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FILLING THE GAPS: HOW ECONOMICS CAN HELP MAKE IMPORTANT DECISIONS WHEN INFORMATION IS MISSING

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ABSTRACT

FILLING THE GAPS: HOW ECONOMICS CAN HELP MAKE IMPORTANT DECISIONS WHEN INFORMATION IS MISSING

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When natural hazard managers need to make decisions about the allocation of resources, there is often information missing that cannot be rapidly obtained. In many cases, these decisions have to be made without waiting for the information to become available. But how can natural hazard managers know that their chosen allocation of resources generates good value for money when there is data missing? There are economic tools available that can support decision making in such cases. We explain how economic analyses cope with missing data and uncertainty. Through case studies, we illustrate how economic tools are used to rank the importance of different pieces of information and to find thresholds where the optimal decision changes. We also demonstrate how these tools can fill-in the gaps when there is little knowledge about a topic, for example, how to explicitly represent intangible values in decision making. The ability of economic tools to manage missing data and uncertainty can provide a wealth of information to natural hazard managers that can help them make better decisions.

INTRODUCTION

Emergency and land management agencies have to deal with the management of multiple natural hazards in multiple locations and decide where to implement mitigation measures. They have limited budgets that often cannot allow for all the mitigation measures to be implemented. Therefore, they have to evaluate their options and decide which ones to go ahead with. To make sure that the mitigation measures selected are those that benefit society (and the environment) the most, governments need to ensure that the benefits justify the cost and that they are getting the best value for money out of the investments in the mitigation options selected. The ideal situation is one where the level of mitigation chosen balances the cost of mitigation with the value of avoided losses (Stein and Stein, 2014). With tighter budgets at both State and national levels, natural hazards managers are increasingly under pressure to justify the use and allocation of resources for mitigation efforts.

To make a decision about the allocation of resources for mitigation activities, it is necessary to know all the benefits (tangible and intangible) that could be generated and compare that to the costs of implementing the mitigation strategy. However, managers do not always know all the benefits that can be generated and there is often information missing that cannot be rapidly obtained to do a full assessment.

In many cases, these decisions have to be made without waiting for the information to become available. Because natural hazards tend to be relatively rare events (albeit becoming more and more frequent in recent years), both their probabilities and the resulting losses are hard to estimate (Stein and Stein 2014). There can be uncertainty or data missing at different levels of the decision process:

1. the future occurrence of natural hazard events,
2. the things that could be affected,
3. and the value of those things.

Which then leads to uncertainty in:

4. the probable resulting losses,
5. the difference that mitigation measures would make to the impact of natural hazards

But how can natural hazard managers know that their chosen allocation of resources generates good value for money when there is data missing or high uncertainty about these parameters?

ECONOMIC TOOLS FOR MISSING OR UNCERTAIN DATA

Economists are still able to model decision outcomes even when there may be a lack of data for a particular parameter or the data has high levels of uncertainty. There are economic tools available that can support decision making in such cases. More importantly, it has been shown that using uncertain information is better than dismissing a piece of information because it has high levels of uncertainty attached to it (Pannell and Gibson, 2016). The outcome of an analysis and the decisions it leads to are generally better with uncertain information compared to incomplete information.

Economic analyses can cope with missing data and uncertainty in many ways and still provide valuable insights. Conceptualising the process provides a wealth of information with regards to the factors involved. In many cases, even a simple and approximate comparison of costs and benefits show whether a policy option is worth discarding or considering further (Stein and Stein 2014).

One of the most common ways in which economists deal with uncertainties and missing data is through sensitivity analysis. In a sensitivity analysis, the information entered into an economic model is changed and the impact of these changes is evaluated. Thus an economist assesses how changes to the data entered into the economic analysis change the results and the conclusions that can be drawn from it (Pannell 1997). There is a wide range of uses for sensitivity analyses, including decision making, communication, increased understanding, and economic model development (see Table 1).

When there is uncertainty, sensitivity analysis is very helpful for making decisions and policy recommendations. If there is uncertainty regarding a particular piece of information, a sensitivity analysis can provide information on:

1. how much confidence can be attributed to the potential value for money of a particular policy decision (Use 1 from Table 1),
2. what information is needed and in what order it needs to be acquired to improve the confidence in a particular decision (Use 19),
3. under what circumstances would the optimal decision change (Uses 2, 3, 5 and 11),
4. what society would lose (how much worse off society would be) if the change in circumstances is ignored and the original optimal strategy is kept (Uses 4 and 6).

If the optimal strategy does not change when the data entered is changed, it is considered robust (insensitive to parameters changes) and there can be confidence in implementing or recommending it. If the strategy is not robust, however, sensitivity analysis can be used to indicate what is potentially gained or lost with the implementation of different strategies.

When data is missing, economists tend to fill the gaps in economic analyses with expert knowledge (even if considered uncertain) and perform sensitivity analysis to evaluate the robustness of the results and how critical it is to invest in the collection of the data missing.

TABLE 1. USES OF SENSITIVITY ANALYSIS

Decision making
1. Testing the robustness of an optimal solution
2. Identifying critical values, thresholds or break-even values where the optimal strategy changes
3. Identifying sensitive or important variables
4. Investigating sub-optimal solutions
5. Developing flexible recommendations which depend on circumstances
6. Comparing the values of simple and complex decision strategies
7. Assessing the 'riskiness' of a strategy or scenario
Communication
8. Making recommendations more credible, understandable, compelling, or persuasive
9. Allowing decision makers to select assumptions
10. Conveying lack of commitment to any single strategy
Increased understanding
11. Estimating relationships between input and output variables
12. Understanding relationships between input and output variables
13. Developing hypotheses for testing
Model development
14. Testing the model for validity or accuracy
15. Searching for errors in the model
16. Simplifying the model
17. Calibrating the model
18. Coping with poor or missing data
19. Prioritising acquisition of information

Source: adapted from Pannell (1997).

EXAMPLE: INCREASING RESILIENCE FOR A COASTAL HIGHWAY

To illustrate our point, we have selected an example of infrastructure betterment after a flood event. Betterment, that is, rebuilding an asset to a more disaster-resilient standard, is still rarely undertaken in Australia. Here we analyse a betterment proposal for a highway in a coastal area connecting a metropolitan area and a major mining and tourism region (adapted from Fleming et al 2016).[1] In 2010, the region and adjacent areas experienced extensive flooding during 8 days, during which many segments of the road had to be closed. Some segments had to be closed for 15 days.

A damage assessment indicates that the total cost for repair and reinstatement of the highway is approximately AUD 15 million (Table 2). In addition to these repair costs, the 2010 flood event resulted in private costs associated with road closure of AUD 10.26 million, public agency costs of AUD 580,000 (clean up and increased maintenance) and social costs of AUD 1.13 million (damage to vehicles and private assets). This amounts to a total of about AUD 12 million in damages. Thus, the total sum of repair costs and damages caused by a flood of this magnitude (repairing the highway plus other flood impacts) amounts to AUD 27 million per flood event.

A betterment option is proposed that would prevent catastrophic failures in the infrastructure (which cause prolonged closure periods and costly repair works) and reduce closure periods in the event of another flood. The betterment upgrade would cost AUD 8 million as a one-off investment (Table 2). It is assumed that the betterment works will be undertaken at the same time as the repair works after an initial flood event[2]. Thus, the total cost of the initial flood event with the betterment option would be AUD 35 million ($15m in repair costs, $12m in damages, $8m in betterment works), relative to the total cost of the initial flood event without the betterment option of AUD 27 million ($15m repair costs, $12 damages).

Implementing the betterment option would mean the repair costs and damages from future floods of this magnitude would be reduced. Subsequent floods would result in an estimated AUD 9 million per flood event for damages and repair costs with the betterment option, compared to the AUD 27 million per flood event without betterment.

The 2010 flood event was considered to have a 10 years average recurrence interval (ARI); that is, an event of this magnitude is likely to occur once every 10 years. Therefore, the expected average annual costs of flooding are AUD 2.7 million without betterment (i.e. sum of repair costs and damages x event probability), and AUD 900,000 with betterment. All of these costs, the benefits of betterment, and the net present value (NPV) and benefit-cost ratio (BCR) of the betterment option are summarised in Table 2. In a Benefit-Cost Analysis, a positive NPV (i.e. >0) and a BCR greater than one indicate that a project is a worthwhile investment; that is, the benefits outweigh the costs.

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[1] This example is adapted from a case study presented in Fleming et al. (2016). In this paper the authors develop and illustrate a method for advancing proposals for the betterment of public assets. Due to confidentiality issues and political sensitivities, the authors had to de-identify the case studies in their paper and further information on their location or the source of the data cannot be provided.

[2] If the betterment works were undertaken at some other time (e.g. in between flood events), they may be more expensive given that equipment, personnel, etc. are not already on-site undertaking the repair works.

TABLE 2. COSTS, BENEFITS AND NET PRESENT VALUE OF HIGHWAY BETTERMENT

Flood damage	Cost (AUD)
Private costs associated with road closure	10,260,000
Public agency costs	580,000
Social costs	1,130,000
Total damages	11,970,000
Repair costs	**Cost (AUD)**
Standard repair costs	15,000,000
Betterment	8,000,000
Total costs of future flood events	**Cost (AUD)**
Total repair costs and damages without betterment	26,970,000
Total repair costs and damages with betterment	9,000,000
Total costs of future flood events	**Cost (AUD)**
Total repair costs and damages without betterment	26,970,000
Total repair costs and damages with betterment	9,000,000
Event recurrence	**prob.**
Probability flood event	0.1
Economic estimates	**Cost (AUD)**
Expected average annual cost of flooding without betterment	2,697,000
Expected average annual cost of flooding with betterment	900,000
Expected annual benefit of betterment	1,797,000
Present value of benefits of betterment (over 30 years)	24,735,402
Present value of costs of betterment (over 1 year)	7,547,170
Net Present Value of betterment	17,188,232
Benefit-cost ratio	3.3

Source: adapted from Fleming et al. (2016).

The results of the Benefit-Cost Analysis presented in Table 2 show that the betterment option yields a positive BCR that is above 1: for every dollar invested in betterment, there is a gain of $3.3. Thus in this case, it is worth investing in betterment of the road infrastructure. But what if the decision makers did not have enough information on the total damage caused by the flood, or the costs and damages with betterment, or if there is a high level of uncertainty on the probability of the flood event?

Let's assume that experts in the area estimate total damages of the 2010 flood to be somewhere between AUD 5 to 20 million, rather than being certain they will amount to AUD 12 million. These same experts believe that with betterment, total repair costs and damages could range between AUD 5 and 26 million, rather than AUD 9 million; that is, in the worst of cases with the betterment option, the total repair costs and damages could reach almost the same total as the current estimate of repair costs and damages without betterment (AUD 27 million).

We can conduct a sensitivity analysis on this information. Table 3 shows the changes in NPV and BCR for different flood probabilities when damage estimates of the 2010 flood vary between AUD 5 to 20 million and Table 4 shows the changes in NPV and BCR for different flood probabilities when total repair costs and damages after betterment range between AUD 5 and 26 million.

As it would be expected, if the flood event occurs much less often, the value of doing betterment works is reduced. However, what is of high interest to decision makers from the sensitivity analysis in Table 3 is that the frequency of the flood event has to be significantly reduced for the investment in betterment to become inefficient; that is, if the ARI is reduced from once every 10 years to once every 50 years. The betterment investment is worthwhile if the flood has a probability of up to 0.5 (once every 20 years), unless the damage caused by a flood of this magnitude is lower than about AUD 10 million.

Something that is less obvious in this sensitivity analysis is the total variation in NPV and BCRs. As the flood probability decreases, the variation between the lowest NPV (or BCR) and the highest NPV becomes smaller (Table 3). This indicates that, the lower the chance of a flood occurring in this coastal highway, the more important it becomes to have a good idea of the total damages that the flood would cause to make better decisions about the resilience levels needed for the road infrastructure.

The sensitivity analysis in Table 4, looking at changes in the results with variations in the impact of betterment, shows an even more glaring disparity. For an ARI of up to 30 years, what is known about the impacts of betterment could make the decision of betterment either a very worthwhile one, or a completely foolish one. This result indicates to decision makers that to make a good decision regarding betterment for this coastal highway, it is important to collect more information on the impacts of betterment on future costs and damages.

Nevertheless, with the current probability estimates for the 2010 flood (i.e. 0.1 probability, or once every 10 years), the reduction in future costs and damages achieved by betterment can be a lot more modest but the investment would still be worthwhile over a wide range of cost reductions (Table 4). If betterment achieves a reduction in total flood costs and damages of only AUD 6 million (as opposed to a reduction of AUD 18 million as estimated in the original model), it would still be sensible to proceed with the investment.

TABLE 3. SENSITIVITY ANALYSIS: VARYING ESTIMATED FLOOD DAMAGE

Total estimated damage of 2010 flood event (AUD million)	Net Present Value and BCRs	Flood probability					
		0.20	0.10	0.05	0.03	0.02	0.01
		Flood ARI (years)					
		5	10	20	30	50	100
5	Net Present Value of betterment (AUD million)	22.7	7.6	0.0	- 2.5	- 4.5	- 6.0
	Benefit-cost ratio	4.0	2.0	1.0	0.7	0.4	0.2
8	Net Present Value of betterment (AUD million)	31.0	11.7	2.1	- 1.1	- 3.7	- 5.6
	Benefit-cost ratio	5.1	2.6	1.3	0.9	0.5	0.3
12	Net Present Value of betterment (AUD million)	41.9	**17.2**	4.8	0.7	- 2.6	- 5.1
	Benefit-cost ratio	6.6	**3.3**	1.6	1.1	0.7	0.3
16	Net Present Value of betterment (AUD million)	53.0	22.7	7.6	2.5	- 1.5	- 4.5
	Benefit-cost ratio	8.0	4.0	2.0	1.3	0.8	0.4
20	Net Present Value of betterment (AUD million)	64.0	28.2	10.3	4.4	- 0.4	- 4.0
	Benefit-cost ratio	9.5	4.7	2.4	1.6	0.9	0.5

TABLE 4. SENSITIVITY ANALYSIS: VARYING IMPACTS WITH BETTERMENT

Total costs and damages with betterment (AUD million)	Net Present Value and BCRs	Flood probability					
		0.20	0.10	0.05	0.03	0.02	0.01
		Flood ARI (years)					
		5	10	20	30	50	100
5	Net Present Value of betterment (AUD million)	52.9	22.7	7.6	2.5	- 1.5	- 4.5
	Benefit-cost ratio	8.0	4.0	2.0	1.3	0.8	0.4
9	Net Present Value of betterment (AUD million)	41.9	**17.2**	4.8	0.7	- 2.6	- 5.1
	Benefit-cost ratio	6.6	**3.3**	1.6	1.1	0.7	0.3
16	Net Present Value of betterment (AUD million)	22.7	7.6	0.0	- 2.5	- 4.5	- 6.0
	Benefit-cost ratio	4.0	2.0	1.0	0.7	0.4	0.2
21	Net Present Value of betterment (AUD million)	8.9	0.7	- 3.4	- 4.8	- 5.9	- 6.7
	Benefit-cost ratio	2.2	1.1	0.5	0.4	0.2	0.1
26	Net Present Value of betterment (AUD million)	- 4.9	- 6.2	- 6.9	- 7.1	- 7.3	- 7.4
	Benefit-cost ratio	0.4	0.2	0.1	0.1	0.0	0.0

CONCLUSION

The example shown here demonstrates that with a very simple analysis using ranges of values for uncertain data, a wealth of information can be obtained that can help decision makers with the allocation of resources and investment decisions for natural hazard management. The changes in the results with different values can indicate how much confidence they can have in their decision, or if they need more information in a particular area to improve the confidence in the decision. In some cases, just the process of conducting a sensitivity analysis can raise new important questions and change the course of a strategy. The ability of economic tools to manage missing data and uncertainty can be very helpful to natural hazard managers and help them make better decisions.

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