Appendix G: Estimating resilience benefits

Cost-benefit analyses (CBA) are a major input in the decision-making process for new infrastructure, as they analyse the expected benefits and costs for the entire community. Monetising resilience benefits in a CBA framework provides a thorough picture of community benefits from new infrastructure, and helps identify cost-effective ways to build resilience into infrastructure.

Given the prevalence of natural disasters in Australia and the significant costs they impose on existing infrastructure, including resilience benefits in CBA is needed to facilitate better consideration of natural disasters in infrastructure decision-making.

Existing Commonwealth, state and territory CBA frameworks (see the list in Table 2.2) provide detailed information on monetising costs and benefits (and on how to select a discount rate, appraisal period and base case) but do not currently provide substantive guidance on resilience benefits. For example, current guidelines for bridge projects clearly specify factors such as the appropriate time period for conducting the analysis; how to measure and forecast traffic volumes; how to value the time of different road users; expected vehicle accident rates; and how to discount future costs and benefits to current values. However, the guidelines do not mention how to account for the risk that the bridge could be unavailable – or even destroyed – due to a flood.

The following section provides an addendum to these existing frameworks, to help practitioners monetise resilience benefits in a rigorous CBA.

Resilience benefits of proposed infrastructure options

In the context of infrastructure, resilience benefits are estimated in terms of the avoided disaster costs. Avoided disaster costs are estimated by comparing disaster costs under a base case (business as usual) scenario, with disaster costs under a project option – that is, base case disaster costs minus project disaster costs. Project options with higher levels of built-in resilience such as options to reduce the exposure of an asset during a hazard event will have lower disaster costs.

PV resilience benefits = PV avoided disaster costs = Base case disaster costs – Project disaster costs

For example, a new main water pipeline may be needed to service a new housing development. A hazard assessment might identify that the direct route from the existing mains network to the new development area is flood prone and landslide prone. This would require multimillion-dollar maintenance expenditure once every 10 years. If the proponent could identify an option that eliminates the need for this maintenance, the benefit of resilience is the reduction in maintenance expenditure.

Identifying avoided disaster costs

The cost of natural disasters includes a wide set of direct and indirect, tangible and intangible costs. Using an approach defined by the Bureau of Transport Economics (BTE) (2001) *Economic Costs of Natural Disasters in Australia,* the total cost of a natural disaster is measured by quantifying and aggregating these costs.

However, in evaluating the benefits of resilient infrastructure, only some of the categories of disaster costs that BTE identified are relevant. That is, in analysing the benefits of resilient infrastructure, analysts must focus on costs that follow from damage to infrastructure. This is because other costs of the natural disaster (such as injury, death and destruction of property) occur regardless of the infrastructure asset.

Relevant disaster costs include the direct impact of infrastructure damage, and indirect or flow-on impacts associated with infrastructure service outages. For example, natural disaster costs associated with an electricity transmission line would include direct costs (such as reconstruction) and additional maintenance of the line following fire or storm, as well as indirect costs associated with loss of supply to electricity users. However, the CBA would not have to consider the cost of property damage that occurred as a result of fire or storm, as this damage would have occurred regardless of what happened to the electricity line.

The following section gives more detail on approaches to measuring the different costs associated with natural disasters and infrastructure.

Measuring avoided disaster costs

Every piece of infrastructure is different and is thus likely to require tailored analysis of the natural disaster risks. This section sets out some of the items likely to arise.

- **Direct damage to infrastructure**

  Costs associated with direct damage to infrastructure will be considered regardless of the type of infrastructure under consideration. Although the damaged assets vary, the general approach is similar for all types of infrastructure. The cost of direct damage to infrastructure is likely to be the largest component of resilience benefits for new infrastructure, so it is critical to develop reliable estimates.

  Infrastructure damage costs associated with disasters are estimated in terms of asset replacement costs or increased maintenance costs. It is important to note that assets are generally underinsured, so these costs will likely be higher than insured losses.

  When considering asset replacement costs or increased maintenance costs, estimating expected replacement costs should take into account the severity of the hazard and the resilience of the asset. That is, the amount of damage to the infrastructure will depend on the intensity of the event. A one-in-20-year flood event might inundate 20 kilometres of a highway, compared to 60 kilometres inundated during a one-in-100-year flood event.

Data on estimated reconstruction costs can be combined with hazard data to estimate average annual losses and the probability distribution of losses over time. An example is provided in Table G.1.

Table G.1: Estimated damage costs

Frequency	Weighting	Damage to infrastructure	Expected annual cost
One in five years	20%	$1m	$0.2m
One in 10 years	10%	$3m	$0.3m
One in 20 years	5%	$6m	$0.3m
One in 50 years	2%	$20m	$0.4m
One in 100 years	1%	$40m	$0.4m
One in 500 years	0.20%	$100m	$0.2m
One in 1,000 years	0.10%	$200m	$0.2m
One in 10,000 years	0.01%	$800m	$0.1m
Total			**$2.1m**

The calculations in Table G.1 would be made for all project options. For example, a more resilient design could reduce the one-in-10,000-year event cost to $300 million, significantly reducing the average annual cost.

This kind of analysis typically requires a range of technical skills. The approach is data-intensive and requires detailed knowledge of the relationship between elements of infrastructure design and disaster hazards. For example, modelling the range of hazards present requires hazard assessment skills; identifying the tolerance of different project options to natural disaster risks requires engineering skills; and estimating the cost of reconstruction requires quantity surveying skills.

- **Indirect impacts**

  Indirect impacts differ significantly between different types of infrastructure. For example, the loss of electricity supply will harm consumers through food spoilage and loss of household amenity, while destruction of a road may result in broken supply chains and increased travel times.

  Despite these differences, indirect costs can be grouped into broad categories that require fairly similar calculations across different types of infrastructure. These broad categories are described in Table G.2.

  - Commercial and household costs
    Infrastructure damage has flow-on impacts for businesses and households. Infrastructure is built for the services it provides so damaged infrastructure results in loss of service and costs for households and businesses. For example, loss of telephony services creates significant costs for individuals – particularly in emergencies when contact with loved ones is highly valued – and for businesses. In the case of transport infrastructure, damage from natural disasters may cause delays and additional travel times. Travel delays can be estimated based on the type and number of road users affected, as well as additional vehicle operating costs (such as of fuel, oil and maintenance costs associated with longer routes or slower speeds).

For utilities and telecommunications infrastructure, the cost of service disruptions or outages can be estimated by using data on a) the number of businesses/households affected and b) the cost of the disruption to each. The number of businesses and households affected can typically be sourced from modelled data on proposed infrastructure usage. The cost of service outages can be estimated as the value of the provided service multiplied by the length of the outage. For example, if damage to transmission lines is expected to cause a two-hour outage, the value of electricity usage can be multiplied by the number of households and businesses affected. Where proxy data on the value of service is not available, 'willingness-to-pay' surveys for avoided disruptions may be useful (where customers indicate their willingness to pay to avoid a disruption).

– Emergency response costs
Damage to infrastructure may affect emergency response costs for government and private organisations. For example, destruction of a bridge may require the use of helicopters to provide supplies to households. Emergency response costs can be estimated using data from past events. Under the NDRRA, state governments may apply to the Australian Government for reimbursement of expenditure on emergency response during a disaster. The submissions provided to Australian Government provide a proxy indicator of these costs.

Care must be taken to isolate those costs attributable to infrastructure damage relative to other costs.

Table G.2: Types of indirect costs

Infrastructure type	Potential indirect costs
Airports	• Travel time delay for passengers • Costs of delay for freight • Increased costs for airlines • Flow-on effects throughout the airport network.
Telecommunications	• Consumer and business value of reliable telecommunications • Cost of delivering emergency backup systems • Disruption to other services, such as electricity, that may rely on telecommunications • Increase in household cost of natural disasters as a result of inability to access emergency support • Increased disaster response costs.
Roads	• Travel time delay for passengers • Costs of delay for freight • Additional vehicle operating costs • Additional road accident costs • Increased disaster response costs.
Railways	• Travel time delay for passengers • Value of delay for freight.
Ports	• Value of delay for freight • Business disruption costs for supply chain.
Electricity	• Consumer and business value of reliable electricity supply • Disruption to traffic following loss of traffic lights • Loss of essential services that rely on electricity (such as streetlights) • Loss of life due to failure of medical equipment • Increased disaster response costs.
Water	• Consumer and business value of reliable water supply • Disruption from follow-on maintenance works • Illness or death resulting from consumption of contaminated water • Increased disaster response costs.

– Economic cost of social impacts, including inconvenience and stress

Social impacts associated with infrastructure damage can be difficult to quantify, particularly when infrastructure is yet to be built. This information typically comes from data collected during previous similar events. The Roundtable report *The Economic Cost of the Social Impacts of Natural Disasters* (2016) suggests intangible costs associated with natural disasters can be substantial. Where data is not available, the cost of social impacts should be included qualitatively in the CBA.

While not comprehensive, Table G.2 below sets out a range of indirect costs for consideration.

Aggregating natural disaster costs

Each cost component should be considered separately, then aggregated to estimate disaster costs for each proposed option. Resilience benefits only arise when a disaster event actually occurs. As such, estimated disaster costs are multiplied by a probability weighting for each hazard to determine an annual average resilience benefit. As such a detailed hazard assessment (see appendix F) is needed before resilience benefits can be estimated.

Continuing with the electricity transmission line example, it might be estimated that the transmission line will receive minor damage from fire once every five years at a maintenance cost of around $2 million. Further, it could be estimated it will be destroyed by fire once every 50 years with replacement costs of $10 million, and damaged by a storm once a year with maintenance cost of $0.5 million. The expected annual costs due to natural disasters are then $1.1 million ($=1/5\times2 + 1/50\times10 + 1/1\times0.5$).

Total disaster costs are then discounted to present resilience benefits in present-value terms (as per other benefits, and as specified in the CBA framework). For example, if the analysis period for the transmission line is 30 years, the present value is around $13.7 million.

These costs can then be incorporated into standard CBAs.

Example application in Infrastructure Australia template

Part of Infrastruture Australia's *Better Infrastructure Decision-Making Guidelines* (2013) is a Template for Stage 7 (Transport Infrastructure) on solution evaluation.

This template provides the required steps for appraising new infrastructure proposals to the Australian Government. Although the template is designed for transport infrastructure, Infrastructure Australia advises a similar level of detail should be provided by other infrastructure sectors.

To embed resilience within this template, amendments could:

- Add resilience benefits to the list of potential monetised benefits and costs
- Add resilience benefits to the 'deliverability assessment'. For example, through questions like 'Does the proposed infrastructure option effectively deal with disaster risks?', 'How has resilience to natural disasters been included in the proposed option?' and 'Have resilience benefits been monetised?'

In practice, Infrastructure Australia does not provide specific guidelines for how costs and benefits should be measured. Consequently, CBA handbooks provided by the Transport and Infrastructure Council and by other states and territories should be updated with a detailed approach for monetising resilience benefits, as provided in this report. There is an opportunity to include this guidance during the planned stage 2 of the National Guidelines for Transport System Management in Australia (NGTSM) revision project. This project plans to update the 2006 guidelines.

Limitation of our work

General use restriction

This report should not be relied on by any party other than our client. We accept no duty of care to any other person or entity for the use of this report.

16. Transport and Infrastructure Council (2015)