount of detail (in terms of the cost estimation methodology, work breakdown schedule) for each stage of a gateway process. It would be ideal, but not necessary, for the appropriate size of contingency funds for estimates of each level of certainty to also be stated.
	Incomplete	N/A. No non-standardised external information is required to implement the cost estimation practices deemed sufficient.
	Poor	No guidelines specify the amount of detail (in terms of the cost estimation methodology, work breakdown schedule) for each stage of a gateway process.
Manage remaining risk	Sufficient	At least one set of guidelines specifies a "complete" approach to risk measurement, where "complete" is defined as in Appendix A.2.2 on page 48.
	Incomplete	At least one set of guidelines specifies a "complete" approach to risk measurement, but does not provide sufficient information for the approach to be properly implemented.
	Poor	No guidelines recommend a "complete" approach.
Account for risk in investment decisions	Sufficient	At least one set of guidelines explicitly states that the cost estimates used in cost benefit analysis should be the expected value, not the median (P50) or P90, costs.
	Incomplete	At least one set of guidelines alludes to the importance of accounting for cost risk in cost benefit analysis.
	Poor	No guidelines mention the treatment of cost risk in cost benefit analysis.
Manage risk throughout construction	Sufficient	At least one set of guidelines relates contingency estimation to the amount of risk accommodated in the base cost estimate, and at least one set of guidelines makes explicit the advantages of managing contingency funds at the portfolio level.
	Incomplete	At least one set of guidelines requires the use of contingency funds, without providing sufficient guidance.
	Poor	No guidelines require the use of contingency funds.

B Methodological appendix

The conclusions drawn in this report are founded on thorough statistical analysis of transport projects completed in Australia since 2001. This appendix provides the supporting details of the data sources and analysis contained in this report.

B.1 Datasets used to measure cost overruns in this report

The analysis contained in this report is based on two unique datasets. First, this report uses a time series dataset built from the archives of the Deloitte Access Economics Investment Monitor which tracks the evolution of project costs over time for all Australian transport infrastructure projects constructed since 2001.

Since 2001, Deloitte Access Economics has routinely screened government budgets, announcements by private companies, the media, and other publicly available data sources to produce a quarterly snapshot of expected investment plans for each sector, including transport. Grattan Institute has linked the quarterly releases of the Investment Monitor from 2001 to 2015 to form a panel dataset that tracks the value and degree of commitment to all publicly announced investment projects from first announcement through to completion.

The analysis also relies on a smaller but far more detailed dataset compiled by Grattan Institute which investigates the circumstances surrounding the cost overruns on 51 of these projects.⁹⁹ This dataset has been manually collected for the express purpose of understanding the dynamics of cost overruns for transport infrastructure projects and the characteristics of affected projects.

99. This dataset is henceforth referred to as the Grattan dataset.

B.1.1 Adjusting expected project costs for inflation

Both these datasets are based on public sources that report project budgets in terms of nominal dollars at the time the underlying sources were published. In order to compare projects that occur in different periods, expected and observed project costs in each dataset have been adjusted for inflation, using the Australian Bureau of Statistics' construction price index.¹⁰⁰

We assume that the distribution of project costs across time is the same for all projects and convert nominal outturn costs to 2016 dollars from the middle year of the period during which each project was under construction. While only approximate, this approach is sufficient for controlling for the effect of inflation at the aggregate level under the assumption that the distribution of project costs over the construction period does not vary with time. Importantly, the inflation adjustment procedure does not affect the estimates of the size of cost overruns in this report, only the relative size of projects that are constructed in different periods.

B.1.2 Measuring cost overruns

We measure cost overruns as the percentage change in project costs over a given period, as a proportion of a project's initial cost. Project costs are defined as the total cost to the public sector of designing and constructing a given asset, and so include public sector project management costs outside of the project contract and exclude any costs incurred beyond the contract price by the contractor.

100. ABS (2016).

We consider overruns on these costs in relation to three project stages: from announcement with a cost estimate but prior to a budget commitment; between a formal budget commitment by an Australian government and the start of construction; and during construction. These project stages correspond to the descriptions of projects' maturity associated with each cost estimate in the Investment Monitor dataset.

B.1.3 Comparing the two datasets

The key differences between the Investment Monitor and smaller Grattan datasets are the accuracy of the cost estimates for projects, and the number of projects that they contain.

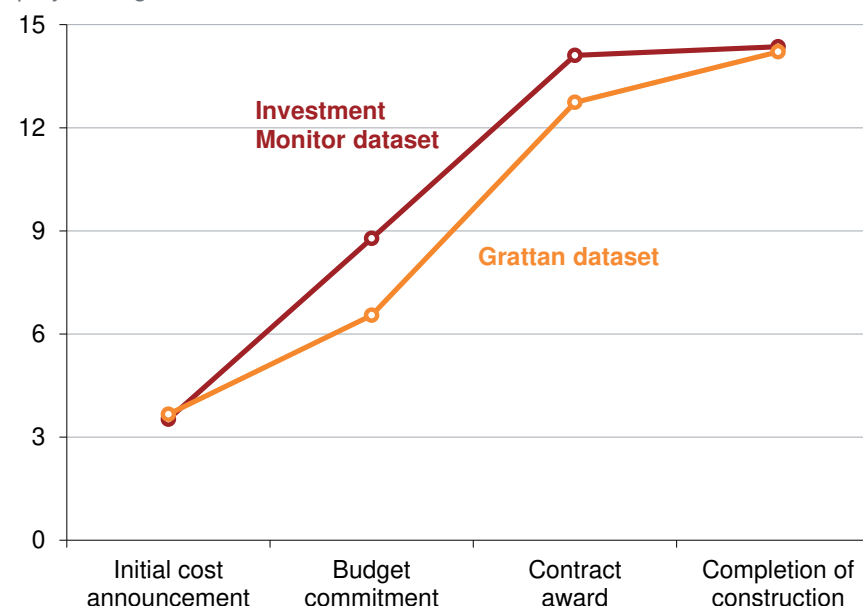
In order to monitor all transport projects from conception to completion, Deloitte Access Economics has employed a routine data collection methodology which involves scanning government budgets and media sources for mentions of the projects of interest. This approach is efficient and standardised, but is arguably less precise as the details and history of each project cannot be examined in detail every time the database is updated for a particular project.

The Investment Monitor is routinely employed for academic analysis of investment in Australia. In support of this analysis, studies have been undertaken into the quality of the dataset, and have found the dataset to be an unbiased record of investment in Australia's resource sector.¹⁰¹

Seeking to ascertain the quality of the Investment Monitor's cost estimates for transport projects, we compared the cost estimates recorded in this dataset against the small sample of carefully investigated transport infrastructure projects that make up the Grattan dataset. Figure B.1 compares the Investment Monitor and Grattan datasets' estimates of the total value of the projects included in the Grattan dataset. Although the Grattan dataset only covers a limited number of projects, the high level

Figure B.1: Cost estimates obtained from the Investment Monitor data appear reliable overall

Total value of the portfolio of projects contained within the Grattan dataset by project stage, \$billion



Source: Investment Monitor; Grattan dataset; Grattan analysis.

101. Clements et al. (2016).

of similarity between the value of the Investment Monitor and Grattan datasets' portfolios at each project stage provides assurance that the Investment Monitor dataset is unbiased. The comparability of the Grattan and Investment Monitor datasets also holds at the individual project level, as there is no statistically significant difference between the average cost change on individual projects observed across the Grattan and Investment Monitor datasets.¹⁰²

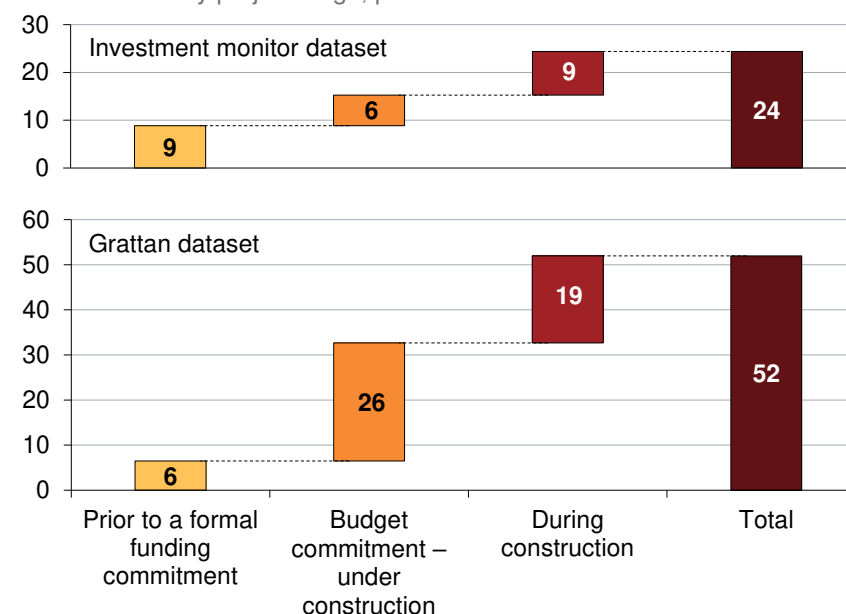
Despite this similarity, we expect that the average magnitude of cost overruns observed in the Investment Monitor will be substantially lower than observed in the Grattan dataset. This is because the Investment Monitor considers all projects valued over \$20 million, the Grattan dataset only includes projects valued above \$100 million and project size has been found in the cost overruns literature to be a consistent predictor of the size of cost overruns¹⁰³. In line with this expectation, we observe higher cost overruns across the Grattan dataset than the Investment Monitor dataset (Figure B.2).

B.1.4 Treatment of outliers

The Investment Monitor dataset contains a number of projects with very large differences between expected and actual costs. The quality of the cost estimates for these projects is dubious and difficult to confirm because not all of the sources underpinning the Investment Monitor dataset are still publicly accessible, and the search cost associated with finding the sources for these data points is high. For this reason, we take a conservative approach and exclude the 56 projects with overruns that are greater than the largest overrun observed in the Grattan dataset

Figure B.2: Cost overrun by project stage in Investment Monitor and Grattan datasets

Cost overruns by project stage, per cent



Notes: A critical difference between these datasets is that the Investment Monitor dataset contains all projects valued above \$20 million, whereas the Grattan dataset only contains projects valued above \$100 million.

Source: Investment Monitor; Grattan dataset; Grattan analysis.

102. The t-distribution critical statistic of the difference between the two means is 0.35, far lower than the threshold of 1.68 required for statistical significance at the 90 per cent level of confidence with a sample of this size.

103. Flyvbjerg et al. (2004); Koushki et al. (2005); and Anastasopoulos et al. (2012).

(520 per cent of project value) or underruns greater than 50 per cent of project value.¹⁰⁴

B.1.5 Missing data

A second notable characteristic of the Investment Monitor is that projects enter the Monitor at different levels of maturity, ranging from “possible” to “under construction”. This results in some projects missing cost estimates for the early project stages. Where this is the case, we assume that no cost overrun occurred prior to the project’s first appearance in our dataset.

As discussed in Section 1.2, a manual check of the history of 51 projects indicated that this assumption is conservative – 37 per cent of projects which were missing data on early cost estimates experienced public overruns during the unobserved period – a proportion only marginally lower than the 51 per cent of projects with early cost estimates.

This indicates that the missing data in the Investment Monitor dataset is associated with unobserved cost changes in some cases, as well as the absence of early cost estimates in others. Consequently, cost overruns may indeed be closer to the upper bound than the lower bound presented in Figure B.1 on page 63. As this report’s analysis assumes that no cost overrun occurred where not observed directly, we note that its conclusions are conservative.

B.2 Analysing cost overruns

The key questions that we use these datasets to answer are how big cost overruns are in Australia, at what period in the project lifecycle cost overruns occur and what factors are associated with larger overruns and

project cancellation. We also investigate the efficiencies associated with managing contingencies at the portfolio level, the distribution of cost overruns assumed in risk measurement guidelines and the average difference between P50 and P90 cost observed in the Investment Monitor sample. This section details the methodologies underpinning each of these analyses.

B.2.1 Magnitude of cost overruns

We measure the average magnitude of cost overruns using a weighted arithmetic mean of the size of cost overruns, where the weights are defined as

$$w_i = \frac{C1_i}{\sum_{i \in N} C1_i}$$

where $C1$ denotes the initial project cost and each project is identified by i in the set of completed projects, N .

This weighting scheme places greater weight on projects that make up a greater share of the overall infrastructure budget.

The key advantage of this approach is that it allows our cost overrun indices to be interpreted as the percentage increase in expected infrastructure expenditure incurred across the portfolio between two project stages, as

$$CO_{12} = \frac{1}{|N|} \sum_{i \in N} \frac{C2 - C1}{C1} \times \frac{C1_i}{\sum_{i \in N} C1_i} = \frac{\sum_{i \in N} (C2_i - C1_i)}{\sum_{i \in N} C1_i}.$$

It should be noted that the estimates obtained through a weighted arithmetic mean of this kind and the unweighted arithmetic mean commonly used elsewhere in the literature is trivial – only 2 per cent.

104. Greater than 50 per cent is a generous definition of outlying underrun, as the largest underrun observed in the Grattan dataset is only 34 per cent of initial project value.

Using this weighting, the cost overruns are estimated as weighted arithmetic means defined by:

$$\begin{aligned}
 CO_{12} &= \frac{1}{|N|} \sum_{i \in N} \frac{C2_i - C1_i}{C1_i} w_i \\
 CO_{23} &= \frac{1}{|N|} \sum_{i \in N} \frac{C3_i - C2_i}{C1_i} w_i \\
 CO_{34} &= \frac{1}{|N|} \sum_{i \in N} \frac{C4_i - C3_i}{C1_i} w_i \\
 CO_{14} &= \frac{1}{|N|} \sum_{i \in N} \frac{C4_i - C1_i}{C1_i} w_i \\
 &= CO_{12} + CO_{23} + CO_{34}
 \end{aligned}$$

Where $C1_i$ represents project i 's first announced cost, $C2_i$ represents its first budget commitment cost, $C3_i$ represents its first cost when under construction and $C4_i$ represents its final cost.

B.2.2 Dependence between cost overruns over time

We partner this aggregate summary of cost overruns with analysis of the linear dependence between cost overruns over time. To do so, we estimate the Pearson coefficient between the indices CO_{12} and CO_{23} , and CO_{23} and CO_{34} , and ascertain the significance of these correlations at the 10 per cent level of confidence through comparison to Chi-Squared critical values.

This allows us to draw conclusions regarding whether individual projects are more or less likely to experience an overrun in a given period if it experienced an overrun in the previous period. We complete this analysis separately for each cohort, as defined by the project's maturity when the first cost estimate is announced.

The Pearson coefficients were defined as:

$$\rho_{t, t+1} = \frac{\sum_{i \in N} \left[\left(CO_t - \frac{1}{|N|} \sum_{i \in N} CO_t \right) \left(CO_{t+1} - \frac{1}{|N|} \sum_{i \in N} CO_{t+1} \right) \right]}{\sqrt{\sum_{i \in N} \left(CO_t - \frac{1}{|N|} \sum_{i \in N} CO_t \right)^2} \sqrt{\sum_{i \in N} \left(CO_{t+1} - \frac{1}{|N|} \sum_{i \in N} CO_{t+1} \right)^2}}$$

Where CO_t and CO_{t+1} refer to cost overruns incurred over the consecutive project stages t = "possible or under consideration" to "committed", "committed" to "under construction", "under construction to completed".

B.2.3 Causes of cost overruns

We also use regression analysis to investigate the relationship between cost overruns at each project stage and independent variables that describe the characteristics of each project and its appraisal process. This analysis is completed in two stages. First, we use a logit model to examine the correlation between our independent variables and the probability that a project experiences a cost overrun of any size. Following this, we model the magnitude of cost overruns where a cost overrun occurred using a log-linear model.

The logit model of the probability of cost overruns occurring is specified as:

$$\text{logit} (1(CO_t > 0)) = \beta_0 + \beta_1 X_1 + \dots + \beta_K X_K + \varepsilon$$

The log-linear model of the magnitude of cost overruns, if they occur, is specified as:

$$\log \left(\frac{C_{t+1} - C_t}{C_1} \mid C_{t+1} > C_t \right) = \beta_0 + \beta_1 X_1 + \dots + \beta_K X_K + \varepsilon$$

Where $\{X_1, \dots, X_K\}$ are independent variables, ε is a zero-mean random error term, and $t \in \{\text{"possible or under consideration"} \text{ to "committed"}, \text{"committed"} \text{ to "under construction"}, \text{"under construction"} \text{ to "completed"}\}$.

Cost overruns are also expected to be partially attributable to scope changes. We assessed the contribution of this cause by thoroughly investigating publicly available evidence of scope changes on the 51 projects contained within the Grattan dataset. We defined scope changes as substantive changes to an asset's functionality. This definition excludes quality improvements because project benefits cannot be assumed to increase alongside costs to the same extent as with functional improvements.

Where scope changes were expressed as a proportion of the total asset – such as road being made “20 per cent longer”, the value of scope changes were estimated by the corresponding proportion of the project costs prior to the scope change. Where the timing of scope changes was made explicit, the value of cost overruns was estimated by the value of all cost overruns incurred during the project stage when the scope change was reported to have occurred. Using this methodology, we found that 11 of cost overruns of cost overruns were attributable to scope changes.

The regression tables for both sets of analysis are in Tables B.1 to B.2 on pages 68–69.

The regression was performed using R and used the packages `mf` and `logistf`, among others.¹⁰⁵ All R packages used were entered in the bibliography using `write_bib` from the `knitr` package.¹⁰⁶

105. Fernihough (2014); and Heinze et al. (2013).

106. Xie (2015).

B.2.4 Survival analysis

In addition to examining the size, timing and causes of cost overruns, we investigated the frequency with which projects were cancelled and the relationship between cost overruns and project cancellation.

Project cancellation rates for each stage were calculated as the number of projects that exited the dataset at each stage, as a proportion of the number of projects with cost estimates recorded for that stage.

We also estimated the appropriate overall rate of cancellation, by calculating the proportion of the 39 business cases for transport infrastructure published by Infrastructure Australia by the 12th of February 2016 which would have had benefit cost ratios less than 1 if project costs increased by the average amount observed across projects in the the Investment Monitor.

The overall cancellation rate of 35 per cent observed across the Investment Monitor projects appears to be insufficient. This is because, given the observed distribution of the Infrastructure Australia business cases, even a two per cent reduction in the average benefit cost ratio would mean that some projects with benefit cost ratios below one would not be cancelled, and there are numerous reasons to suspect that this is the case.

For instance, the benefit cost ratios of cancelled projects are likely to be worse than the 39 projects that had undergone an advanced level of planning and voluntarily submitted their business cases for publishing. It is also reasonable to suspect that benefit cost ratios are overestimated by more than 2 per cent on average, as numerous studies have found that estimates of project benefits are routinely optimistic.¹⁰⁷ Finally, the business case for completing projects with benefit cost ratios that are

107. Flyvbjerg (2016b).

Table B.1: Results of logit regression with instance of cost overrun in given period as dependent variable

Feature	First cost estimate to final cost estimate		Prior to budget commitment		Budget commitment to start of construction		During construction	
	Marginal effect	signif.	Marginal effect	signif.	Marginal effect	signif.	Marginal effect	signif.
Announced prematurely	0.13	*			0.02		0.11	*
Days pre-construction (log)	0.04	***	0.11	***	0.08	*	−0.02	
State								
Queensland	−0.13	**	−0.07	*	0.05		−0.17	***
(small state)	−0.00		0.15		0.16		−0.01	
Victoria	−0.19	***	−0.09	***	−0.06		−0.19	***
WA	−0.06		−0.02		0.12		−0.12	*
Road	0.05		−0.09		−0.04		0.03	
Constructed post-GFC	−0.21	***	−0.04		−0.17	***	−0.14	**
Cost (real) when construction commenced	0.06	***	0.07	***	0.03		0.01	
Announced within 180 days of an election	−0.02		0.37	*	−0.12	**	0.03	

*Notes: Marginal effects of independent variables are defined relative to the reference group of rail projects built in New South Wales. *, ** and *** indicate that a marginal effect is significant at the 10%, 5% or 1% levels of significance.*

Source: Investment Monitor; Grattan analysis.

Table B.2: Results of log-linear regression with instance of cost overrun in given period as dependent variable

Feature	First cost estimate to final cost estimate		Prior to budget commitment		Budget commitment to start of construction		During construction	
	Marginal effect	signif.	Marginal effect	signif.	Marginal effect	signif.	Marginal effect	signif.
(Intercept)	0.07		−0.78	**	−0.90	***	0.76	***
Announced prematurely	0.14	*			−0.13	*	0.05	
Days pre-construction (log)	0.00		0.08	*	0.13	***	−0.05	***
State								
Queensland	0.04		−0.06		0.05		0.01	
(small state)	0.09		0.12		0.06		0.02	
Victoria	−0.05		−0.09		−0.03		0.00	
WA	0.23	***	0.09		0.27	***	−0.03	
Road	0.19	***	0.02		0.07		0.06	
Constructed post-GFC	−0.02		0.12		−0.05		−0.06	
Cost (real) when construction commenced	0.03		0.07	**	0.06	**	−0.07	***
Announced within 180 days of an election	0.23	**	0.50	***	−0.32	***	0.17	**

Notes: Marginal effects of independent variables are defined relative to the reference group of rail projects built in New South Wales. *, ** and *** indicate that a marginal effect is significant at the 10%, 5% or 1% levels of significance.

Source: Investment Monitor; Grattan analysis.

only very marginally above one is contentious, given the existence of competing budget objectives.

We also investigate the relationship between cost overruns and project survival through a logit model of the probability of a project being cancelled at each stage, given the magnitude of cost overruns as incurred up to that point.

$$\text{logit}(\text{Survival}_t) = \beta_0 + \beta_1 CO_{1t} + \varepsilon$$

Where:

$$CO_{1t} = \frac{C_t - C1}{C1}$$

We find that the value of cost overruns incurred to date, expressed as a percentage of projects' initial value, does not have a statistically significant effect on the probability of a project being cancelled at any stage in a project's development.¹⁰⁸

B.2.5 Contingency analysis

Figure 5.1 on page 41 presents the financial advantages of managing cost risk at the portfolio level relative to the project level.

108. Tests of the hypothesis that cost overruns incurred up to a particular project stage affect the probability that a project is cancelled at that point were conducted relative to each project's first formal budget commitment, commencement of construction and completion. The p-values associated with this hypothesis at each each of these stages were 0.39, 0.38 and 0.8, respectively. As all of these p-values are substantially lower than the threshold of 0.1 required for significance at even the 10 per cent level, we find no evidence of cost overruns affecting the probability that a project will be cancelled.

The value of contingencies required to provide assurance that 90 per cent of projects will finish within budget has been estimated as the 90th quantile of the observed distribution of cost outcomes, using the median-unbiased sample quantile estimator.¹⁰⁹

To estimate the necessary size of a contingency fund to achieve this level of confidence *at the project level*, this analysis was conducted on the distribution of project's cost outcomes observed through the Investment Monitor.

To estimate the necessary size of a contingency fund to achieve this level of confidence *across the portfolio* of infrastructure projects, this analysis was conducted on a simulated distribution of average portfolio cost outcomes. This simulated distribution was constructed by bootstrapping 1000 sample means with replacement from the observed distribution of project outcomes.¹¹⁰

B.2.6 Distributional analysis

Box 7 on page 35 features a stylized representation of the distribution of cost overruns. This stylized distribution, presented as Figure B.3 on the next page below, is also employed in Figure A.2, Figure A.3 and Figure A.4 on page 52 of Appendix B.

The stylized representations of distribution of cost overruns features a slightly smaller kurtosis than the observed distribution of cost overruns. This modification was made so that the diagrams were easier to label clearly and a key characteristic of the distribution - the heaviness of its right tail – was more visible.

Figure B.4 on page 72 confirms that the stylized distribution employed is a fair representation of the underlying data. As emphasised in Box 7

109. Hyndman and Fan (1996).

110. Bootstrapping was completed using ordinary nonparametric simulation.

on page 35, the expected value of cost overruns falls far closer to the distribution's 90th percentile than its median. Though less visible than in the stylized distribution, the heaviness right tail of the observed distribution is notable: 17 percent of projects experienced cost overruns greater than the smallest cost underrun.

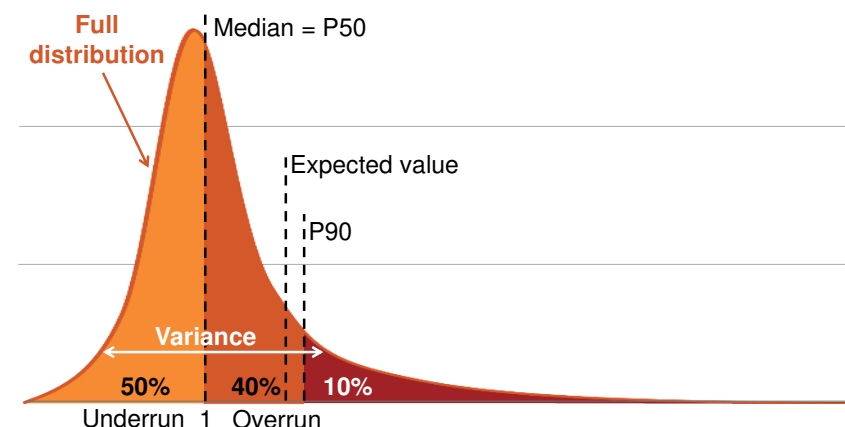
Figure 4.1 on page 29 and Figure A.4 on page 52 compare the distribution of observed cost overruns against an illustration of the distribution of cost overruns assumed in risk management guidance. The shape of this assumed distribution is founded upon two key observations.

Firstly, costs quoted in state budget papers are typically P75 - P90 costs. This implies that less than 25 per cent of projects are expected to overrun. For evidence of this practice see, for instance, that:

- Queensland Department of Transport and Main Roads' *Project Cost Estimating Manual* requires cost estimates to be P75 while initial designs are being completed,¹¹¹
- Transport for New South Wales' *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives* require P90 cost estimates to be used from the pre-tender stage,¹¹² and
- the Victorian submission to the Productivity Commission's inquiry into public infrastructure noted that P90 costs often form the budget against which a project's success is assessed.¹¹³

While both P50 and P90 cost estimates are required for requests for funding from the Commonwealth government,¹¹⁴ a review of the 23 project summaries published by Infrastructure Australia as of 23rd of

Figure B.3: Stylized probability distribution



Notes: The distribution of cost risk depicted is a stylized representation of the distribution of cost overruns observed in the Investment Monitor; see Appendix B.2.6 for details. This graph's illustrative purpose is to depict the relative distances between key points of the distribution

Source: Investment Monitor; Grattan analysis.

111. Queensland Department of Transport and Main Roads (2015, p. 12).

112. Transport for New South Wales (2013, p. 56).

113. Victorian Department of Treasury and Finance (2014, p. 42).

114. Department of Infrastructure and Regional Development (2013, p. 47).

October 2016 reveals that the cost estimates submitted for funding requests are P79, on average.

The second key observation is that risk management guidance commonly implies that cost risk is symmetrically distributed, either by specifically recommending that symmetric distributions should be used for Monte Carlo simulation or by not providing sufficient guidance on Monte Carlo simulation of asymmetric risks.

Very few of the reviewed guidelines provide any guidance to project proponents on the expected distribution of project risks,¹¹⁵ and symmetric distributions are commonly recommended and depicted in those that do.¹¹⁶

The honourable exception to this practice is the Victorian Department of Treasury and Finance's Economic Evaluation for Business Cases Technical guidelines for "High Risk High Value" projects, which clearly indicates that probabilistic probability pricing should assume that cost risks are asymmetrically distributed. However, even these technical guidelines do not go as far as to explain how to simulate asymmetric cost risk distributions.¹¹⁷

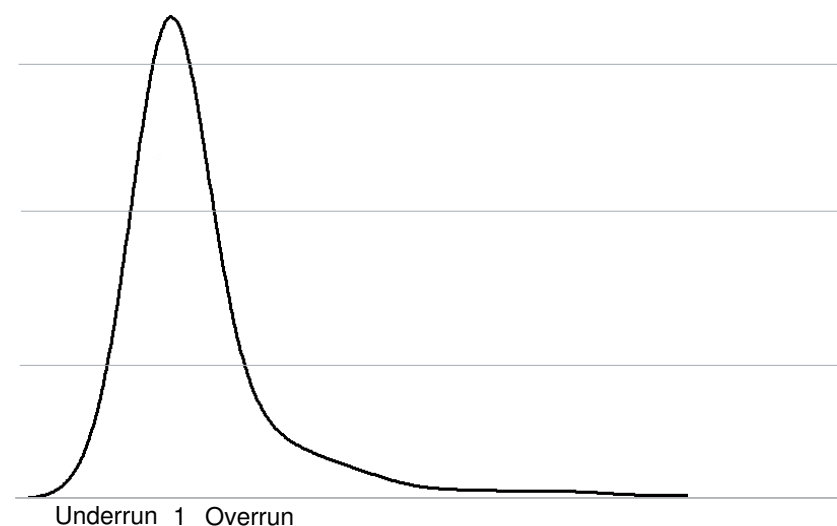
In these ways, most guidelines do not provide clear guidance on how to conduct Monte Carlo simulation, those that do mostly recommend

115. Of those reviewed, only Queensland Department of Transport and Main Roads (2015), Department of Infrastructure and Regional Development (2013), Transport for New South Wales (2013) and Victorian Department of Treasury and Finance (2015) provided detailed guidance.

116. See, for instance Queensland Department of Transport and Main Roads (2015).

117. It is reasonable to expect guidelines to provide this level of detail because multiple asymmetric distributions being readily available in the commonly used excel package for Monte Carlo simulation, *@RISK*. Instead, guidelines uniformly recommend the use uniform, triangular, PERT and other symmetric probability distributions, without guidance on how to design correlation matrices in such a way that Monte Carlo simulation from these distributions could produce an asymmetric risk distribution.

Figure B.4: Observed probability distribution



Source: *Investment Monitor*; Grattan analysis.

that risks be assumed to be symmetrically distributed and even those that recommend that risk is assumed to be asymmetrically distributed do not explain how to simulate an appropriate asymmetric risk distribution. Consequently, guidelines' general warnings regarding the perils of optimism bias are not supported by their recommended practices.

As the lower bound of the distribution is necessarily equal to or greater than zero,¹¹⁸ symmetric distributions that predict as little as 25 per cent of projects experiencing cost overruns must severely underestimate the likelihood and potential magnitude of extreme cost overruns. The assumed distributions presented in Figure 4.1 on page 29 and Figure A.4 on page 52 reflect this key characteristic.

In these ways, Australia's risk management guidelines suggest that cost risks are assumed to take a distribution not dissimilar to that depicted as the assumed distribution in Figure A.4. The observed distribution of cost overruns corroborates this conclusion, as the size and prevalence of the overruns observed are also consistent with the assumption of a distribution like that depicted in this figure. Specifically,

- the observation of an average cost overrun of 24 per cent is consistent with a the expected value of cost overruns being substantially underestimated, and
- the substantial underestimation of the difference, as a percentage of initial project costs, between P50 and P90 costs,¹¹⁹ is consistent with the length of the right tail of the distribution of cost risk being substantially underestimated,

118. As neither initial nor final project costs can be less than zero, cost overruns, as defined as the ratio of final and initial costs, have a zero lower bound.

119. The observed difference between P50 and P90 costs is 26 per cent, three times higher than the 9.2 per cent difference between P50 and P90 costs in the business cases assessed in Table 4.1.

as would be the case if assuming a distribution similar to the triangular distribution presented in Figure A.4. This indicates that, although no distribution of cost risks was consistently recommended, the distribution assumed on average in practice appears similar to the triangular distribution presented in Figure A.4.

B.2.7 Expected difference between P50 and P90 costs

We use projects' first cost estimates when classified as "committed" in the Investment Monitor to analyse the accuracy of the current probability pricing practices.

We pick this point in the Investment Monitor because it corresponds to the point that projects first receive a budget commitment, and this is the earliest point for which there is a clear requirement that probability pricing is employed.

The guidance regarding what type of probability price should be used in budget statements is inconsistent. Mostly, it is requested that P90 cost estimates are used as for budget estimates. However, in some cases budget estimates are use P75 costs. To allow for this variation in practices, we make the conservative assumption that budget estimates are all P75 estimates. Under the less conservative assumption that budgets contain P90 cost estimates, probability prices would be downwardly biased by an additional 15 percent.

Table B.3 on the next page reports the percentage of projects observed to have cost overruns greater than each estimated probability price. This comparison is founded on the assumption that budgeted costs are P75 cost estimates, which we know to be exceeded by 34 per cent of projects. This means that cost estimates that have been defined to be P75 costs should, on average, be P66 costs.

To identify the estimated probability prices for different levels of risk tolerance, we assumed that all probability price estimates are biased by the same amount, in the same direction.¹²⁰

That is, we know the P75 probability price estimate is downwardly biased by 9 percentage points because it is exceeded by 34 per cent, rather than 25 per cent, of observations. We invoke the assumption that this bias is consistent across the distribution implies, which implies that P50 estimates will be exceeded by 59 per cent of observations, rather than 50 per cent of observations, for example.

The final column of Table B.3 reports the the difference, as percentage of budget commitment project costs, between the P50 and other estimated probability prices. These figures have been calculated as the difference between the 90th and 50th quantiles of the observed distribution of final costs over budgeted costs, using the median-unbiased estimator of sample quantiles.¹²¹

This column reports that there is no difference between the P50 and P75 price, on average. This is because 57 per cent of projects finish exactly on budget, which means that there is no difference between most central quantiles. However, there is an increasingly large gap, as a percentage of initial project costs, between the P50 and the upper quantiles: the average P88 (equivalent to the expected value) is 21 per cent higher than the average P50 cost estimate, and the average P90 is 26 per cent higher than the average P50 estimate.

120. This is the most forgiving assumption that could be invoked regarding the average distance between each probability price under the current estimation methodology, as it is equivalent to assuming that the estimated probability prices were based off a probability distribution which takes the exact shape of the observed data.

It should be noted that this assumption goes a long way to explaining the deviance between the expected and observed difference between P90 and P50 costs. Current probability pricing methodologies would be substantially improved if they employed historical data like that analysed in this report.

121. Hyndman and Fan (1996).

Table B.3: Value of probability prices as proportion of initial cost

Estimated probability price	Difference between the P50 and other estimated probability prices [†]
P50	0 per cent
P75	0 per cent
P88	21 per cent
P90	26 per cent
P99	64 per cent

[†] As a per cent of projects' first budget commitment costs

Source: *Investment Monitor*; Grattan analysis

We draw two conclusions from this analysis. The first conclusion is that the expected value of cost overruns after budget commitments have been made is closer to a P90 cost estimate than a P50 cost estimate. This is based on the observation that the expected value of cost overruns after a budget commitment has been made is 21 per cent, and under the current probability price estimation methodology, and a 21 per cent cost uplift is equivalent to a P88 cost estimate.

Building on this finding, we also conclude that the average difference between P50 and P90 cost estimates as a percentage of budgeted project costs is approximately 26 per cent, under the current probability price estimation methodology. This is because, as budgeted cost estimates could also be interpreted as P50 cost estimates,¹²² the 26 per cent cost uplift required to convert a budget commitment cost estimate to a P90 cost estimate is also the appropriate uplift rate for converting a P50 cost estimate to a P90 cost estimate.

The uplift required to convert a P50 cost estimate to a P90 cost estimate may actually be far higher than this. Under an accurate probability

122. 34 per cent of projects finish above their budget commitment costs, but 91 per cent of projects finish on or above their budget commitment costs. This means that P9-P66 cost estimates should all be set equal to budget commitment costs.

pricing methodology, this difference could actually be as large as 64 per cent. We refrain from making this claim so as to only interpret observed outcomes in relation to the probability price estimates that prevailed when the cost outcomes were generated. This is because switching to an accurate probability price estimation methodology could change cost behaviour.

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