Appendix F: CBA Handbook

A rigorous and well executed Cost Benefit Analysis (CBA) is critically important in convincing State and Commonwealth Government Agencies of the benefits of a proposed resilience plan. A successful CBA can help with:

i. Securing funding

ii. Identifying the most beneficial resilience measure available

iii. Convincing local residents of the overall benefits of the project

iv. Understanding the range of costs and risks that could be incurred in completing the project.

While the CBAs undertaken in this report are more general than what would be required if a specific resilience measure was being implemented, they do follow a standard framework which can be generally applied. This handbook aims to be a brief guide to Local Governments for conducting CBAs relating to developing resilience to natural disasters. It does not necessarily provide the level of on-the-ground information that is required to carry out a reliable CBA, but seeks to outline an approach and data sources which may be useful.

Introduction to CBA

In the context of a policy intervention such as building resilience, the purpose of a CBA is to provide a structured approach to assessing whether or not the policy is likely to result in overall benefits to the economy. A CBA considers the economy in a broad way and should take into account non-monetary factors such as the environment, health and leisure time – the precise set of costs and benefits to be assessed as part of building resilience will be outlined later.

To carry out this economic assessment, a baseline representing business as usual is normally compared to a policy case where the proposed intervention takes place. By comparing outcomes in the baseline with those in the policy case we are able to reach a conclusion on the overall benefit of the proposed policy. There are various ways of measuring the overall net benefit of the project.

Other resources

CBA is an extremely common and long standing approach to assessing the benefits of a proposed policy. As such, there is a wealth of information available on how to undertake CBAs more generally. For example, most jurisdictions have CBA guidelines available from their Treasury, regulatory or Finance departments. These guidelines provide information on conceptual issues such as how to value life as well as practical issues, such as what discount rates should be used in what circumstances.

This type of general information will not be reproduced in this handbook. Rather, this handbook can be seen as an addendum to these general guides which seeks to provide specific information relevant to natural disaster resilience. Important guidelines from each jurisdiction are:

- Australian Government
  - Department of Finance and Deregulation: Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies
  - Department of Finance and Deregulation: Handbook of Cost-Benefit Analysis
  - Department of Finance and Deregulation: Appendix E of the Best Practice Regulation Handbook
  - COAG: Appendix C of the COAG Best Practice Regulation Guide
  - Infrastructure Australia: Guidelines for making submissions
  - Infrastructure Australia: Regional Infrastructure Fund Guideline.

Table F.1: Common measures of benefit in a CBA

Measure	Calculation	Interpretation
Net present value (NPV)	Future flows of costs and benefits are brought to present value terms and netted	A value >0 implies net benefits
Benefit cost ratio (BCR)	The ratio of present value of benefits and present value of costs is calculated	A value >1 implies net benefits
Internal rate of return	The implicit return on initial investment is calculated.	IRR > alternative rate of return implies net benefits

- **Queensland**
  - – Treasury: Project Assurance Framework – Cost Benefit Analysis
  - – Environmental Protection Agency: Environmental Economic Evaluation.
- **NSW**
  - – Treasury: NSW Government Guidelines for Economic Appraisal
  - – NSW Department of Urban Affairs and Planning: Guideline for economic effects and evaluation in EIA.
- **ACT**
  - – Treasury: Appendix C of Best Practice Guide for Preparing Regulatory Impact Statements.
- **Victoria**
  - – Department of Treasury and Finance: Appendix C of the Victorian Guide to Regulation
  - – Department of Transport: Guidelines for Cost-Benefit Analysis
- **South Australia**
  - – Government of South Australia: Appendix G of the Better Regulation Handbook
  - – Department of Treasury and Finance: Guidelines for the Evaluation of Public Sector Initiatives.
- **Western Australia**
  - – Department of Treasury and Finance: Project Evaluation Guidelines.

CBA for natural disaster resilience

The guidelines listed above will provide a firm basis for conducting a CBA. The rest of this handbook provides guidance on how these general approaches can be refined into an analysis that is closely targeted at natural disasters and building resilience.

Overall approach

Conducting a CBA for building resilience to natural disasters is somewhat different to a standard CBA as it focuses almost entirely on costs.

The canonical CBA involves weighing up the initial costs of an investment against a stream of benefits flowing into the future. A good example of this is construction of a bridge to reduce travel time. Building the bridge requires an initial investment (the cost) but results in a permanent reduction in travel time for all those using the bridge (the benefits). In this case if the benefits in terms of reduced travel time outweigh the costs of building the bridge then the project creates net economic benefits.

In contrast, a CBA looking at building natural disaster resilience considers the expected costs of natural disasters in a baseline case and the costs of natural disasters in a policy case. The difference between the two cases is created by expenditure on a resilience measure – another cost. The CBA is therefore weighing up the costs of investment in resilience compared to the reduction in natural disaster costs.

In a more stylised sense, the overall process of a natural disaster resilience CBA is to:

1. Estimate baseline natural disaster costs
2. Identify and cost a series of resilience measures
3. Re-estimate natural disaster costs
4. Compare costs of resilience to reduction in natural disaster costs.

Each of these steps will be considered in order.

Figure F.1: Overall CBA process

Estimate baseline natural disaster costs

The most important point to note here is that total economic costs of natural disasters are different from insured costs. Insured costs of natural disasters only capture the losses accruing to insured assets – they do not pick up uninsured assets or broader economic costs (such as emergency response costs and loss of life).

When conducting a CBA for a resilience measure the total economic costs are used, rather than insured costs.

The main source for how to estimate total economic costs of natural disasters is a report from the Bureau of Transport Economics (2001) 'Economic Costs of Natural Disasters in Australia' (BTE is now known as the Bureau of Infrastructure, Transport and Regional Economics). This source provides an overall framework which allows us to go through item by item to quantify costs and benefits where possible or consider effects qualitatively where quantification is not possible.

Under BTE's approach, the total economic costs of a natural disaster are broken down into four broad categories based on a combination of whether the costs are directly and indirectly caused by the natural disaster and whether the costs are tangible or intangible:

The total economic costs of a natural disaster can then be estimated by considering each of these cost categories in turn.

However, before considering each cost category it is also worth noting that BTE provide a set of general multipliers which can be used to turn insured losses into total economic losses. These multipliers may be useful to get an initial estimate of total economic costs before commencing a line by line estimation. Alternatively they could be used in initial analysis of resilience measures where a detailed estimate of total economic costs is not justified. The multipliers recommended by BTE are shown in the table below.

To apply these multipliers, the insured losses are simply multiplied by the multiplier. For example, if insured losses of a storm were estimated at \$1.5bn then total economic costs would be estimated at \$4.3bn (= \$1.5bn × 2.86).

Table F.3: Total economic cost multipliers

Natural disaster type	Multiplier
Storm	2.86
Cyclone	5
Flood	10
Earthquake	4
Fire	2.86
Hail	2.86

Source: BITRE (2001)

Table F.2: Economic costs of a natural disaster

	Direct	Indirect
Tangible	• Damage to buildings • Damage to infrastructure • Damage to crops and livestock.	• Emergency response costs • Household costs • Commercial costs • Loss of production.
Intangible	• Death • Injury • Personal items and memorabilia.	• Psychological • Inconvenience and stress.

Source: BTE (2001)

While these multipliers may be suitable for an initial or high level analysis, for a detailed CBA it is important to consider each cost category separately and build up a total picture of natural disaster costs. Each category in Table F.2 is considered in turn below. Most categories have a bottom-up and top-down approach outlined. The bottom-up approach is likely to provide more detail and a higher level of accuracy while, in some cases, the top-down approach may be the only approach available given data restrictions or may provide a level of analysis suitable to the current task. In a sense the top-down approaches below sit somewhere between the multipliers, shown above, and the bottom-up approach in terms of accuracy, reliability and detail.

Note on costs

Costs below are presented in 2011 dollars to align with the most up to date cost estimates included in the Insurance Council of Australia natural disaster database. Costs from BTE (2001) have been updated using a CPI adjustment.

• Damage to buildings

This cost category also encompasses damage to other property such as motor vehicles and home contents. When assessing these costs it is important to keep in mind that total asset losses are likely to be higher than insured losses as assets are, generally, underinsured.

These costs are likely to be the largest component of the costs of a natural disaster and it is therefore critical to develop good estimates in this area.

Assessing the extent of this damage requires information on:

- The natural disaster risks present in the area
- The value of assets in the area
- The relationship between the natural disaster risk and the value of assets that are damaged.

The task is, in essence, to model the presence of natural disaster risks and relate the risk to damage of assets. This can be done in a bottom-up way (looking at the nature of the risks and the presence of assets in the area) or in a top-down way (looking at historical probabilities of disaster and the associated loss).

Bottom-up

For example, bottom up modelling of flood risks could be done by considering the topography of the local area, the likely depth of flood waters, the location and floor heights of housing, the height of storage of goods within houses and the value of these assets. This could be combined to provide an annual average loss estimate as well as a probability distribution of this loss over time.

Bottom up modelling of this type is a complicated task and requires specific skills and experience. Some Councils have teams already established with the range of meteorological and actuarial skills required to undertake this modelling.

However, it is likely that external sources will need to be drawn on. As an initial source of external data, there are projects underway from the Commonwealth Government to centralise and disseminate available information on natural disasters. The prime example here is the National Flood Risk Information Project being undertaken by Geoscience Australia.

In addition, modelling of risks may require the use of external consultants or the use of State Government agencies. For example, CSIRO has capabilities in modelling flooding and bushfire events and the Bushfire CRC is developing a detailed bushfire model. There are also many models and data available from private consultancies such as AIR Worldwide's Australian models covering bushfire, cyclone and earthquake as well as PSMA's G-NAF database of housing locations in Australia.

Top-down

Modelling from a top-down perspective is far less data intensive but still requires the application of specific skills and techniques. A top-down perspective would mainly focus on the historical data on disasters in the local area and the damage that these disasters caused. For example, it might be found that an average year sees $20m of flood damage while, approximately, every 10 years there is damage exceeding $50m and every 50 years there is damage exceeding $100m. Good examples of this type of analysis can be found in research undertaken by Risk Frontiers, such as 'Australian Bushfire: Quantifying and Pricing the Risk to Residential Properties'.

While being easier to undertake, top-down modelling may miss some important features that bottom-up modelling can identify. These could include: increased risk from housing developments in new areas; or increased prevalence of natural disasters.

Output

The main output from this type of analysis is a table similar to the following:

Table F.4: Estimated risk to buildings, vehicles and contents

Approximate frequency of event	AEP (probability weighting)	Estimated loss ($m)
1 in 5 year	20%	5
1 in 10 year	10%	15
1 in 20 year	5%	30
1 in 50 year	2%	100
1 in 100 year	1%	200
1 in 500 year	0.2%	500
1 in 1000 year	0.1%	1,000
1 in 10,000 year	0.01%	4,000
Average annual		**10**

This table allows for an annual average loss to be used in the CBA as well as a distribution of this average annual loss to be used in risk assessments. Each of the following categories of cost can be added as an additional column to the table above.

Other output which could be generated from this modelling and which is required for further analysis is:

- Number of buildings damaged (residential, commercial and public)
- Number of buildings destroyed (residential, commercial and public)
- Number of people evacuated or made homeless
- Number of people killed
- Number of people injured
- Area of farmland affected.

• Damage to infrastructure

The damage to infrastructure category captures costs associated with assets not covered in the damage to buildings category. These are assets such as roads, electricity networks, sewerage, telecommunications networks and parks.

All of these assets have the same feature that they are large and concentrated in specific locations. Many of these assets will also be owned by governments and may not have information on their value readily available.

As with damage to buildings, damage to infrastructure can be estimated in a bottom-up or top-down way.

Bottom-up

The bottom up approach here is similar to the bottom up approach for estimating damage to buildings. It involves assessing the presence, type and location of infrastructure within the geographic area and modelling the risks of this infrastructure being damaged. For example, it may be found that there are 20km of highway within the area which would be inundated in a 5% AEP flood and 60km that would be inundated in a 1% AEP flood. This information can be used to calculate costs of reconstruction and can be added to the costs shown in Table F.4.

This approach is data intensive as it requires a knowledge of what infrastructure is present, its exposure to natural disaster risks, its resilience to natural disaster risks and the cost of reconstruction.

A good example of a bottom-up assessment of damage to infrastructure is contained in Molino Stewart's 2012 report on the Hawkesbury Nepean.

Top-down

Alternatively, a top down approach can be used. In this case the top down approach relies on the fact that most essential public infrastructure which is not captured in damage to buildings, falls under Category B of the NDRRA. Under the NDRRA, state governments apply to the Australian Government for re-imbursement of expenditure resulting from natural disasters. As part of this process, state governments must make submissions to the Australian Government. These submission can be used as a data source for the extent of damage to infrastructure caused by a natural disaster.

Gathering this information for a specific local government area would require the assistance of the State Government.

This data can be used to align infrastructure expenditure to past natural disaster events to gauge the relationship between natural disaster severity and expenditure on infrastructure.

As a rule of thumb, our historical analysis suggests that every dollar of insured losses results in the following expenditure by all levels of government on infrastructure:

Table F.5: Public infrastructure expenditure as proportion of insured costs

Expenditure per dollar of insured costs	
ACT	Historical data unreliable, maximum of 60c
NSW	20c
Victoria	19c
Queensland	15c
Western Australia	Historical data unreliable, maximum of 60c
South Australia	18c
Tasmania	32c
Northern Territory	15c
Total	**15c**

Source: BTE (2001) updated by Deloitte Access Economics

Additionally, our analysis of historical claims suggests that claims are made, on average, over the three years following the natural disaster with 48% made in the year following the natural disaster, 32% the year after that and 20% the year after that.

• Damage to crops and livestock

Assessment of costs related to crops and livestock can be done in a number of ways, each in varying levels of detail.

Bottom-up

If the natural disaster modelling undertaken for buildings also covers damage caused to agricultural areas then it is possible to build up a picture of total costs. This is done by accounting for the number (or value) of beasts, crops and infrastructure damaged. For example, ABARES' AGSurf database has information available on average area sown and average herd and flock size as well as data on average sale prices for farm outputs. These can be used to estimate a value of assets on farms in the area. This can then be combined with the following standard values from BTE (2001) for agricultural infrastructure to estimate the total value of agricultural assets.

Table F.6: Standard values for agricultural infrastructure

Item	Value
Fences ($/km)	7,300
Pasture ($/Ha)	
Dryland	
5-7days inundation	0
>7 days inundation	131
Irrigated	
5-7days inundation	44
>7 days inundation	539

Source: BTE (2001) updated by Deloitte Access Economics

Top-down

The top-down approach for valuing agricultural production is to consider the value of agricultural production lost due to natural disasters. As with the bottom-up approach, this requires some information about the severity of natural disasters in the area but relates this to aggregate agricultural production in the area, rather than the stock of agricultural assets in the area.

Table F.7: Standard values for livestock ($/head)

Item	Dairy	Beef	Sheep for wool production	Sheep for lamb production
Value	948	700	48	73
– High	816	598	39	66
– Average	671	496	34	51
– Low	87	87	12	12
Carcass disposal	948	700	48	73

Note: carcass disposal is added onto value to estimate total cost per head

Source: BTE (2001) updated by Deloitte Access Economics

For example, according to ABS cat number 7503.0, the Riverina region of NSW produces $1.8m of agricultural commodities each year. If the natural disaster modelling suggests that a flood will affect 5% of agricultural land every 10 years and 20% of land every 50 years then this translates to average losses of $90,000 every five years and $360,000 every 50 years. This calculation should also take into consideration seasonal patterns in agricultural production in the area. For example, if a flood occurs in a primarily wheat producing area during a time when many fields are fallow than losses would be expected to be far lower than the average value of production.

• Death and Injury

Estimating the costs of death and injury relies on two pieces of information. First, the number of people killed and injured is required. Second a dollar value for the value of death and injury is needed.

The first piece of information, the number of people killed and injured, should be sourced from the natural disaster modelling undertaken as part of the assessment of damage to buildings.

The second piece of information, the value of death and injury, relies on an economic concept called the value of statistical life. According to the OBPR (2008): 'the value of statistical life is an estimate of the financial value society places on reducing the average number of deaths by one' and 'the value of statistical life is most appropriately measured by estimating how much society is willing to pay to reduce the risk of death'. The VSL is a well established economic concept but there is a great deal of variability in estimates. For example:

- Updating the VSL used by BTE (2001) to today's dollars provides an estimate of $1.9m per death avoided
- Guidelines from OBPR based on a literature review recommend a value of $3.5m (OBPR 2008)
- Recent academic research identified a VSL in Australia of around $6m (Hensher et al 2009).

In general we recommend using a VSL of $3.5m in line with recommendations from OBPR. However, some jurisdictions may have their own recommendations for VSL and, if this exists, it should be used in preference to the OBPR recommendation.

Values for serious injury and minor injury can be inferred from the VSL. Recommendations from OBPR do not contain any VSL estimates and so we recommend using figures drawn from BTE (2001):

- Serious injury: $850,000
- Minor injury: $28,500.

BTE (2001) also recommends assuming a ratio between serious and minor injury of 1:2.

• Emergency response costs

Emergency response costs are estimated in roughly the same way as top-down approach to damage to infrastructure. Expenditure on emergency response falls under Category A of the NDRRA. Under the NDRRA, state governments apply to the Australian Government for re-imbursement of expenditure resulting from natural disasters. As part of this process, state governments must make submissions to the Australian Government. These submission can be used as a data source for the extent of damage to infrastructure caused by a natural disaster.

Gathering this information for a specific local government area would require the assistance of the State Government.

This data can be used to align emergency response costs to past natural disaster events to gauge the relationship between natural disaster severity and expenditure on infrastructure.

As a rule of thumb, our historical analysis suggests that every dollar of insured losses results in the following expenditure by all levels of government on infrastructure:

Table F.8: Emergency response expenditure as proportion of insured costs

	Expenditure per dollar of insured costs
ACT	Historical data unreliable, likely maximum of 4c
NSW	3c
Victoria	36c
Queensland	2c
Western Australia	Historical data unreliable, likely maximum of 4c
South Australia	18c
Tasmania	7c
Northern Territory	3c
Total	**4c**

Source: Deloitte Access Economics analysis

Additionally, our analysis of historical claims suggests that claims are made, on average, over the three years following the natural disaster with 48% made in the year following the natural disaster, 32% the year after that and 20% the year after that.

• Commercial and household costs

Similar to death and injury estimating commercial and household costs relies on two pieces of information. First, the number of premises affects and, second, a dollar value for each premises.

The number of premises affected should be established in the natural disaster modelling undertaken as part of the assessment of damage to buildings.

Standard multipliers can then be used to convert the number of premises affected into a total cost. Based on BTE (2001) a reasonable set of multipliers to be used are set out in the table below. These are based on a combination of fixed and labour costs set out in more detail in BTE (2001).

In addition to these clean-up costs, evacuation costs should also be included. Again, BTE provides reasonable standard values for these:

Evacuation costs: $77 fixed cost and $38 for each additional night, per person.

Table F.9: Commercial and household clean-up costs per building

	$ per building
Residential	5,900
Commercial	3,800
Public	14,600

Source: BTE (2001) and Deloitte Access Economics

• Loss of production

In general, loss of production is not included in a CBA looking at natural disaster costs.

However, whether to include or exclude production largely comes down to a decision on the scope of the CBA. It is generally good practice to consider the CBA in terms of the broader Australian economy; from this perspective it is likely that production is able to shift from one location to another. That is: losses in production for a business in the disaster area are offset by gains in production for another business elsewhere in Australia.

For example, a light manufacturer located in Brisbane may have to close their business for a week following a flood and so cannot supply their products to market. Users of their products would then seek out the next best alternative and purchase from its manufacturer – transferring their expenditure within the economy.

From a national perspective, it is only in rare cases where loss of production from natural disasters should be accounted for. This involves cases where imports or exports are affected or where unique production abilities are affected. For example, if there is the potential for exports of key commodities to be affected then the loss of these exports could be included in the CBA.

• Personal items, memorabilia, psychological, inconvenience and stress

These costs, while important, are generally difficult to quantify and so are normally treated in a qualitative manner. A good approach is to develop case studies of individuals affected by previous natural disasters.

With this underlying modelling and associated valuations it is then possible to create an estimation of the extent of total economic costs of the natural disaster. The approach is, essentially, to extend Table F.4 adding a column for each disaster cost identified above. As a guide, the following page contains an example calculation (populated with dummy data) of total economic costs of a natural disaster (Table F.10).

The CBA can then move onto the second stage of the analysis: identify and estimating the benefits related to building resilience.

Table F.10: CBA Model Extract (1)

Standard Values

Fences ($/km)	7,300

Death ($ per person)	3,500,000

Pasture ($/Ha)		
Dryland	Dryland	Irrigated
5–7days inundation	0	44
>7 days inundation	131	539

Cleanup ($ per building)	
Commercial	5,900
Residential	3,800
Public	14,600

Evacuation	
Fixed cost per person	77
$ per night per person	38

	Value	Share
Major injury ($ per injury)	850,000	33%
Minor injury ($ per injury)	28,500	67%

Livestock ($/head)				
Item	Dairy	Beef	Sheep for wool production	Sheep for lamb production
Value	948	700	48	73
– High	816	598	39	66
– Average	671	496	34	51
– Low	87	87	12	12
Carcass disposal	948	700	48	73

Natural Disaster Modelling results

			Assets ($)						Agriculture				People			Buildings
Frequency	Weighting	Damage to buildings ($m)	Damage to infrastructure	Hectares of farmland inundated	Fences destroyed (km)	Dairy (head)	Beef (head)	Sheep for wool production (head)	Sheep for lamb production (head)	Deaths	Injuries	Number evacuated	Nights evacuated	Commercial	Residential	Public
1 in 5 year	20%	5	1	10	100	28	65	71	40	1	7	101	253	4	34	1
1 in 10 year	10%	15	3	17	300	49	194	124	120	3	21	304	760	13	102	4
1 in 20 year	5%	30	6	22	500	63	323	160	201	5	35	506	1,235	21	169	6
1 in 50 year	2%	100	20	30	900	84	581	214	361	9	63	909	2,271	38	303	11
1 in 100 year	1%	200	40	35	1,200	97	775	247	481	12	84	1,212	3,030	50	404	15
1 in 500 year	0.20%	500	100	39	1,500	109	969	277	602	15	105	1,512	3,781	63	504	19
1 in 1000 year	0.10%	1,000	200	42	1,800	119	1,163	303	722	18	126	1,817	4,543	76	605	23
1 in 10,000 year	0.01%	4,000	800	46	2,100	129	1,357	327	842	21	147	2,118	5,294	88	706	26

Cost estimates ($m)

Frequency																Weighting	Total
1 in 5 year	20%	5.0	1.0	0.0	0.7	0.0	0.1	0.0	0.0	3.5	2.0	0.0	0.0	0.0	0.1	0.0	12.5
1 in 10 year	10%	15.0	3.0	0.0	2.2	0.1	0.2	0.0	0.0	10.5	5.9	0.0	0.0	0.1	0.4	0.1	37.5
1 in 20 year	5%	30.0	6.0	0.0	3.7	0.1	0.4	0.0	0.0	17.5	9.8	0.0	0.0	0.1	0.6	0.1	68.5
1 in 50 year	2%	100.0	20.0	0.0	6.6	0.1	0.7	0.0	0.0	31.5	17.7	0.1	0.1	0.2	1.2	0.2	178.4
1 in 100 year	1%	200.0	40.0	0.0	8.8	0.2	0.9	0.0	0.1	42.0	23.6	0.1	0.1	0.3	1.5	0.2	317.8
1 in 500 year	0.20%	500.0	100.0	0.0	11.0	0.2	1.2	0.0	0.1	52.5	29.5	0.1	0.1	0.4	1.9	0.3	697.2
1 in 1000 year	0.10%	1,000.0	200.0	0.0	13.1	0.2	1.4	0.0	0.1	63.0	35.4	0.1	0.2	0.4	2.3	0.3	1,316.6
1 in 10,000 year	0.01%	4,000.0	800.0	0.0	15.3	0.2	1.6	0.0	0.1	73.5	41.3	0.2	0.2	0.5	2.7	0.4	4,936.0
Average Annual		10.4	2.1	0.0	0.8	0.0	0.1	0.0	0.0	3.9	2.2	0.0	0.0	0.0	0.1	0.0	19.6

Identify and cost a series of resilience measures

After establishing the underlying economic costs of the natural disaster, the next stage of the CBA is related to the resilience measures. The tasks in this stage are to:

1. Identify resilience measures
2. Estimate the costs of the resilience measure.

Both of these steps are intimately related to the resilience measure that is being considered but some general principles can be set out.

• Identify resilience measures

The identification of resilience measures should, initially, seek to encompass a large range of potential policy responses. This broader set can then often be narrowed down to a smaller set of resilience options by a high level consideration of the likely costs and benefits of the option.

The broad set of resilience options should include relatively straightforward approaches such as infrastructure intervention as well as more subtle responses such as information gathering, changed planning, new approaches to compliance or development of community and social based approaches to resilience.

For example, an initial set of resilience options for addressing the flood risk in the Hawkesbury Nepean could include raising the height of the dam wall, river straightening, building levees, improving emergency response planning, changing the required floor height or construction materials of new houses or development of community plans for response to flooding.

From this broader set of resilience options, a smaller group of preferred options can then be looked into in more detail.

• Estimate the costs of the resilience measure

Working with a small group of preferred resilience measures (maybe only one) the next step is to estimate the costs of the measure. This should take into account not only the initial capital expenditure but any ongoing expenditure as well as other effects, such as destruction of environment, reduction in quality of living or shifting natural disaster effects onto neighbours.

The approach to estimating costs will vary significantly from resilience measure to resilience measure. For some basic resilience measures there may be good market data available. This could be the case where the resilience measure involves adding off the shelf products (such as stronger doors) to existing buildings.

In other cases a quantity surveyor may be able to provide estimates of the costs of the resilience measure or, in cases where costs are largely time based, estimates can be developed from the ground up and costed using average wage data. In cases of large, specific resilience measures (such as constructing a dam or levee), there is likely to be a need to commission original engineering analysis of project costs.

This stage of the analysis will allow an additional set of calculations to be added to the CBA. As a guide, Table F.11 contains an example calculation (populated with dummy data) of costs of a resilience measure.

With these pieces of information it is then possible to estimate the costs of the resilience measure (measured in net present value terms) and to then move into estimating the benefits of the resilience measure.

Estimate benefits of resilience and re-estimate natural disaster costs

The final stage of the analysis, Table F.12, is to re-estimate baseline natural disaster costs taking into consideration the reduction that is created by implementing the resilience measure.

This stage first requires estimating the benefits of resilience for each of the costs outlined in 'estimate baseline natural disaster costs' and then recalculating these costs after accounting for resilience benefits.

Taking an example from the paper, it was found that changing the building code for South East Queensland could be expected to reduce damage from a cyclone by around 66%. This figure was based on historical analysis of the performance of housing in northern Queensland that was built before and after the introduction of similar standards.

In practice, a figure like the 66% above is likely to either be sourced from historical analysis, simulation or by small scale experimentation. In our experience, historical analysis is the most likely source of data. Historical analysis normally takes the form of a research paper looking at trends in natural disaster costs. By comparing areas which differ in aspects of resilience (such as their building standards, their height above sea level, their distance from bushland or their urban surroundings) the benefits of resilience measures can be fairly easily measured – given that there is sufficient historical data to overcome the high degree of variability in natural disasters from year to year.

Table F.11: CBA Model Extract (2)

Resilience calculation

Discount rate	**7%**

Costs of resilience	
Initial cost ($m)	15
Year of construction	2015
Ongoing cost ($m/year)	0.25

Reduction in total natural disaster costs	20%

	Expenditure on resilience
Present Value	14.9
2013	0
2014	0
2015	15
2016	0.25
2017	0.25
2018	0.25
2019	0.25
2020	0.25
2021	0.25
2022	0.25
2023	0.25
2024	0.25
2025	0.25
2026	0.25
2027	0.25
2028	0.25
2029	0.25
2030	0.25
2031	0.25
2032	0.25
2033	0.25
2034	0.25
2035	0.25
2036	0.25
2037	0.25
2038	0.25
2039	0.25
2040	0.25
2041	0.25
2042	0.25
2043	0.25
2044	0.25
2045	0.25
2046	0.25
2047	0.25
2048	0.25
2049	0.25
2050	0.25

Modelling is an alternative approach to historical analysis and can be advantageous where good historical data is not available or where the underlying relationship between a natural disaster event and the resulting damage is well known. For example, modelling is particularly useful in flooding where the height of floods can be lowered within a model and the number of households no longer affected can be easily measured.

Small scale experimentation such as exposing scale model housing to various natural disaster risks can generate good data on the benefits of resilience measures which have not yet been implemented but is, in our experience, rare.

After establishing the likely benefits of resilience the task is largely a mechanical exercise of reducing estimated effects where appropriate. Taking up the cyclone example again, the reduction in damage to housing could realistically be applied to damage to residential and commercial buildings. A reduction in emergency response expenditure, clean-up costs, death, injury and evacuation would also be expected as fewer houses are damaged. However, a reduction in agricultural losses would not be expected to result from this resilience measure.

The task in this case would be to reduce damage to residential and commercial buildings, emergency response expenditure, clean-up costs, death, injury and evacuation costs by around 66% (there might be variability from 66% due the presence of fixed costs, for example).

Table F.12: CBA Model Extract (3)

Resilience calculation

Discount rate	7%

Costs of resilience	
Initial cost ($m)	15
Year of construction	2015
Ongoing cost ($m/year)	0.25

Reduction in total natural disaster costs	20%

	Expenditure on resilience
Present Value	14.9
2013	0
2014	0
2015	15
2016	0.25
2017	0.25
2018	0.25
2019	0.25
2020	0.25
2021	0.25
2022	0.25
2023	0.25
2024	0.25
2025	0.25
2026	0.25
2027	0.25
2028	0.25
2029	0.25
2030	0.25
2031	0.25
2032	0.25
2033	0.25
2034	0.25
2035	0.25
2036	0.25
2037	0.25
2038	0.25
2039	0.25
2040	0.25
2041	0.25
2042	0.25
2043	0.25
2044	0.25
2045	0.25
2046	0.25
2047	0.25
2048	0.25
2049	0.25
2050	0.25

	Baseline natural disaster costs	Reduced natural disaster costs
Present Value	745.9	596.8
2013	19.6	15.7
2014	19.6	15.7
2015	19.6	15.7
2016	19.6	15.7
2017	19.6	15.7
2018	19.6	15.7
2019	19.6	15.7
2020	19.6	15.7
2021	19.6	15.7
2022	19.6	15.7
2023	19.6	15.7
2024	19.6	15.7
2025	19.6	15.7
2026	19.6	15.7
2027	19.6	15.7
2028	19.6	15.7
2029	19.6	15.7
2030	19.6	15.7
2031	19.6	15.7
2032	19.6	15.7
2033	19.6	15.7
2034	19.6	15.7
2035	19.6	15.7
2036	19.6	15.7
2037	19.6	15.7
2038	19.6	15.7
2039	19.6	15.7
2040	19.6	15.7
2041	19.6	15.7
2042	19.6	15.7
2043	19.6	15.7
2044	19.6	15.7
2045	19.6	15.7
2046	19.6	15.7
2047	19.6	15.7
2048	19.6	15.7
2049	19.6	15.7
2050	19.6	15.7

Compare costs of resilience to reduction in natural disaster costs

The final stage of the analysis is purely mechanical. The difference in natural disaster costs under the baseline and in the case where resilience measures are put into place are compared to the costs of building resilience. This can be done using a number of measures but for natural disaster resilience the two most useful are to consider are net benefits and the benefit cost ratio:

Net benefits = Present value of Benefits-Present value of costs

$$\textit{Benefits cost ratio} = \frac{\textit{Present value of benefits}}{\textit{Present value of costs}}$$

Using figures from the above example

$$\begin{aligned}\textit{Present value of Benefits} &= \textit{Baseline natural disaster costs} - \textit{Reduced natural disaster costs}\\ &= 745.9 - 596.8 = 149.2\end{aligned}$$

$$\begin{aligned}\textit{Present value of costs} &= 14.9\\ \textit{Net benefits} &= 149.2 - 14.9 = 134.3\end{aligned}$$

$$\textit{Benefit cost ratio} = \frac{149.2}{14.9} = 10.0$$

These can then be analysed using the decision rules outlined in Table F.1, which suggest that the modelled resilience measure creates significant economic benefits.

Summary

Conducting a cost benefit analysis for natural disaster resilience is not significantly different from other cost benefits analyses. As such, the starting point is to be familiar with the applicable guidelines documents. Following on from these, there are a number of specifics which can be added for natural disaster resilience.

The overall approach for natural disaster resilience is to estimate the economic costs of a natural disaster a baseline and under a policy of improved resilience. The difference in these costs can be compared to the costs of developing the resilience – this is the CBA.

The approach for estimating economic costs of a natural disaster is well established and is clearly outlined in BTE (2001). This handbook has provided an update and streamlined guide to the BTE report as well as presenting some various options for analysis depending on the level of detail required. If these steps are followed a CBA can be developed which will clearly show the expected costs and benefits of any resilience measure.

Limitation of our work

General use restriction