

Handbook CATLoG (Climate Adaptation Tool for Local Governments)

Prioritising Climate Change Adaptation Investments for Local Governments with Particular Focus on Extreme Events

Background

Development of CATLoG (Climate Adaptation decision-making support Tool for Local Governments) is a National Climate Change Adaptation Research Facility (NCCARF) funded project specifically meant to assist decision makers in comparing and prioritising climate change adaptation investments with particular reference to extreme events. The Excel-based Tool is specifically developed for Local Government use and is a result of contributions from a multi-disciplinary research team at Macquarie University and University of New South Wales and partner Councils Ku-ring-gai and Gosford.

The analysis of climate extremes is particularly important because of their high impact nature. Unfortunately, often end users do not understand the range of uncertainties surrounding the research outputs they use for extreme event climate adaptation decision-making. CATLoG will equip end users with an MS Excel™ based software Tool to analyse and rank adaptation options with the help of a combination of quantitative and qualitative evaluation methods. This handbook comprises of a guideline to assist stakeholders' usage of the CATLoG Tool. A simple worked out example is given as Appendix A and potential solutions to compile errors of the Tool are given as Appendix B.

1) Introduction

In CATLoG the evaluation of adaptation investment options is conducted in two main steps:

- A. Economic (or financial) analysis of options (quantitative evaluation of options):
 - a. Analysis of extreme events
 - b. Assessment of economic damage
 - c. Cost-Benefit Analysis (CBA) of adaptation options
- B. Multi-Criteria Analysis (MCA) of adaptation options (Qualitative evaluation of options)

A. Economic analysis of options

a. Analysis of Extreme Events

Extreme events are characterised by little data and hence their analysis i.e. frequency and severity predictions usually require additional sources of information such as expert opinions. This software tool determines the frequency of occurrence of events based on information provided by experts and past observations of the extreme event considered. The method of combining expert opinions with historical data is known as Bayesian inference and has become quite popular in financial risk analysis when only a small number of observations is available, see e.g. Shevchenko and Wüthrich (2006) or Shevchenko (2011). In the current version of the tool, past observations of damage due to extreme events are not used for calculating the economic damage as it was observed that damage data was difficult to obtain and software modelling of the expert opinions and severity data together was complex and time consuming. Thus, in this version of the Tool economic damage (severity of events) is calculated based only on the information entered by experts. Frequency of extreme events is modelled using the Poisson distribution (commonly used for frequency modelling) and the severity (damage) is modelled using the Lognormal, Weibull or Burr distributions in CATLoG. Thus in short analysis of extreme events requires entering details of frequency and severity of the extreme events.

b. Assessment of economic damage

Economic assessment of damage includes calculation of the economic impact of the extreme event considered over a period of time. This requires entering values for input parameters such as time horizon, discount rate and growth rate. The time horizon represents the total time period over which the damage assessment is to be conducted (e.g. 40 years). This depends on the planning periods of the Council conducting the assessment. At the Council level, it is usual to have short term planning periods, but we suggest a minimum time horizon of 20-40 years as the focus is on climate change impacts which are long term whose effects become evident at longer time scales than the planner periods. Next, discounting is necessary to convert future monetary units into present monetary amounts so that a valid comparison can be made with the costs incurred in present money terms.

Currently, there is a lot of debate around the appropriate choice of a discount rate for such analysis, with suggestions ranging from relatively low values around 0.5-1.5% per annum (social discount rate) up to the financial cost of borrowing what could be up to >10% (under a high interest rate scenario). To illustrate the so-called *time value of money* and the importance of the discount rate let us consider the following example: assume that John invests \$10,000 today into a risky asset with an annual interest rate of 10%. At the end of the year, John gets a return of \$11,000. This means that \$11,000 a year later is equivalent to having \$10,000 today and from an investor's point of view a discount rate of 10% may be apt here. The impacts of climate change on the other hand deal with ethical concerns as they extend to different generations. The ethical justifications for a low discount rate (near zero) are based on the thought that current and future generations should be treated equally and the idea that there is a need to preserve assets for future use as well.

The next input parameter growth rate may also be chosen to represent economic growth, i.e. rising costs for replacement of e.g. infrastructure, but also increase in exposure to risk or increase in economic damage due to the extremes along the time horizon considered. For instance, suppose an expert estimates a damage of 10 houses today in a bushfire risk zone which is likely to increase to 11 houses the next year due to more development in the bushfire risk zone, a growth rate of 10% may be used to represent this increase in the Tool.

The values of parameters such as discount rate, growth rate, time horizon, frequency of events and severity of events are uncertain and hence the Tool provides option to understand the effect of these parameters on the final economic output uncertainty by conducting sensitivity tests. This will help to understand the importance of each parameter and also choose parameter values more carefully. One or more of the parameters: time horizon, discount rate, growth rate, frequency and severity may be changed to study the wide range of possible economic outputs.

c. Cost-Benefit Analysis

Cost-Benefit Analysis that calculates the costs and benefits of a number of alternative adaptation options is used to prioritise the adaptation options. The net benefits in monetary units determine the economic viability of options as well as identify the most preferred option. The benefit of each option is calculated based on the information entered by experts competent and familiar with the local extreme event under consideration. In this part of the Tool, information on to what extent implementation of the adaptation options would reduce the median damage and the worst case damage has to be entered.

B. Multi-Criteria Analysis

The second main part of CATLoG includes qualitative evaluation of the adaptation options. This part is important as economic evaluation as described as the first main part of the tool may not be able to account for all the costs and benefits. Lack of a monetary estimate for climate impacts will not mean that the less tangible can be excluded from the assessment for choosing appropriate

adaptation options (Metroeconomica, 2004). Reliance on qualitative tools becomes necessary if both the costs and/or benefits are not available in monetary units. This CATLoG tool uses MCA (Multi-Criteria Analysis) a qualitative evaluation method to evaluate less tangible impacts of climate extremes and benefits of options. Unlike the Cost-Benefit Analysis discussed earlier, where economic efficiency is the key objective, MCA evaluates adaptation options against multiple objectives such as net economic benefit, improvement of environmental quality, poverty alleviation etc. (Wegner and Pascual, 2011). It can thus also incorporate qualitative, quantitative, monetary and non-monetary data. In summary, in MCA each expert scores (e.g. -100 to 100) each adaptation option against a set of criteria (e.g. environmental benefit, social benefit). Similar to the economic assessments, sensitivity tests also play an integral part of understanding uncertainty in the decisions made using MCA. Sensitivity tests may be conducted by entering different weights for each criterion as well as different weights to the expert confidence attached to each scores.

2) Starting CATLoG

The CATLoG Tool has been programmed using VBA script in MSExcel™ and has been tested to work on MS Office 2003 and higher versions. To start CATLoG open (double-click) the Excel file CATLoG.xls (for MS Office 2003) and CATLoG.xlsm (for MS Office 2007 and higher versions) and follow procedure sections. Macros should be enabled for the Tool to work. If you are running CATLoG for the first time and getting a compile error, you may need to link XLA Solver to ensure the program is able to run in the MS-Excel software installed on your computer (see Appendix B). In MS Office 2003, once the CATLoG Excel file is open select 'Tools' from the main menu and the buttons: Economic analysis and Multi-Criteria Analysis will be seen. In MS Office 2007 and higher versions, after opening the CATLoG.xlsm file, click on the 'Data' tab in the ribbon and then two menu items 'Economic Analysis' and Multi-Criteria Analysis will appear at the right end of the top menu bar.

Table 1 Functionality of start buttons: 'Economic Analysis' and 'Multi-Criteria Analysis'

Economic Analysis	<ol style="list-style-type: none"> 1. Simulate financial losses of extreme event over a period of time 2. Conduct sensitivity tests using different input parameters 3. Conduct Cost-Benefit Analysis of various adaptation options
Multi-Criteria Analysis	<ol style="list-style-type: none"> 1. Rank adaptation options based on qualitative scores given by experts against multiple criteria. 2. Conduct sensitivity analysis of ranks subject to changes in importance assigned to the criteria and confidence attached to the scores of each expert.

3) Economic Analysis

To conduct an economic impact assessment of damage caused by an extreme event over a period of time and/or to conduct Cost-Benefit Analysis of a list of adaptation options, click the 'Economic Analysis' button for MS Excel™ 2003 or select 'Economic Analysis' from the drop down menu of 'Economic Tool' for MS Excel™ 2007 and higher versions. This will take you through 3 input windows before calculating the financial loss distribution. In the first window details on the frequency of occurrence of the events needs to be added.

Input window 1: Frequency of events

This input window consists of questions that help to collect information on the frequency (number of events per year) of the extreme event under study. Firstly, the users will have to enter details on how frequent the extreme event under study is on an average case. If the event occurs every 10 years, then events per year should be entered as 0.1, alternatively the number of events and number of years considered may be entered in the two input boxes below events per year and the number of events per year will be automatically calculated. If the event is once in every 20 years, then events per year should be entered as 0.05 or as 1 event per 20 years. Next, a range for the frequency of extreme events (upper and lower bounds) should be entered along with a probability that the average number of extreme events will fall under this range: default value is 0.66.

The screenshot shows a software window titled "Climate Extremes Wizard Step 1 of 3". The main heading is "Frequency of Events". It is divided into two columns of input fields. The left column, under "Expert Opinion", has three pairs of input boxes: "Events per Year" (with an empty box), "Lower Bound" (with an empty box), and "Upper Bound" (with an empty box). Each pair is followed by "Or" and two more empty boxes with "per" and "years" labels. Below these is a "Probability" field containing the value "0.6666667". The right column, under "Previous Events", has two input boxes: "Number of Years" and "Number of Events", both empty. At the bottom, there are four buttons: "Cancel", "<< Previous", "Next >>", and "Run". A progress bar at the bottom left shows "0%".

Figure 1 Snapshot of input window where user enters details on the frequency of the extreme event

Assume that an event occurs once in 10 years (0.1), then information of a range should also be given into which the average frequency will fall into. This means a range may be described as say there is a high chance (0.66 is used as default value) that the event occurs between once in 5 years (upper bound = 0.2) and once in 15 years (lower bound = 0.06667). Note that lower bound is less than upper bound and the average frequency is in between, that is lower bound < average < upper bound. In the above discussed example, upper bound = 0.2; average = 0.1 and lower bound = 0.06667. Finally, users should also enter information based on any previous events as the total number of events in a given time horizon considered. For instance, consider that there were 2 events in the past 40 years of historical data, then enter number of years as 40 and number of events as 2. The Tool will automatically update the expert opinion with the information on the previous events.

Input window 2: Severity of events

In this input window details on the median (value that separates upper half of the data from the lower half data) expected damage of an event (in Australian dollars) as well as the expected worst-case damage are required. Apart from that users can choose type of distribution (Weibull, Lognormal and Burr distribution used to model less extreme damage to most extreme damage) to model the extreme event damage. For example, the user enters may enter median to be 10,000,000 (10 Million Australian dollars) and the worst-case as 15,000,000 (15 Million Australian dollars). By default, the Lognormal distribution will be chosen as it is most commonly used for financial loss modelling. There is no shortcut method to determine the most suitable distribution, but other distributions may be chosen based on the opinion from the experts involved in the study. This may depend on the type of extreme considered and the level damage expected.

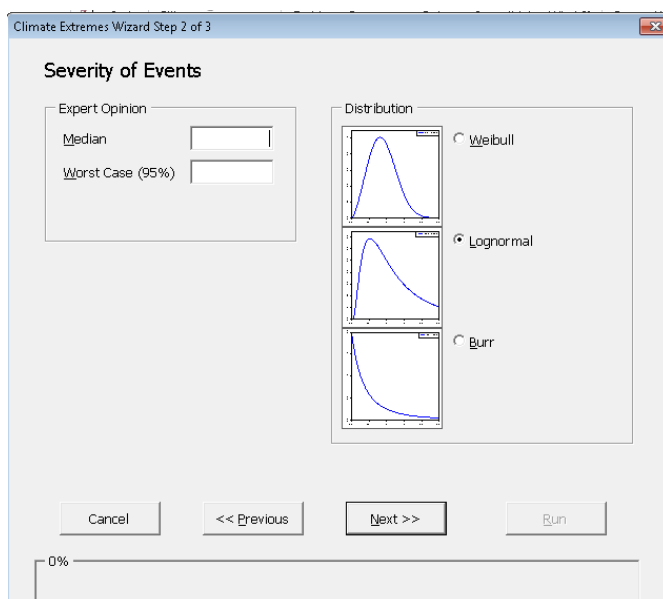
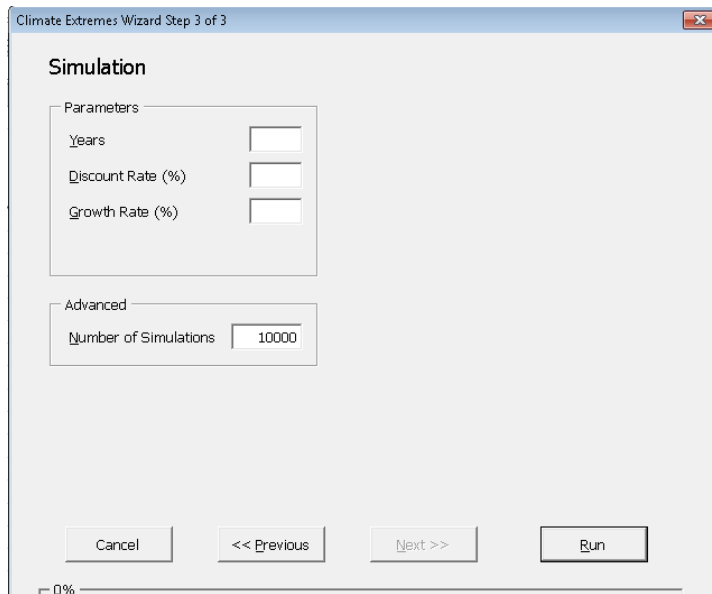


Figure 2 Snapshot of severity input window where users enter details on the damage caused by an extreme event

Input window 3: Simulating the total loss due to the extreme events

In this input window, values of parameters required to simulate the total loss caused by an extreme event over a period of time have to be entered. If the value of the discount rate chosen is 6%, then enter the value 6 should be entered and if the damage is likely to increase annually by 2%, then the value 2 should be entered in the input window. If there is no growth of the damage in the time horizon considered, then 0 should be entered. Under the input space years, enter the time horizon to which the total damage should be calculated, if it is 50 years, then 50 should be entered there.



The screenshot shows a software window titled "Climate Extremes Wizard Step 3 of 3". The window contains a "Simulation" section with two sub-sections: "Parameters" and "Advanced".

- Parameters:** This section contains three input fields:
 - "Years": An empty text box.
 - "Discount Rate (%)": An empty text box.
 - "Growth Rate (%)": An empty text box.
- Advanced:** This section contains one input field:
 - "Number of Simulations": A text box containing the value "10000".

At the bottom of the window, there are four buttons: "Cancel", "<< Previous", "Next >>", and "Run". A progress bar at the bottom left shows "0%".

Figure 3 Snapshot of input simulation window where users enter details on parameters required for modelling the damage accumulated over a period of time

Sensitivity tests: Economic damage

This completes all three input windows for the economic damage assessment and once the Run button is selected in the third window, results of this base-case will be shown in an Excel sheet named Simulation Output. Once the base-case is completed next sensitivity tests may be completed by selecting 'sensitivity test' from the drop down menu of the 'Economic Tool' for MS Office 2007 and higher versions. All base-case values will be automatically displayed in the sensitivity input window. Undertaking a series of sensitivity analyses is an essential part of using any planning tool. In everyday life we arrange our future plans by considering the 'what if' (e.g. what if my salary increases or my partner loses his/her job; what if we have to downsize our home to keep up with loan repayments / rent etc.). Using this planning tool it is also true that gaining an understanding of how important input is, is essential. For example, different economic rates may be chosen based on if loaned funds came free or were charged at 10% interest rates. The other benefit of running a number of sensitivity test is that a user can gain confidence in how the tool behaves and also begin to understand which input variables are very important and which less so. Once this is understood,

extra effort can be focussed on obtaining correct values for parameters that are critical to predictions.

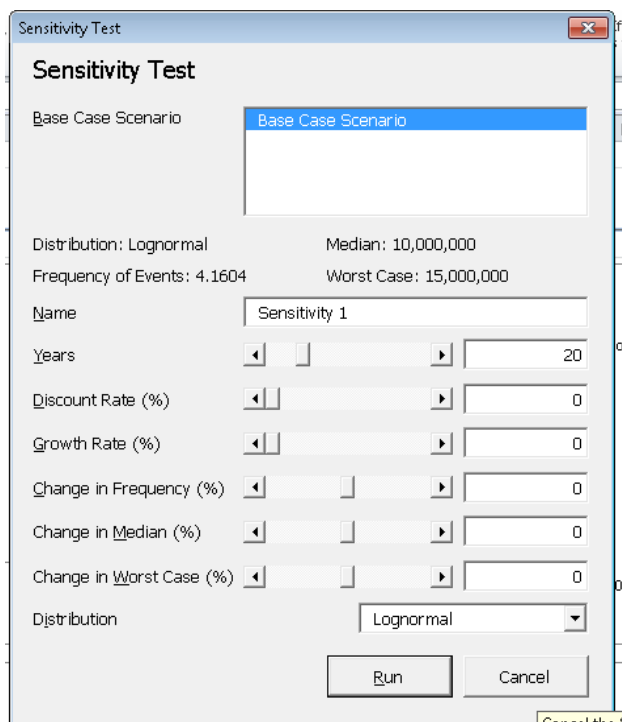


Figure 4 Snapshot of sensitivity test window where users changes input parameters (different from base-case parameters) to understand the significance of each parameter value on the outputs

If a discount rate of 6% is chosen then the damage is discounted annually by 6% and if a growth rate of 2% is chosen that would mean that the damage grows annually by 2%. Similarly, an increase in severity by 10% would mean that the severity is increased annually by this amount. A change in frequency by 10% means that this increment happens uniformly over the chosen time horizon (not annual increment of 10%). For instance, assume that the current frequency is 1 event per year, then a 10% increase in frequency would mean that after 40 years the frequency will be $1 + 0.1 = 1.1$. Here the 10% increment is uniformly distributed over the years with a change of $0.1 / 40 = 0.0025$ every year.

4) Cost-Benefit Analysis

Councils may also want to evaluate the net benefit of adaptation options suitable for their location. A Cost-Benefit Analysis may be conducted by clicking on the 'Cost-Benefit Analysis' button that appears in the drop down menu of the 'Economic Tool'. There will be two input windows for each adaptation option: a window to enter option name and costs and a window to enter benefit due to options as percentage damage reduced, snapshots of which are shown below.

The screenshot shows a dialog box titled "Economic Analysis Step 1 of 2" with a close button in the top right corner. The main heading is "Adaptation Option". Below this heading are several input fields: "Name" (empty), "Description (optional)" (empty), "Capital Cost" (empty), "Annual Maintenance Cost" (empty), "Time Horizon" (set to 40), and "Discount Rate" (set to 6). At the bottom of the dialog are four buttons: "Cancel", "<< Previous", "Next >>", and "Run".

Figure 5 Snapshot of input window where users enter details on adaptation options such as its costs. By default, the input values for time horizon and discount rate are retained as in the base-case for proper comparison with the base-case simulation

The screenshot shows a dialog box titled "Economic Analysis Step 2 of 2" with a close button in the top right corner. The main heading is "Benefit". There are two main sections: "Frequency Reduction" and "Severity Reduction".
Under "Frequency Reduction":
- "Base Case" is 0.113 events per year.
- "Reduction by (%)" is an empty input field.
Under "Severity Reduction":
- "Base Case" has a "Median" value of 20000000.
- "95%" has a value of 100000000.
- "Reduction by (%)" has a "Median" input field and a "95%" input field, both empty.
At the bottom of the dialog are four buttons: "Cancel", "<< Previous", "Next >>", and "Run".

Figure 6 Snapshot of input window where local experts enter details on frequency and severity reduction due to each adaptation option

In the window shown in Figure 6 the base-case values are automatically displayed. Not all options will reduce the frequency of the events and the severity of the events. The value 0 may be entered if an option does not vary say the frequency of events (with respect to the base case damage).

Sensitivity tests: Cost-Benefit Analysis

Now that you have looked at the costs and benefits of your adaptation options, it is useful to see how sensitive they are to changes in the parameters.

Open the sensitivity test window, as above, and select one of the cost-benefit analyses from the list. The parameters that were used for that analysis should be shown in the sensitivity analysis window.

The frequency and severity values used will be from after the adaptation option has been taken into account. So, for example, if the median severity in the base case is 1,000,000 and the adaptation option has a median severity reduction of 20%, the new value of the median severity will be 800,000. This value will also be used in the sensitivity test based on the adaptation option. Therefore, if you want to use this median severity value you should change the “Change in Median” value to 0.

After you have run the sensitivity analysis the numeric results will appear in the last column of the spreadsheet. The loss distribution and cumulative loss will appear on their respective graphs, and the net benefit graphs. Note that the benefit and net benefit are compared to the cost-benefit analysis you selected as the base case for this sensitivity analysis, not the initial scenario.

Multi-Criteria Analysis

The next evaluation option of the Tool includes qualitative evaluation of the adaptation options using Multi-Criteria Analysis. To conduct the criteria analysis, click the 'Data' tab on the ribbon in MS Office 2007 & higher versions / Tools menu in MS Office 2003. The 'Multi-Criteria Analysis' button will appear close to the 'Economic Tool' button. Click on the 'Multi-Criteria Analysis' button and follow the steps described below.

In general, in a Multi-Criteria Analysis a set of options are evaluated against a set of criteria with the help of scores. One or more experts may be involved in this process¹. In the first window, enter the criteria required for evaluation as well as the number of experts participating in the evaluation.

The default criteria are 'Economic', 'Environmental', 'Social' and 'Co-Benefit', as seen in Figure 7. These can be kept as is or removed by highlighting each criterion (by clicking on it) and clicking on the Remove button. Other criteria may be added by typing the name of the criterion in the Criterion Name box and clicking on the Add button. It will appear in the Criteria list. Each criterion can also have a longer description attached to it, but this is optional.

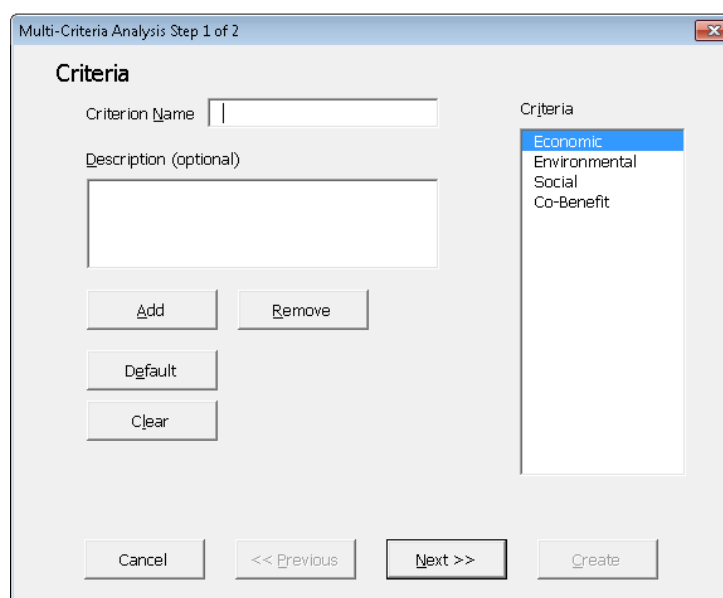


Figure 7 Snapshot of input window where users enter details on qualitative criteria used for evaluation

In the second window (see Figure 8), the name of adaptation options and number of experts involved may be entered.

¹ An "expert" does not need to be a single person. It could be a panel of experts or a community consultation group, for example, who decide on a score together.

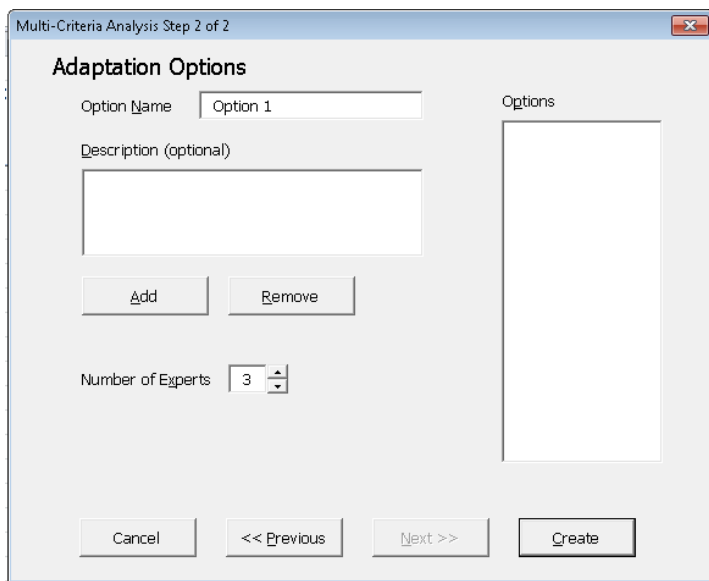


Figure 8 Snapshot of input window where users enter details on options as well as number of experts involved

When you click the Create button a new Excel workbook is created. The workbook has an Expert sheet for the number of experts you entered. The sheets are named Expert1, Expert2, etc., and appear similar to Figure 9. In this table, the involved experts can enter a score between -100 to 100 for each adaptation option against each criterion in the red space provided. Comments to justify the scores may also be given in this table. The comments are not used by the analysis but may be useful when coming back to an analysis or when writing a report.

Further, since we are likely to have experts who may be less confident on evaluating options against some of the criteria, there is space provided for the experts to rate their expertise or confidence level. This can be done by assigning a score between 0-100 for each criterion in the expertise row. This table has to be completed by each expert.

	Expert1	Economic	Environmental	Social	Co-Benefit
	Expertise	100 Comment	50 Comment	100 Comment	100 Comment
Options	Option 1	75	-20	25	10
	Option 2	75	40	-10	30
	Option 3	50	40	20	10
	Option 4	20	60	20	10
	Option 5	-10	80	50	25

Figure 9 Snapshot of table created where each user may enter scores for options against each criterion as well as scores indicating their confidence level

	Expert2	Economic		Environmental		Social		Co-Benefit	
	Expertise	50	Comment	100	Comment	50	Comment	50	Comment
Options	Option 1	50		-30		30		0	
	Option 2	100		30		20		50	
	Option 3	40		40		25		10	
	Option 4	40		50		25		10	
	Option 5	20		100		75		50	

	Expert3	Economic		Environmental		Social		Co-Benefit	
	Expertise	10	Comment	100	Comment	100	Comment	100	Comment
Options	Option 1	60		-50		25		20	
	Option 2	80		0		0		40	
	Option 3	60		10		40		20	
	Option 4	10		40		50		20	
	Option 5	25		80		80		40	

Figure 10 Expert 2 and 3 from the same example

You can see that each expert has entered a score for all the criteria for each option. Expert 1 has less expertise in evaluating environmental benefits compared to the other criteria, Expert 2 has the most experience in evaluating environmental benefits relative to the other criteria and Expert 3 has little economic expertise compared to the other criteria.

Output and Sensitivity Tests

The Multi-Criteria Analysis tool has 2 sheets of output, named Sensitivity and Scores. The Scores sheet shows the aggregated score for each option in each criterion. The Sensitivity sheet gives the overall score and rank for each option and allows you to perform sensitivity tests.

Scores

The scores for each of the adaptation options are aggregated by the criteria, taking into account the expertise of each expert. They are ranked within each criterion (see Figure 11).

		Economic		Environmental		Social		Co-Benefit	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank
Options	Option 1	66.25	2	-36.00	5	26.00	4	12.00	5
	Option 2	83.13	1	20.00	4	0.00	5	38.00	1
	Option 3	47.50	3	28.00	3	29.00	3	14.00	3
	Option 4	25.63	4	48.00	2	33.00	2	14.00	3
	Option 5	1.56	5	88.00	1	67.00	1	36.00	2

Figure 11 Snapshot of summary table created after each user has entered scores for options against each criterion as well as scores indicating their confidence levels

There are 2 graphs that show different views of these scores. The first, Figure 12, shows the criteria scores grouped by each adaptation option. The second, Figure 13, shows the same data but this time grouped by criteria.

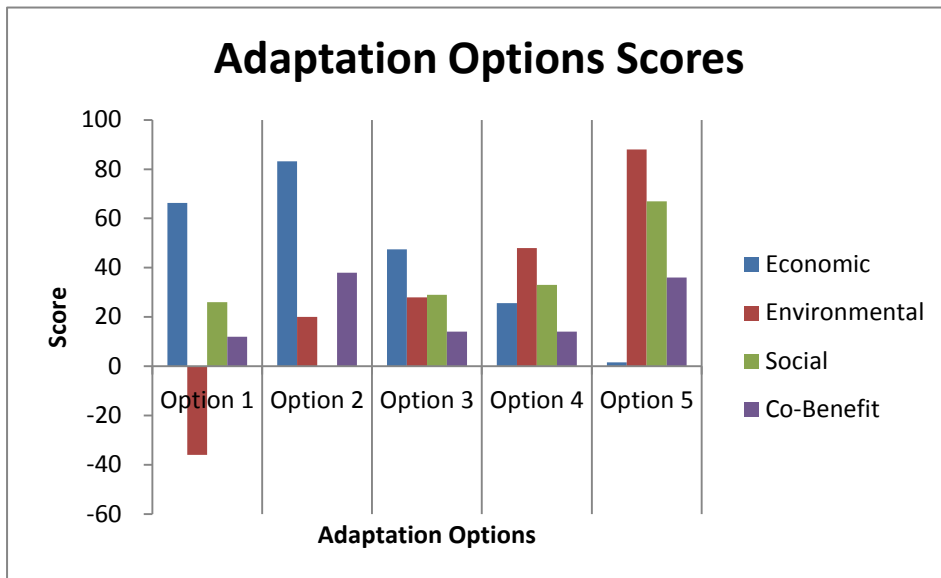


Figure 12 Criteria scores for each adaptation option

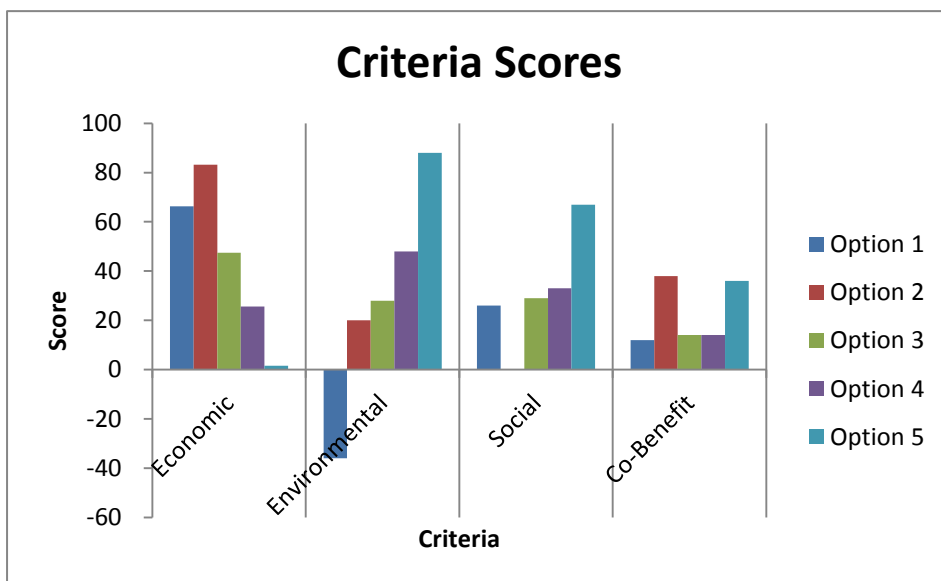


Figure 13 Scores grouped by criteria

Sensitivity

The other output sheet from the Multi-Criteria Analysis is the Sensitivity sheet. This shows the overall rank of each option and is where you perform sensitivity tests. Figure 14 shows the sheet after 4 sensitivity tests have been performed.

		Weight		Weight		Weight		Weight		Weight	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Criteria	Economic	100		100		50		75			
	Environmental	100		0		100		50			
	Social	100		0		100		100			
	Co-Benefit	100		0		50		100			
Options	Option 1	17.06	5	66.25	2	9.71	5	21.44	5		
	Option 2	35.28	2	83.13	1	26.85	4	33.95	2		
	Option 3	29.63	4	47.50	3	29.25	3	28.50	3		
	Option 4	30.16	3	25.63	4	33.60	2	27.76	4		
	Option 5	48.14	1	1.56	5	57.93	1	45.59	1		

Figure 14 Multi-Criteria Analysis sensitivity tests

By default the first sensitivity test is set with all criteria getting equal and full weight (100). The score and rank of the options under these weights are shown. You can alter these weights or perform sensitivity tests with other weights by using the other 6 columns. Up to 7 sensitivity tests are supported. Weights should be in the range of 0-100.

A graph similar to Figure 15 is produced, which is useful when comparing the different sensitivity tests.

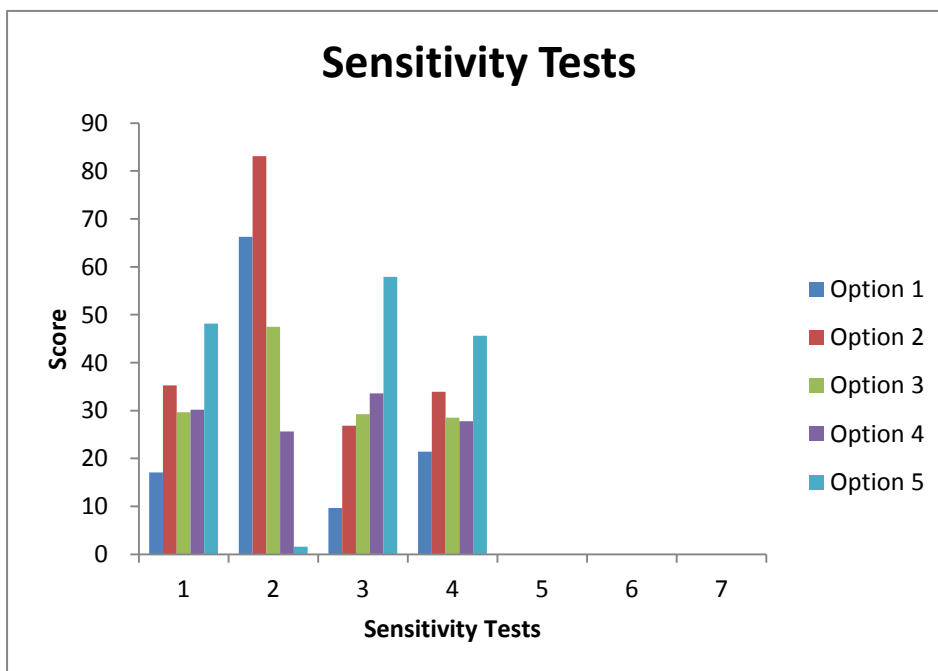


Figure 15 Graph of sensitivity tests

Appendix A

Example 1: Responding to Bushfires in Council X using the Economic Tool

Context of analysis: Council X has a large proportion of land area designated as national parks, public parkland, bushland or reserves. Bushfires are thus one of the major extreme events of concern to Council X. The Council authorities want to assess the potential economic damage due to bushfires in their local government area. The main economic damage relevant for this location is damage to houses. Consider average price of a house in the area to be \$440,000 including its contents. This is likely to increase over the years, say by 2% annually which means the growth rate is 2%.

Records of past bushfire occurrences show that in the last 10 years 2 bushfires have occurred. Based on the past data and Council's bushfire expert estimates that if we assume that the current climate continues to say 2050, the Council area is likely to face a bushfire every 10 years (frequency is 1 in 10 years i.e. 0.1), and that the likelihood that this bushfire will fall between every 15 years (frequency is 1 in 15 years i.e. 0.067) and every 7 years (frequency is 1 in 7 years i.e. 0.143) with a probability of two thirds (2/3 or 0.667). In short, this means that the probability that there is a 66% probability that the 1 in 10 year event may occur between every 15 years and every 7 years. Based on historical occurrences of bushfires, Council experts expect that the median damage due to a bushfire to be \$20M (Million dollars) and in the worst- case this could be \$100M. Further the experts chose a Lognormal distribution for modelling the damage as the Poisson-Lognormal distribution is the most commonly used distribution.

Their financial expert suggested that they use a discount rate of 6%, a growth rate of 2% and a 40 year time horizon. These were chosen because: 6% was their historic loan rate; CPI was running at around 2% and their Councils long-term planning extended to around 3 to 4 decades out. The local experts also wanted to investigate 4 possible options to reduce their risk. These were building a fire trail, building a fire control tower, rezoning the land in the at-risk area, and prescribed burning. The costs and risk reductions are summarised in Table 2.

Table 2 Risk reduction options for bushfires

	Fire Trail	Fire Control Tower	Rezone Land	Prescribed Burning
Capital Cost	\$3,000,000	\$1,000,000	\$30,000	\$1,000,000
Annual Maintenance Cost	\$5,000	\$600,000	\$2,000	\$1,200,000
Frequency Reduction	0%	0%	0%	50%
Median Severity Reduction	20%	20%	50%	50%
Worst Case Severity Reduction	40%	40%	80%	80%

Step 1

To start you will need an estimate of what the expected losses would be under current conditions. Open the 'Economic Tool', select 'Economic analysis' and enter the appropriate values in the three input windows. This will be considered the base-case scenario.

The screenshot shows the 'Frequency of Events' window. It has two main sections: 'Expert Opinion' and 'Previous Events'.
In 'Expert Opinion':
- 'Events per Year' is set to 0.1.
- Below it, 'Or 1 per 10 years' is selected.
- 'Lower Bound' is 0.0666667, with 'Or 1 per 15 years' selected below it.
- 'Upper Bound' is 0.14285714, with 'Or 1 per 7 years' selected below it.
- 'Probability' is 0.6666667.
In 'Previous Events':
- 'Number of Years' is 10.
- 'Number of Events' is 2.
At the bottom, there are buttons for 'Cancel', '<< Previous', 'Next >>', and 'Run'. A progress bar at the very bottom shows 0%.

The bushfire expert has estimated that the frequency of bushfires will be 1 in 10 years, between 1 in 15 years and 1 in 7 years with a probability of 2/3. In the last 10 years there have been 2 bushfires.

The screenshot shows the 'Severity of Events' window. It has two main sections: 'Expert Opinion' and 'Distribution'.
In 'Expert Opinion':
- 'Median' is 20000000.
- 'Worst Case (95%)' is 100000000.
In 'Distribution':
- Three graphs are shown for Weibull, Log-normal, and Burr distributions.
- The 'Log-normal' distribution is selected with a radio button.
At the bottom, there are buttons for 'Cancel', '<< Previous', 'Next >>', and 'Run'. A progress bar at the very bottom shows 0%.

The median severity is expected to be \$20M with the worst case being \$100M.

The screenshot shows the 'Simulation' window. It has two main sections: 'Parameters' and 'Advanced'.
In 'Parameters':
- 'Years' is 40.
- 'Discount Rate (%)' is 6.
- 'Growth Rate (%)' is 2.
In 'Advanced':
- 'Number of Simulations' is 10000.
At the bottom, there are buttons for 'Cancel', '<< Previous', 'Next >>', and 'Run'. A progress bar at the very bottom shows 0%.

We will simulate 40 years of events using a discount rate of 6% and a growth rate of 2%. Once we run the simulation the results will appear in a spreadsheet named 'Simulation Outputx' and are given below. All the input values will also be displayed in the excel sheet.

Loss Distribution	Base Case Scenario
Mean	75,793,133
Median	60,492,650
Standard Deviation	63,544,988
90% of loss	149,781,011
95% of loss	192,167,392
99% of loss	304,690,002

Along with the simulated damage information, there will also be two graphs indicating loss distribution (Figure 16) and cumulative loss (Figure 17). The title and axis may be edited in the Excel sheet to represent each case.

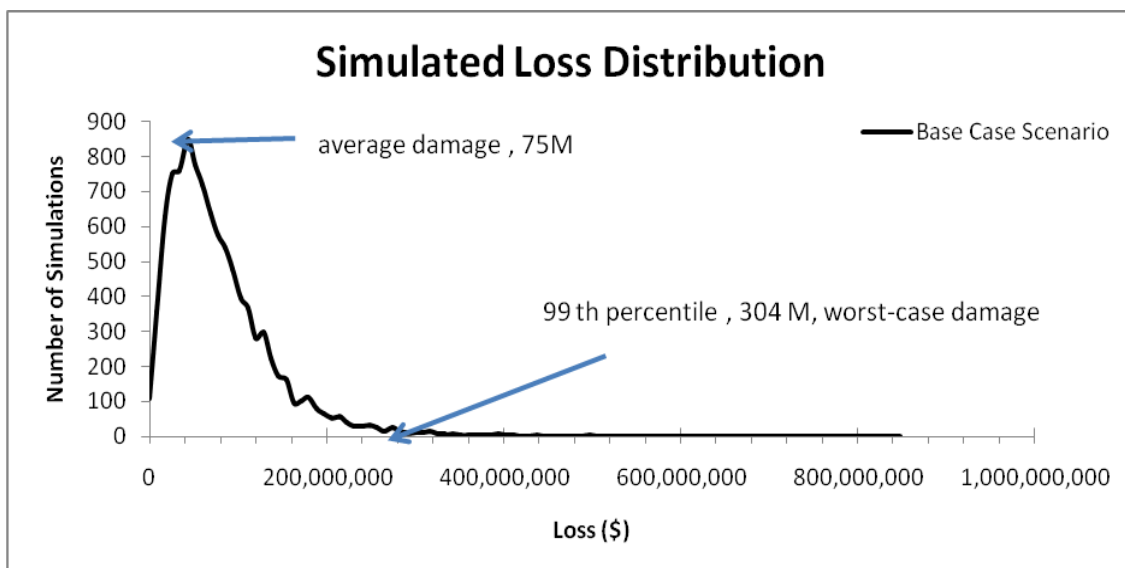


Figure 16 Loss Distribution



Figure 17 Yearly damage accumulated over the time horizon considered

Now that we have the loss distribution for the base case, we should do a sensitivity analysis to study the effect of the input parameters. As mentioned before, the parameters that can be varied are the number of years to simulate, discount rate, growth rate and change in frequency (positive or negative).

Sensitivity test parameters

	Ignore future	Protect future	Faster growth	Climate disruption
Discount Rate	15%	1%	6%	6%
Growth Rate	2%	2%	4%	2%
Change in Frequency	0%	0%	0%	50%
Change in Severity	0%	0%	0%	10% median & severity

We now have a loss distribution for each of the sensitivity tests the values of which are given below.

Loss Distribution	Base Case Scenario	Ignore future	Protect future	Faster growth	Climate disruption
Mean	75,463,653	31,201,377	177,432,344	104,518,043	91,426,088
Median	60,402,577	20,356,496	146,454,447	85,931,644	75,337,155
Standard Deviation	62,348,561	35,407,972	137,343,581	81,277,021	71,725,238
90% of loss	154,558,949	71,467,275	349,937,381	205,159,714	180,510,075
95% of loss	195,849,786	97,620,586	433,261,134	257,920,391	224,654,044
99% of loss	287,491,791	171,126,817	651,021,362	377,222,381	336,900,937

The loss distribution (Figure 18) and cumulative loss (Figure 19) are shown graphically.

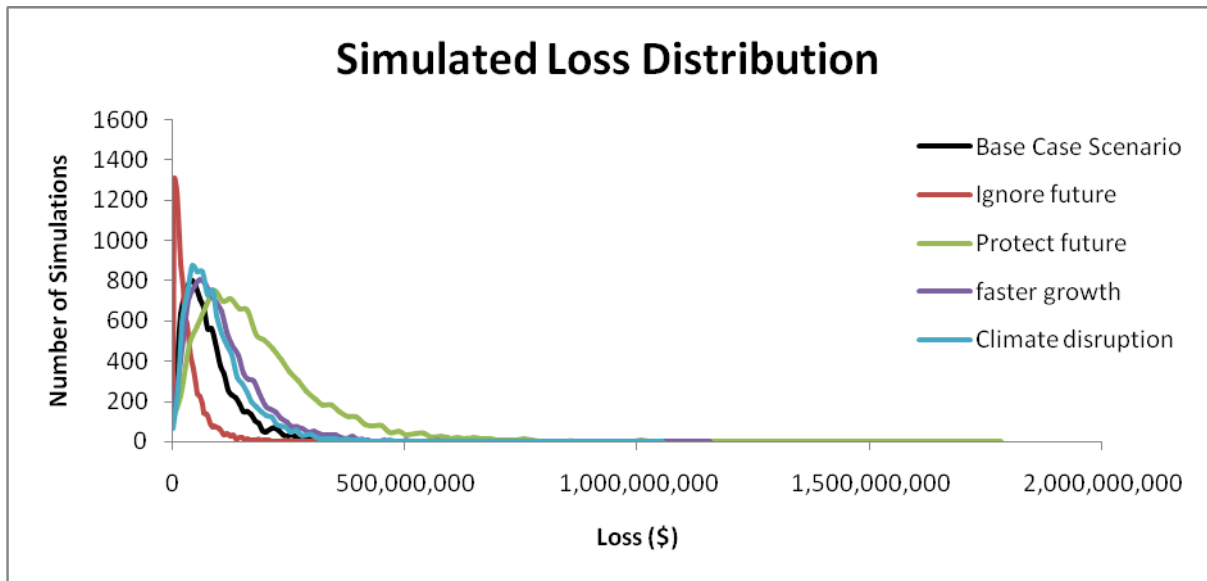


Figure 18 Loss distribution of sensitivity tests

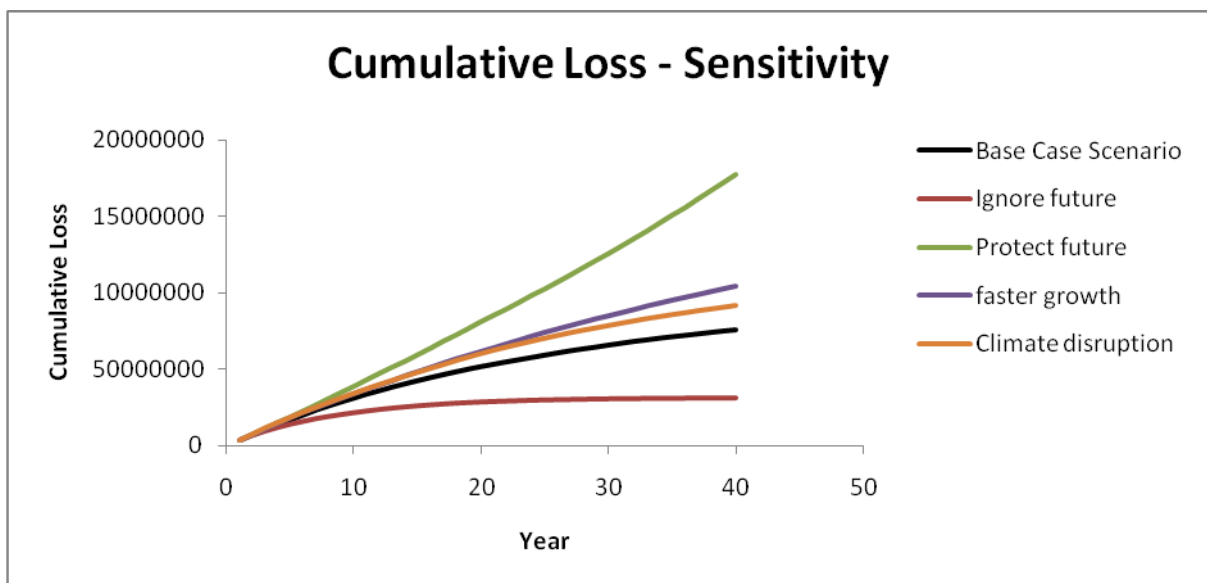


Figure 19 Cumulative loss in sensitivity tests

These sensitivity tests were conducted to study the impact of discount rates, growth rates as well as the effect of climate change. The first two tests 'ignore future' and 'protect the future' choose higher discount rates (15%) and lower discount rates (1%) compared to the base-case discount rate (6%). The damage indicates that the value of the discount rate plays an important role in the final damage values, with higher potential damage simulated for the 'protect future' scenario. Future economic developments may vary and so the growth rate is changed from 2-4% for the sensitivity tests. Apart from these, climate change can affect the frequency of the bushfire as well as its severity and hence the scenario climate disruption is also considered. The cumulative loss graphs indicate highest

accumulated loss for the 'protect future scenario'. The values of the parameters for the sensitivity tests should also be derived through expert consultation to include all potential ranges of uncertainties.

Risk Reduction Options

Recall that the 4 risk reduction options being investigated were building a fire trail, building a fire control tower, rezoning the land in the at-risk area, and prescribed burning. The costs and risk reductions were given in Table 2.

The screenshot shows a dialog box titled "Economic Analysis Step 1 of 2" with the sub-header "Adaptation Option". It contains several input fields: "Name" (Fire Trail), "Description (optional)" (empty), "Capital Cost" (3000000), "Annual Maintenance Cost" (5000), "Lifetime of Option" (40), and "Discount Rate" (6). At the bottom, there are buttons for "Cancel", "<< Previous", "Next >>", and "Run". A progress bar at the bottom left shows 0%.

The screenshot shows a dialog box titled "Economic Analysis Step 2 of 2" with the sub-header "Benefit". It is divided into two sections: "Frequency Reduction" and "Severity Reduction".
 - "Frequency Reduction": Base Case (0.113 events per year), Reduction by (%) (0).
 - "Severity Reduction": Base Case Median (20000000), 95% (100000000), Reduction by (%) Median (20), 95% (40).
 At the bottom, there are buttons for "Cancel", "<< Previous", "Next >>", and "Run". A progress bar at the bottom left shows 0%.

Table 3 Loss distribution for risk reduction options

Loss Distribution	Base	Fire Trail	Fire Control Tower	Rezone Land	Prescribed Burning
Mean	76,972,768	39,402,256	39,295,356	19,751,896	9,871,509
Median	60,941,968	32,840,399	32,690,555	17,892,135	8,107,413
Standard Deviation	64,968,137	30,037,359	30,048,671	12,141,943	8,418,477
90% of loss	153,105,613	78,650,031	78,612,680	36,213,152	21,232,486
95% of loss	196,165,377	96,316,078	96,060,446	42,326,667	25,719,844

99% of loss	316,020,586	139,662,136	138,742,455	56,180,877	35,850,802
Capital		3,000,000	1,000,000	30,000	1,000,000
Maintenance		5,000	600,000	2,000	1,200,000
Option Cost		3,104,056	13,486,740	71,622	25,973,480
Benefit (Mean)		37,570,512	37,677,412	57,220,872	67,101,259
Benefit (95%)		99,849,300	100,104,931	153,838,711	170,445,533
Net Benefit (Mean)		34,466,456	24,190,672	57,149,250	41,127,779
Net Benefit (95%)		96,745,243	86,618,191	153,767,088	144,472,053

Considering the net benefit with respect to the mean as well as the worst-case Rezoning Land appears to be the economically preferable option. Here also sensitivity tests may be conducted to make sure that the ranks of the options do not change. This may be conducted by clicking the Sensitivity test button again from the drop down menu of the Economic Tool.

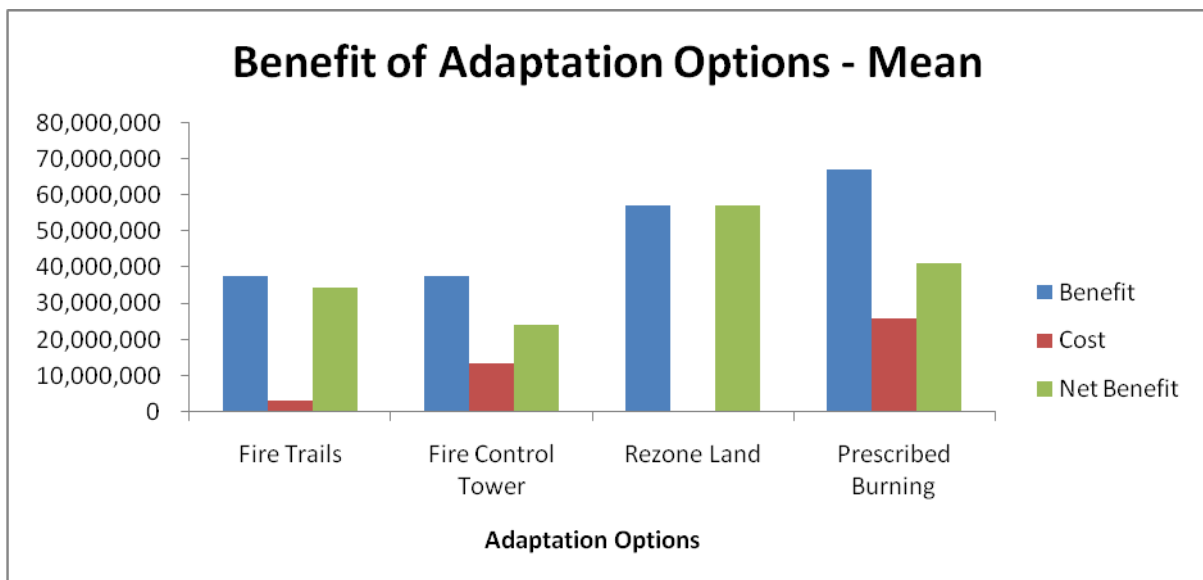


Figure 20 Benefit with respect to the average damage

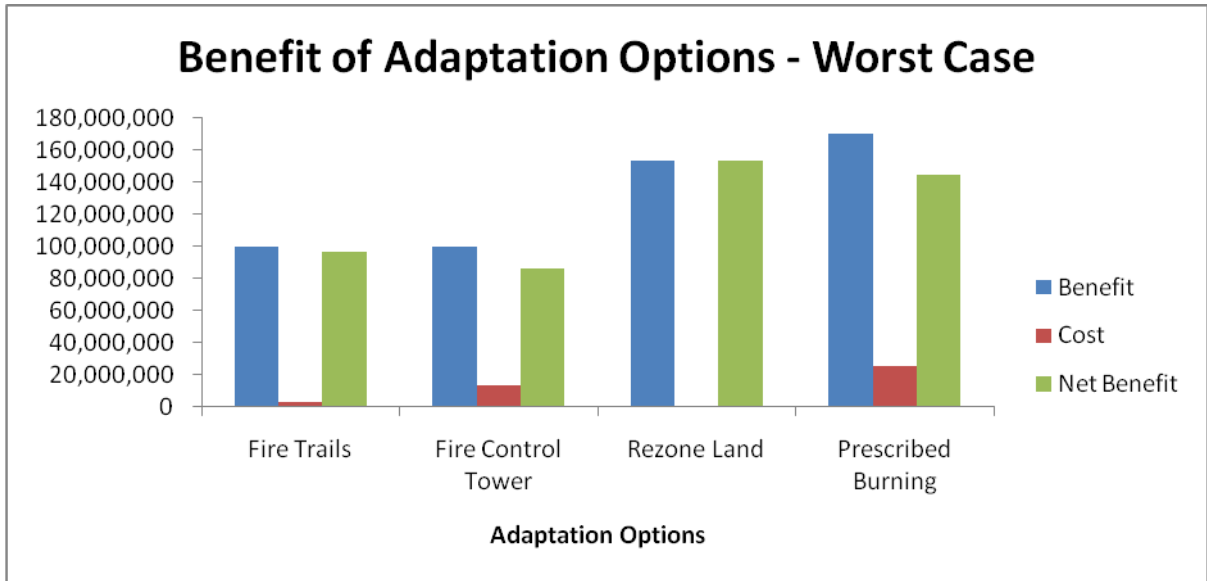
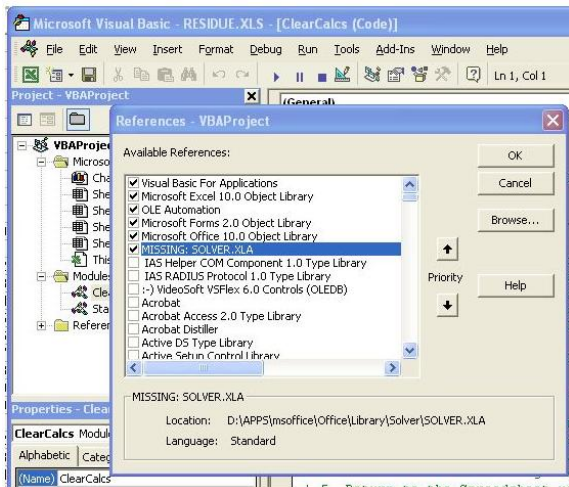


Figure 21 Benefit with respect to the worst case damage

Appendix B – Linking XLA solver in MS Excel

If you are using a version other than Excel 2010 and get a compilation error that says project or library missing, then most probably 'solver' may not have been installed. On Excel's Tools menu, choose Add-Ins. If the add-in 'Solver' is shown on the list, check the box in front of its name. If the add-in is not found, click Browse, navigate to the add-in file, then when it appears on the add-in list, check its checkbox. Then a reference should be set to the Solver, so on VB Editors Tools menu (Press Alt+F11 after opening excel sheet to go to the VB editor), click on references and then check the box adjacent to Solver if it appears in the list. If the Solver does not appear in the references window, but 'Missing: Solver.xla appears as shown in the figure below.



Select it if it is not already selected, then click the button in the "References VBAPProject" dialog box for Browse and in the Add Reference dialog box, click "Files of Type:", select Microsoft Excel files, browse to find the location of the file Solver.xla (By default Solver is located in Excel 2003 in "C:\Program Files\Microsoft Office\OFFICE11\Library\SOLVER) and click open on Solver.xla as seen in the figure below. Now Solver.xla should appear in the VB editors tools>references menu. Save and reopen Excel files.

