Three out of twelve

Australian CBA guidelines recognise resilience to natural disasters

2. Infrastructure investment – planning for resilience

Key points

- Annual investments in essential infrastructure are large, and are expected to grow substantially to meet the needs of our growing population and economy
- All levels of government and the private sector share responsibility for making infrastructure investment decisions. While decision-making processes vary according to the type of infrastructure being considered, the geographic location and the stakeholders involved, cost-benefit analysis (CBA) is a standard evaluation tool used to compare project options and prioritise investments
- While land use planning, building codes and engineering standards provide minimum requirements for resilience, assessing resilience during the initial project appraisal and approval processes, within a CBA, may demonstrate that it is cost-effective to build a higher level of resilience than is mandated
- The importance of resilience is recognised in Australia and internationally. However, there is limited guidance on how to incorporate resilience into CBAs for infrastructure projects. Only three of the 12 Australian CBA guidelines reviewed have reference to resilience
- Both the Productivity Commission (2014) and Infrastructure Australia (2015b) recognise the need for greater consideration of natural disaster risks and resilience when selecting projects and managing assets.

Between now and 2050, an estimated $1.1 trillion will be spent on building new critical infrastructure (see section 4.2). Given the scope of this investment, it is essential that governments, businesses and communities work together to ensure resilience is considered when deciding on investments. This chapter reviews the decision-making process for investing in infrastructure and highlights areas in which resilience should be integrated, drawing on domestic and international best practice.

2.1 Infrastructure investment in Australia

More than $60 billion worth of essential hard infrastructure investment was completed in 2014–15 (ABS, 2015a; 2015b). This investment is likely to grow substantially in the next 20 years to meet the needs of a growing population and economy. This infrastructure facilitates productivity and growth through providing essential public services. The economy-wide value-add attributed to infrastructure services will increase from $187 billion per year in 2011 to $377 billion in 2031 (Infrastructure Australia, 2015b).

Infrastructure Australia acknowledges the importance of infrastructure investment to the economy:

'Major reforms are needed to improve the way we plan, finance, construct, maintain and operate infrastructure to ensure it can underpin gains in Australia's productivity in the decades ahead, and contribute to economic growth.' (2015a)

It is not a focus of this report but maintenance costs for infrastructure assets is significantly greater than the costs of building new infrastructure. In this context, there are two considerations: first, if addressing resilience up-front may reduce the ongoing maintenance requirements for infrastructure. Second, if there are cost-effective options for improving infrastructure resilience as part of maintenance work. These issues are considered in Box 3.

Box 3: Maintaining existing infrastructure

Infrastructure costs are greater than just the initial cost of construction. Maintenance is a significant proportion of the cost of infrastructure over its lifetime. It is estimated that half of the $16 billion spent on roads each year by local, state and federal governments is spent on maintenance and repairs (Infrastructure Partnerships Australia, 2011).

While this report focuses on new and replacement infrastructure, there are opportunities to improve resilience when planning and investing in infrastructure maintenance. Further, new infrastructure projects should include resources to help maintain and enhance resilience as part of proposed maintenance programs.

The Productivity Commission's *Natural Disaster Funding Arrangements* inquiry report (2014) notes it is important to regularly maintain infrastructure. In its submission to the Productivity Commission, the Department of Infrastructure and Regional Development argued that 'An avoidance of adequate ongoing maintenance has the potential to increase the impact of natural disasters [since] poorly maintained assets are more likely to be susceptible to damage'. It claimed there was a tendency to delay funding for maintenance until it was absolutely necessary.

Infrastructure owned and managed by local government is often the most susceptible to damage due to poor maintenance, particularly where local councils are financially constrained (Jeff Roorda and Associates, 2010). Local councils across New South Wales (NSW) spent only 74% of their estimated investment in required infrastructure maintenance in 2011–12 (NSW Department of Premier and Cabinet, 2013). While the Productivity Commission observed a renewed focus by local governments on developing infrastructure maintenance plans, it concluded there 'would be merit in more explicit integration of natural disaster risk into asset management plans' (2014).

Floodwaters cover Albion Park raceway in the inner Brisbane suburb of Albion on January 13, 2011. *(Jonathan Wood / Getty Images)*

2.2 The decision-making process

The decision-making process for investing in proposed infrastructure varies according to the type of infrastructure being considered, the geographic location and the decision-maker. A stylised view of this process includes:

- **Stage 1:** Funds are allocated to various types of infrastructure. If they are public assets, governments may decide on the share of investment allocated to transport versus hospital construction, for example. For private assets, businesses may decide on the share of investment in technology, buildings or service delivery
- **Stage 2:** Assessment of specific infrastructure projects to finance. For example, governments decide whether to invest in delivering road services to location X or location Y. This involves submitting proposals to a centralised decision-maker. Local governments may submit proposals to state governments, or business units may submit proposals to the executive. These decisions are often designed to meet particular demands for infrastructure services
- **Stage 3:** Appropriate delivery and specifications are determined. For example, whether a road to location X should require two or four lanes, whether it should be sealed or unsealed, and where it will be located.

Given the importance of infrastructure to the economy, and the differences between types of infrastructure, this decision-making process is often complex, requiring trade-offs between objectives within budget constraints.

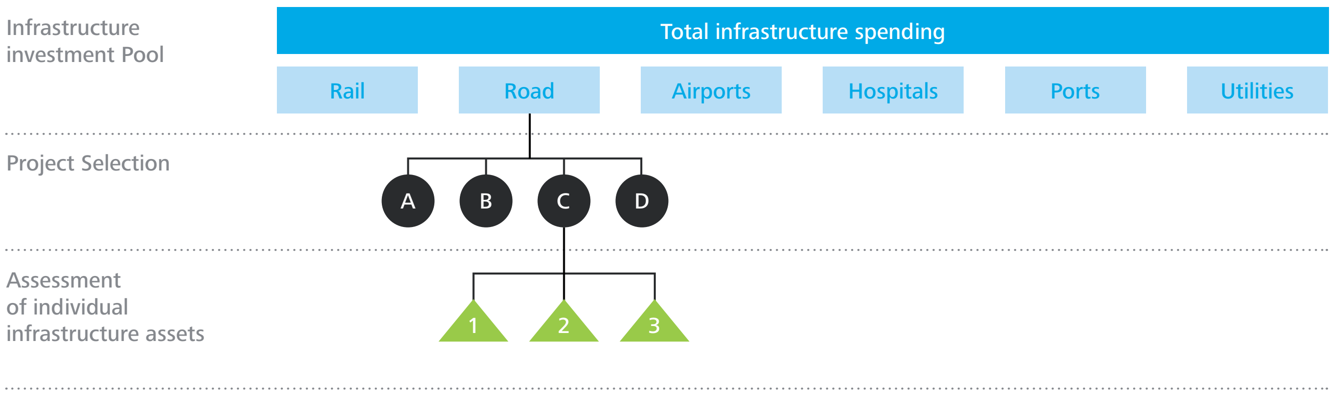
Determining appropriate service levels for new and replacement infrastructure involves multiple considerations, which vary by infrastructure type, location and the current and future needs of end-users.

Decision-makers rely on a number of inputs to evaluate and approve options. A typical input is CBA, which is used to compare options and provide economic justification for an infrastructure project.

While building codes and standards provide a minimum requirement for resilience (including specific guidelines for mitigating disaster risks – see Section 2.3.3), this report considers if incorporating resilience in the initial project appraisal and approval processes may shift investment decisions. For example, examining resilience during CBA may reveal it is cost-effective to build to a higher level of resilience than is mandated under building requirements. Alternatively, it may be found to be more efficient to build in a different area or to change the infrastructure design.

Integrating resilience into CBA will mean existing project appraisal processes can continue to be used, with the added assurance that natural disasters resilience has been thoroughly assessed.

Figure 2.1: Example of the layers involved in infrastructure investment decision-making



2.2.1 Who makes infrastructure investment decisions?

The decision-making process for investing in major public infrastructure projects is complex and approval often involves multiple levels of government.

For example, local councils are responsible for local roads but to build a major new local road, they may need to work with (or seek funding from) state or federal governments. In some instances, councils may work with private property developers who may fund and deliver the road. The Federal government typically approves other significant assets, such as airports and national highways.

Thus, investment and ownership may involve several levels of government and the private sector. Similarly, while state governments are generally responsible for investing in infrastructure such as hospitals and transport, Federal government funding is often required. For privately owned infrastructure, such as telecommunications assets, the private sector is typically responsible for making decisions, yet these also need to satisfy government approval processes.

Figure 2.2 provides a stylised example of a large infrastructure project initiated by local government, showing the roles of other stakeholders in delivering it. This representation does not include the environmental assessments generally required across all levels of government. Projects funded at state or federal levels,

Table 2.1: Division of responsibility for infrastructure approval among the tiers of government

Level of government	Economic infrastructure	Social infrastructure
Federal	Aviation services (air navigation etc)	Tertiary education
		Public housing (shared)
	Telecommunications	Health facilities (shared)
	Postal services	
	National roads (shared)	
	Local roads (shared)	
	Railways (shared)	
State	Roads (urban, rural, local) (shared)	Educational institutions (primary, secondary, technical) (shared)
	Railways (shared)	Childcare facilities
	Ports and sea navigation	Community health services (shared)
	Aviation (some regional airports)	Public housing
	Electricity supply	Sports, recreation and cultural facilities
	Dams, water and sewerage systems	Libraries
	Public transport (train, bus)	Public order and safety (courts, police stations, traffic signals)
Local	Roads (local) (shared)	Childcare centres
	Sewerage treatment, water and drainage supply	Libraries
	Aviation (local airports)	Community centres and nursing homes
	Electricity supply	Recreation facilities, parks and open spaces
	Public transport (bus)	

Source: Australian Parliamentary Library (2004) or jointly funded, typically require a CBA as part of the appraisal process.

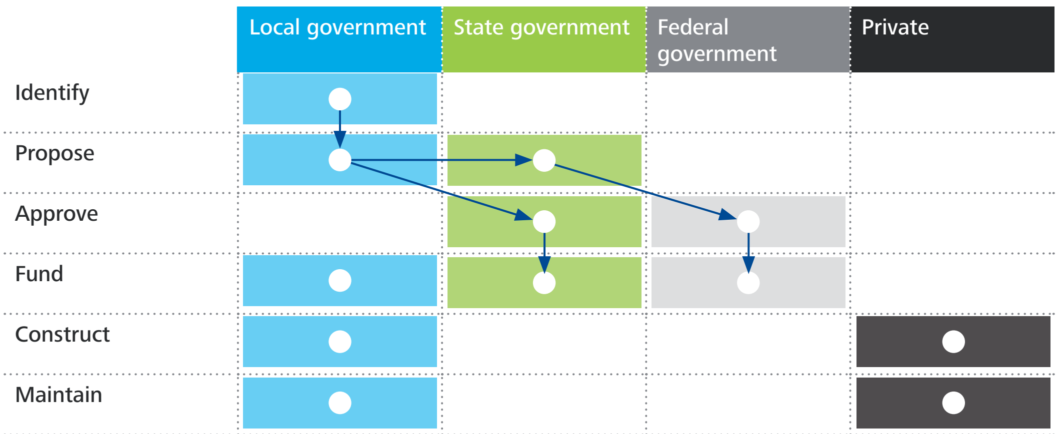
These responsibilities can also change over time. For example, the Federal government's investment in public transport infrastructure varies significantly depending on its policy positions.

Each party varies in its capacity and incentives to consider embedding resilience in infrastructure projects. For example, local councils may have fewer resources available for project appraisal and, more importantly, may lack the resources to fund resilient project options even when they lead to higher net benefits for society.

Further, given the complex interactions between the stakeholders that make decisions on infrastructure, it is not always clear which should be responsible for assessing natural disaster risks and resilience.

A National Resilience Advisor, as advocated in *Building our Nation's Resilience to Natural Disasters,* could support various decision-makers to overcome these constraints by leading the integration of resilience into the project appraisal processes.

Figure 2.2: Stylised example of the infrastructure investment process



Source: Deloitte Access Economics (2016)

2.3 Resilience in government policy and investment decisions

2.3.1 Resilience in Australian policy guidelines

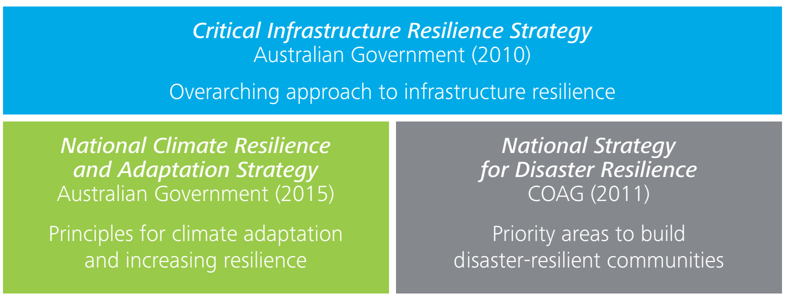
A number of government departments have policies and strategies that aim to build resilience, which is broadly defined as the ability to mitigate the impact of natural disasters and recover quickly after emergencies. These documents are mostly high-level papers that do not consider how resilience could be achieved.

The Federal government's strategy to ensuring infrastructure resilience is outlined in the *Critical Infrastructure Resilience Strategy* (2010) (Figure 2.3). The resilience strategy is managed by several groups. For example, the Trusted Information Sharing Network for Critical Infrastructure Resilience shares information between industry and government; while the Critical Infrastructure Program for Modelling and Analysis collects data and models the potential effects of hazards on critical infrastructure. The National Critical Infrastructure Resilience Committee, meanwhile, coordinates critical infrastructure resilience activities between various states and territories.

The *National Climate Resilience and Adaptation Strategy,* released by the Federal government in 2015, outlines the risks to cities and the built environment, what is currently being done to improve resilience, and what needs to be done. The strategy acknowledges that 'Population trends, urbanisation and residential shifts to high risk areas will intersect with climate change to increase Australia's exposure to natural hazards as a whole'. It notes the importance of sharing information and disclosing risks to help businesses, communities and governments manage their exposure to climate change and natural disasters.

The Federal government's policy on infrastructure resilience is supplemented by the Council of Australian Governments' (COAG) *National Strategy for Disaster Resilience* (2011). The strategy focuses on improving links between government and the business sector, because a substantial portion of infrastructure is privately owned or managed. It argues that both public and private risks should be accounted for in development decisions. Furthermore, it calls for a regular review of building standards.

Figure 2.3: High-level resilience policy documents



Source: Deloitte Access Economics (2016)

In contrast to these broad guidelines, the Australian Building Codes Board (ABCB) has developed a set of specific standards for ensuring structural resilience in commercial and residential buildings, included in the *National Construction Code* (2015). For commercial buildings, the standards of structural resilience depend on the importance of the building. For example, buildings that are essential to post-disaster recovery must be able to withstand an earthquake with an annual exceedance probability (AEP) of 0.067% and cyclonic winds with an AEP of 0.05%.[2] For residential buildings, metal roof assemblies must be able to stay in position under a number of different cyclone frequencies and pressures. Residential properties should be able to withstand an earthquake with an AEP of 0.20% and cyclonic winds with an AEP of 0.20%. Individual states may have additional standards.

At the state level, Victoria has an extensive policy on infrastructure resilience, as outlined in its *Critical Infrastructure Resilience Strategy* (2015). 'Vital', 'major' and 'significant' infrastructure is placed on a register of critical infrastructure. Owners and/or operators of vital infrastructure must participate in a four-state 'resilience improvement cycle'. The cycle includes submission of an annual Statement of Assurance to government that summarises the foreseeable risks and outlines strategies to deal with them. Owners must develop a program to test emergency plans, which must be audited. Accountable officers within companies are assigned to each vital development to certify the Statement of Assurance and ensure all actions of the cycle are performed.

NSW's approach to ensuring resilient infrastructure is expressed in Infrastructure NSW's *State Infrastructure Strategy 2012–2032* (2012). Resilience is one of three key strategic assessment criteria, along with connectivity and improving quality of life. It specifies that public and private infrastructure should be able to withstand disruption during crises.

Queensland has likewise developed the *Queensland Strategy for Disaster Resilience* (2013). The report outlines key resilience outcomes, along with which agencies oversee the outcomes, performance metrics and how these metrics are measured. This helps to assess if effective resilience strategies are being implemented. However, the metrics tend to be broad, using terms such as 'improve' rather than specifying exact standards.

Although not solely focused on resilience, in recent years sustainability considerations have been increasingly recognised when investing in infrastructure. For example, the Infrastructure Sustainability Council of Australia (ISCA) is a member-based, not-for-profit industry council focused on promoting infrastructure sustainability across design, construction and operation. Formerly known as the Australian Green Infrastructure Council, ISCA was established in 2008. It now has more than 60 public and private sector members.

ISCA administers an Infrastructure Sustainability (IS) rating scheme, described further in Box 4, to help embed sustainability considerations in infrastructure developments and operations. The scheme includes consideration of flood risks and adaption to climate change among other aspects of sustainability with themes including resource use, emissions, pollution and waste, people and place, ecology, innovation, and management and governance.

2. For example, an individual born in Australia today can expect to live to 82. Cyclonic winds with an AEP of 0.05% (a one-in-2000-year event) have a 0.05% of occurring every year. This means there is a 96% chance that the cyclonic winds will not occur over the course of 82 years, or – put another way – there is a 4% chance of one-in 2000-year cyclonic winds occurring.

Box 4: Infrastructure Sustainability Council of Australia – IS rating scheme

In 2012, ISCA launched a rating scheme to evaluate transport, water, energy and communications infrastructure projects and assets against sustainability criteria including environmental, social and governance aspects. Depending on the stage of an infrastructure project, it can be assessed for a 'design', 'as built' or 'operation' rating.

To date, ISCA has provided 14 certified ratings, and a further 44 projects are currently registered for a rating, with a capital value of almost $60 billion (ISCA, 2015). Typically ratings are required by government agencies for specific infrastructure projects or voluntarily sought by private sector firms to demonstrate a commitment to sustainability when submitting government tenders. In particular, Transport for NSW requires an IS rating for projects involving capital expenditure of more than $50 million, and Main Roads Western Australia requires it for projects valued at more than $100 million.

The current IS rating scheme includes some consideration of aspects related to natural disaster resilience, granting credits for climate change risk assessment, climate change adaptation options and flooding design. The scheme's technical manual gives detailed guidance on the evidence applicants must provide to meet the benchmarks. ISCA is currently updating the rating scheme and anticipates putting a greater focus on resilience to natural disasters and adapting to climate change.

2.3.2 Resilience in Australian infrastructure guidelines

Regulatory approval for major infrastructure projects usually requires a CBA as a key input to decision-making. State and federal government departments have issued a number of guidelines for completing CBAs.

Three out of the 12 Australian CBA guidelines reviewed in this report referenced resilience to natural disasters as a possible benefit (Table 2.2):

- The Department of Finance and Administration's *Handbook of Cost-Benefit Analysis* (2006) recommends valuing flood and fire protection using hedonic prices*
- NSW Treasury's *NSW Government Guidelines for Economic Appraisal* (2007) provides flood protection as an example of a potential benefit. It notes, however, that 'One difficulty in this and similar cases is that major floods, which are critical to such assessments [of risk reduction], occur infrequently and the probability estimates are accordingly unreliable'
- The Queensland Department of Transport and Main Roads provides a detailed and extensive guide to valuing flood resilience in CBAs as part of its *Cost-Benefit Analysis Manual* (2011). It notes that all-weather road access may not be economically efficient. The benefits of flood proofing are measured by avoided delays or diversion costs.

  The manual also presents a number of case studies to give users an understanding of the principles involved in evaluating projects. One case study relates to improving flood immunity, showing how to calculate the benefits of a more resilient bridge.

With the exception of Queensland's guideline to measure the benefits of flood proofing transport infrastructure, there are no explicit guidelines on valuing the benefits of improved infrastructure resilience.

While it is arguably, implicit that any comprehensive CBA should include resilience to natural disasters as a benefit for proposed infrastructure projects, without explicit mention it is possible that many would overlook these benefits, contributing to underinvestment. As the Organisation for Economic Co-operation and Development (OECD) remarks in *Improving the Practice of Cost Benefit Analysis in Transport* (2014), resilience is a 'relatively new' concern so it is not always included in CBAs. Also, resilience can be difficult to measure in economic terms. As noted by NSW Treasury (2007), accurate estimates of the probability of extreme events, which are necessary to calculate risk, are difficult to obtain.

* Hedonic prices are modelled prices estimated in terms of the characteristics of a good (or service). The approach is most commonly applied to the housing market.

Additionally, CBA that hasn't incorporated natural disaster risks will assume that the benefits associated with the asset will flow over the life of the asset. If the asset is disabled or requires significant maintenance as a result of a disaster, then the period where the benefits flow will be reduced.

Integrating an appraisal of resilience as a specific step in CBA guidelines would support practitioners in evaluating resilience as a routine part of appraising projects. This step – alongside stronger references to resilience in government appraisals, such as a requirement to demonstrate if natural disaster risks are present and, if so, how resilience options have been considered – could improve the cost-effectiveness of investment decisions. Unless appraisal processes are changed and further guidance is given, there is little incentive for the private sector to consider resilience beyond the minimum requirements.

Indeed, the Productivity Commission's 2015 *Natural Disaster Funding Arrangements* inquiry report recommended that:

'All governments should put in place best-practice institutional and governance arrangements for the provision of public infrastructure, including road infrastructure. These should include:

- *stronger processes for project selection that incorporate requirements for cost-benefit analyses that are independently scrutinised and publically released*
- ***consideration of natural disaster risk in project selection and asset management planning***
- *a clearer link between road-user preferences and maintenance and investment decisions.'*

The Commission argues that increasing the transparency and rigorousness of CBAs for infrastructure investments can provide a framework for debating the financial trade-offs between project options, and for prioritising approaches for betterment and mitigation (2014:224).

These findings are supported by Infrastructure Australia, which indicated that project proposals primarily address capacity and economic issues, with less reflection on what resilience meant for the scoping, design and prioritisation of projects.

There are a number of areas for improvement, particularly in sophisticated analysis scenarios that consider resilience and allow trade-offs to be evaluated in a transparent way. An increased focus on resilience at the project assessment stage will help ensure infrastructure solutions are strategically and economically robust.

Greater guidance and support is required to develop stakeholders' capacity to rigorously test resilience options.

Table 2.2: Government guidelines for cost-benefit analysis

CBA	Department	Reference to resilience as a benefit:				
		Cyclones	Floods	Fires	Earthquakes	Other
Cost-Benefit Analysis Guidance Notes (2014)	Office of Best Practice Regulation, Department of Prime Minister and Cabinet, Australian Government	● (red)	● (red)	● (red)	● (red)	
Handbook of Cost-Benefit Analysis (2006)	Department of Finance and Administration, Australian Government	● (red)	● (green)	● (green)	● (red)	
Reform and Investment Framework – Templates for Use by Proponents, Stage 7 (2013)	Infrastructure Australia, Australian Government	● (red)	● (red)	● (red)	● (red)	
Better Infrastructure Decision-making (2013)	Infrastructure Australia, Australian Government	● (red)	● (red)	● (red)	● (red)	Drought
National Guidelines for Transport System Management in Australia (2006)	Australian Transport Council [3]	● (red)	● (red)	● (red)	● (red)	
NSW Government Guidelines for Economic Appraisal (2007)	NSW Treasury, NSW Government	● (red)	● (green)	● (red)	● (red)	
Project Assessment Framework: Cost-benefit analysis (2015)	Queensland Treasury, Queensland Government	● (red)	● (red)	● (red)	● (red)	Earthquakes are given as a risk example
Cost-Benefit Analysis Manual (2011)	Department of Transport and Main Roads, Queensland Government	● (red)	● (green)	● (red)	● (red)	
Guidelines for the evaluation of public sector initiatives (2014)	Department of Treasury and Finance, South Australian Government	● (red)	● (red)	● (red)	● (red)	
Program Evaluation (2015)	Department of Treasury and Finance, Western Australian Government	● (red)	● (red)	● (red)	● (red)	
Economic Evaluation for Business Cases: Technical guidelines (2013)	Department of Treasury and Finance, Victorian Government	● (red)	● (red)	● (red)	● (red)	
Policy Essentials: Cost-Benefit Analysis (2012)	Business Council of Australia	● (red)	● (red)	● (red)	● (red)	

3. Now the Transport and Infrastructure Council

2.3.3 Resilience in other aspects of infrastructure planning

Resilience may be also considered during other stages of the infrastructure investment process, such as land use planning, engineering and construction. Land use planning may be regulated by state governments or local government. Engineering standards set a minimum level of risk that a particular asset can be exposed to. Building codes set out specific structural minimums for resilience in commercial and residential buildings.

Land use planning may require certain assets to be located in areas safe from risk of flood or fire, contributing to resilience. The *National Strategy for Disaster Resilience* highlights the importance of land use planning and building standards in reducing risks in the built environment:

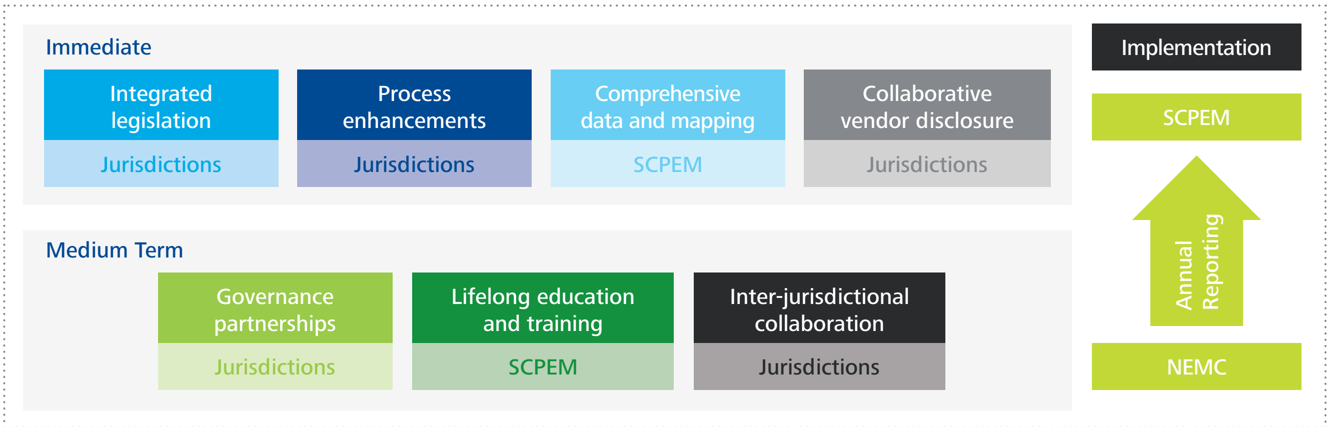
'Planning approaches that anticipate likely risk factors and the vulnerability of the population can reduce the future possible impact of disasters. Responsible land use planning can prevent or reduce the likelihood of hazards impacting communities. Building standards can mitigate the likelihood of loss of life, as well as damage to and/or destruction of property and infrastructure.' (2011:11)

In 2013, the Land Use Planning and Building Codes Taskforce – established by the National Emergency Management Committee (now the Australia and New Zealand Emergency Management Committee) – undertook a national review of land use planning and building codes. There was four stages, involving:

- Developing a vision statement describing the resilience of the built environment to future natural disasters
- Undertaking a national stocktake of relevant strategic land use planning and building code policies, instruments and regulations
- Identifying opportunities for new land use planning and building resilience initiatives
- Developing a roadmap outlining activities to implement disaster resilience (PlanDev Business Solutions, 2012).

The roadmap framework is presented in Figure 2.4, highlighting the different priorities for action: integrated legislation, process enhancements, comprehensive data and mapping, vendor disclosure, governance partnerships, education and training, and inter-jurisdictional collaboration. The Productivity Commission (2014) has recommended that state and territory governments prioritise and accelerate implementation of the roadmap, including reviewing the regulatory components of vendor disclosure statements.

Figure 2.4: Enhancing Disaster Resilience in the Built Environment Project: land use planning and building codes roadmap framework



Source: PlanDev Business Solutions (2012)
Note: NEMC – National Emergency Management Committee (now the Australia and New Zealand Emergency Management Committee) and SCPEM – Standing Council on Police and Emergency Management (since replaced by the Law, Crime and Community Safety Council)

Engineering standards are another example of where resilience is considered outside formal investment decision-making process. All Australian engineering construction projects must be delivered to an appropriate standard. The standards cover safety, reliability, productivity and efficiency specifications, and are defined for specific assets across various regulation, codes and guidelines. These standards normally include specific requirements about resilience. For example, the standards may dictate that a bridge or road must meet a particular threshold, such as being resistant to a one-in-100-year flood (with an AEP of 1%). These standards are one input considered when scoping, designing and building new and replacement infrastructure.

Box 5: Graceful failure

Graceful failure is a relatively new concept in engineering, where structures have a strategic or engineered weaker point. When faced with a massive natural disaster, they will fail in a manner that minimises other damage and loss of life.

For example, making a flood levee deliberately weaker in a particular section. If a rare flood occurs, that could breach the levee and flood a town, the levee would break in the weaker section and flood into farmland instead – reducing the downstream flood peak heights.

Graceful failure can also involve designing a major piece of infrastructure so that if it fails, it is non-catastrophic. Thus, it could be quickly returned to full serviceability after the disaster.

In the context of built infrastructure, staged failure can allow partial building collapse and safe evacuation – a standard design requirement in earthquake zones (Tye et al., 2015)

Because standards typically improve over time, restored assets are usually rebuilt to higher standards. However, applying betterment principles, as recommended by the Queensland Reconstruction Authority (QRA), when infrastructure is rebuilt following a natural disaster can restore assets to an even higher standard of resilience than prescribed by engineering standards.

The *Framework for Betterment* (QRA, 2015) highlights the benefits of reducing future expenditure on restoring assets when rebuilding infrastructure affected by natural disasters. In 2013, the Australian and Queensland governments undertook an $80 million program to rebuild infrastructure damaged during Cyclone Oswald to a standard that was more resilient to natural disasters. Many of these assets had been repeatedly damaged and restored during previous disasters in 2011 and 2012. Subsequent disasters have affected 71 assets restored under the program. Only two projects sustained severe damage, while 82% of the assets received no damage and 10% merely superficial damage. While $16 million was spent to enhance resilience, more than $22 million has already been saved in restoration costs.

Alongside enhancing resilience in land use planning, building codes and engineering standards, it is also important to use CBA to holistically assess resilience options when scoping and approving projects. The wider public benefits of having resilient infrastructure – and avoided costs – may mean that different infrastructure investment decisions are made and infrastructure is built with more resilience than that prescribed by building codes or engineering standards.

In particular, while planning codes and standards are important for setting baseline levels of resilience, CBA frameworks need to test on a case-by-case basis if it is possible to cost-effectively achieve higher levels of resilience to better suit local risks and community needs. For example, the new parallel runway at Brisbane Airport. In recognition of future climate change risks in the area, such as storm surges and rising sea levels, the runway is being constructed 1.8 metres above the minimum regulatory requirements for flood and storm tides (Investor Group on Climate Change, 2015).

2.3.4 Resilience in architecture and design education

Current design and architecture courses in Australia allocate little time to covering natural disaster risks or the resilience of buildings in future urban centres. While there are broad references to resilience, architecture schools in Australia offer very few, if any, courses that include training on how to consider resilience.

It is important to incorporate resilience into tertiary studies to ensure future designers and engineers have the knowledge to design and build infrastructure that reflects the risk of natural disasters damage. Teaching these skills early also places resilience at the top of their minds when thinking about infrastructure design.

Resilience is, however, increasingly acknowledged through cross-disciplinary integrated programs. RMIT now offers a Master of Disaster, Design and Development, developed in partnership with the International Federation of Red Cross and Red Crescent Societies and UN-Habitat. The course emphasises the need to build the resilience of buildings in disaster-prone and socially marginalised communities.

International universities – such as Oxford Brookes University, the International University of Catalonia (UIC), University College London, Harvard University and the University of Auckland – are also offering courses in risk and resilience.

Given the extent of natural disasters in Australia and their impacts on infrastructure, it is evident Australia is underinvesting in resilience education.

2.3.5 Resilience in international policy

The benefits of building resilient infrastructure are not limited to Australia. The need for policies and strategies to improve resilience applies globally.

Internationally, the United Nations (UN) has led the call to ensure resilience in infrastructure – under the Hyogo Framework (2005), for example. The Hyogo Framework promotes a systematic approach to reducing risks posed by natural disasters (since been replaced by the Sendai Framework, 2015).

The Sendai Framework is a 15-year, voluntary, non-binding agreement that recognises that governments are primarily responsible for reducing the risk of natural disasters, with other stakeholders sharing this responsibility as enablers, supporting government. It aims for:

' The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.' (UN, 2015)

To achieve this, the Sendai Framework is looking to improve the resilience of infrastructure and implement strategies to reduce the risks posed by natural disasters by 2020. More broadly, the Sendai Framework lists seven global targets as part of its framework:

- Reduce disaster damage to critical infrastructure and disruption of basic services
- Increase the number of countries with national and local strategies to reduce the risks posed by natural disasters
- Substantially increase the availability of, and access to, multi-hazard early warning systems, information about natural disasters and risk assessments
- Reduce global mortality rates from natural disasters
- Reduce the number of people affected by natural disasters globally
- Reduce direct economic loss from natural disasters in relation to global gross domestic product (GDP)
- Enhance international cooperation for implementing this framework.

These goals are associated with four key priorities, one of which emphasises the need to invest in disaster risk reduction for resilience. The four priorities are:

- Understand disaster risk
- Strengthen governance to manage disaster risk
- Invest in resilience strategies to reduce disaster risk
- Enhance disaster preparedness to ensure effective responses and to 'build back better' during recovery, rehabilitation and reconstruction.

Japan pledged US$4 billion in 2015 to support implementation of the Sendai Cooperation Initiative for Disaster Risk Reduction over the next four years. The package focuses on developing disaster-proof infrastructure, promoting global and regional cooperation, and training 40,000 government officials and local leaders to lead national efforts to reduce disaster risk.

The Sendai Framework highlights the importance of increasing resilience on a global scale. Yet, in practice, there is little or no consideration of resilience in many infrastructure projects in developing countries. This has been noted by the World Bank's *Building Resilient Communities* toolkit, which aims to identify where World Bank funding is used to improve resilience. In developing countries, resilience investments are often low-hanging fruit as the costs of basic hazard-proofing can be minimal, relative to the benefits. Therefore, investments in community-based preparedness and early warning systems, particularly in places more at risk of natural disasters, can save lives, protect property and reduce economic losses.

The UN is also responsible for the *Making Cities Resilient* campaign, which provides guidance documents and measurement tools to assist cities, particularly through local government, to improve their resilience and reduce the risks associated with natural disasters.

The following section provides an overview of relevant major policies in New Zealand, Canada, the UK and the US.

New Zealand

New Zealand has taken steps to integrate resilience into legal standards. In response to the Canterbury earthquakes in 2011, the Building (Earthquake-prone Buildings) Amendment Bill 2013 introduced a number of new earthquake resilience policies. New Zealand established a national earthquake resilience system to replace the previous local council systems. The bill stipulated that all earthquake-prone buildings must be strengthened or demolished within 20 years. The extensive scope of the measures faced criticism for their costliness and the possible destruction or abandonment of heritage buildings (Jones, 2015). The government introduced a more focused approach that targeted high-risk areas in 2015, which reduced the number of buildings affected from 500,000 to 30,000.

Canada

The Canadian government announced a National Platform for Disaster Risk Reduction (DRR) in 2009 to build coordinated, multi-stakeholder leadership to reduce the risks posed by disasters. This affirmed Canada's commitment to the Hyogo Framework. Canada's platform seeks to build a sense of national, cross-sectoral ownership in the DRR process through a coordinated participatory process.

In 2014, the Canadian Government earmarked C$200 million over five years to establish the National Disaster Mitigation Program (NDMP). The NDMP plans to address rising flood risks and costs, and build the foundation for informed investments to mitigate the effects of future floods. The NDMP is designed to reduce the impacts of natural disasters by focusing investments on areas where flooding and costs are significant and recurring, and by advancing work to facilitate private residential insurance for overland flooding.

The NDMP will also help to build the foundation for implementing informed and proactive prevention and mitigation strategies by investing C$17 million in three key areas:

- Risk, resilience and return on investment tools to provide provinces, territories and communities with the information and capacity they need to plan and evaluate flood mitigation projects
- A risk and resilience repository to collect, store, manage and share NDMP information to inform the future direction of policies and programs for all levels of government
- Public awareness and engagement activities.

United Kingdom

The UK Government published its national infrastructure resilience strategy, *Keeping the Country Running: Natural Hazards and Infrastructure,* in 2011. The report notes that the UK lacks explicit national standards for infrastructure resilience – a shortcoming also noted by the Pitt Review (2008). The report argues that investments in ensuring the resilience of infrastructure should be proportional to the risk, and delivered at the lowest practicable level. Government departments responsible for each national infrastructure sector are required to develop an annual resilience plan for their relevant minister, in conjunction with infrastructure owners and regulators. There are nine national infrastructure sectors: communications, emergency services, energy, finance, food, government, health, transport and water. As these plans are classified, however, it is difficult to assess their effectiveness.

United States

In the US, the launch of the National Disaster Resilience Competition in 2014 gave disaster resilience significant attention. The competition provides grants to communities that have experienced natural disasters to help rebuild and increase their resilience. Communities affected by natural disasters between 2011 and 2013 are eligible to compete for approximately US$1 billion.

Phase 2 of the competition was announced in 2015, in which 40 states and communities were invited to compete for up to US$500 million for projects to address unmet needs from past natural disasters and vulnerabilities that could put Americans in harm's way during future disasters.

The competition includes funding to restore infrastructure and housing, and applicants must demonstrate how they are reducing future risks. For example, a community that lost housing during a mudslide may construct homes in a safer area for the survivors (US Department of Housing and Urban Development, 2015b).

Box 6: 100 Resilient Cities – The Rockefeller Foundation

The Rockefeller Foundation has run the 100 Resilient Cities (100RC) program since December 2013, seeking to 'help cities around the world become more resilient to the physical, social and economic challenges that are a growing part of the 21st century' (2016).

The program provides the 67 cities currently in the 100RC network, including Sydney and Melbourne, with resources to help develop a roadmap to resilience, including:

- Financial and logistical guidance to have a chief resilience officer employed in the city or local government, with the responsibility to lead the city's resilience efforts
- Expert support to develop a robust resilience strategy
- Access to solutions, service providers and partners from the private, public and non-government sectors that can help develop and implement resilience strategies
- Membership in a global network of cities that can learn from and help each other.

The 100RC program defines resilience more broadly than this paper as: 'the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience'. It includes other stresses such as high unemployment and inefficient public transportation. Nevertheless, the focus on resilience can still be applied to infrastructure projects, as considered in this report.

2.3.5.1 Resilience in international infrastructure guidelines

To assess the extent to which resilience is incorporated in infrastructure decision-making in other countries, this report reviewed four international guidelines and five cases where CBA was applied to infrastructure resilience that made reference to resilience as a benefit (see Table 2.3 and Table 2.4).

International guidelines for CBA were more likely to explicitly reference natural disaster resilience than Australian guidelines. This may be because many of the reviewed guidelines are designed for developing countries, which are often highly vulnerable to natural disasters. However, there is still relatively little guidance for practitioners looking to quantify resilience benefits both within Australia and internationally.

A notable exception is the World Bank's *Building Urban Resilience: Principles, Tools and Practice* methodology (2012). The report advocates the use of CBA to compare options for reducing risks and also includes a specific methodology for identifying hazards.[4]

Other international papers reviewed – not specifically CBA guidelines – are also examples of the need for a greater focus on resilience, typically using ex-post CBA to demonstrate significant benefits. For example, papers written by the International Federation of Red Cross and Red Crescent Societies (2012), Copenhagen Consensus (2012) and Asian Development Bank (2013).

Table 2.3: International guidelines for cost-benefit analysis

CBA	Organisation	Reference to resilience as a benefit:			
		Cyclones	Floods	Fires	Earthquakes
Cost-Benefit Analysis in World Bank Projects (2010)	World bank	🔴	🔴	🔴	🔴
Building Urban Resilience: Principles, Tools and Practice (2012)	World bank	🟢	🟢	🟢	🟢
Making Communities More Flood Resilient (2014)	Zurich Flood Resilience Alliance	🔴	🟢	🔴	🔴
The Economics of Early Response and Resilience: Approach and Methodology (2013)	UK Government	🟢	🟢	🔴	🔴

4. The methodology includes consideration of the frequency, duration, area extent, speed of onset, spatial dispersion, temporal spacing and the possibility of secondary hazards (2012:50). A combination of probabilistic hazard models and mapping can be used to make these assessments. A similar methodology for hazard assessment has been developed by Geoscience Australia for the purpose of managing and responding to natural disaster events.

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Table 2.4: International papers estimating resilience benefits

	Organisation	Reference to resilience as a benefit:			
		Cyclones	Floods	Fires	Earthquakes
The long road to resilience: Impact and cost-benefit analysis of community-based disaster risk reduction in Bangladesh (2012)	International Federation of Red Cross and Red Crescent Societies	🟢	🟢	🔴	🔴
Policy Options for Reducing Losses from Natural Disasters: Allocating $75 billion (2012)	Copenhagen Consensus	🟢*	🟢*	🔴	🟢*
Disaster Resilience: A National Imperative (2012)	The National Academies	🟢	🟢	🟢	🟢
2015 Global Assessment Report on Disaster Risk Reduction (2015)	United Nations	🟢*	🟢*	🟢*	🟢*
Investing in Resilience: Ensuring a Disaster-Resistant Future (2013)	Asian Development Bank	🟢	🟢	🔴	🔴

* Refers to 'disaster risk reduction'

May 19, 2011: Christchurch, NZL. The City Centre or Red Zone, remains closed in Christchurch, New Zealand, as the city continues to recover three months after a 6.3 magnitude earthquake hit in February, 2011, which resulted in multiple deaths and widespread property damage. *(Newspix)*