APPENDIX 2

PRINCIPLES OF BENEFIT-COST ANALYSIS

Introduction

Benefit-cost analysis is required for nearly all FEMA mitigation project grant applications and is often a key determinant of mitigation project eligibility. Overall, benefit-cost analysis is a tool that provides answers to a central question for hazard mitigation projects: **"Is it worth it?"**

If hazard mitigation were free, individuals and communities would undertake mitigation with robust enthusiasm and the risks from hazards would soon be greatly reduced. Unfortunately, mitigation is not free, but often rather expensive. For a given situation, is the investment in mitigation justified? Is the owner (public or private) better off economically to accept the risk or invest now in mitigation to reduce future damages? These are hard questions to answer! Benefit-cost analysis can help a community answer these difficult questions.

In the complicated real world of mitigation projects, there are many factors which determine whether or not a mitigation project is worth doing or which of two or more mitigation projects should have the highest priority. Consider a town which has two flood prone neighborhoods and each neighborhood desires a mitigation project. The two neighborhoods have different numbers of houses, different value of houses, different frequencies and severity of flooding. The first neighborhood proposes storm water drainage improvements at a cost of $3.0 million. The second neighborhood wants to elevate houses at a cost of $3.0 million. Which of these projects should be completed? Both? One or the Other? Neither? Which project should be completed first if there is only funding for one? Are there alternative mitigation projects which are more sensible or more cost-effective than the proposed projects?

Such complex socio-political-economic-engineering questions are nearly impossible to answer without completing the type of quantitative flood risk assessment and benefit-cost analysis discussed below.

Risk Assessment for Benefit-Cost Analysis

In determining whether or not a given mitigation project is worth doing, the level of risk exposure without mitigation is critical. Consider a hypothetical $1,000,000 mitigation project. Whether or not the project is worth doing depends on the level of risk before mitigation and on the effectiveness of the project in reducing risk. For example, if the before mitigation risk is low (a subdivision street has a few inches of water on the street every couple of years or a soccer field in a city park floods every five years or so) the answer is different than if the before mitigation risk is high (100 or more houses are expected to have flooding above the first floor every 10 years or a critical facility is expected to be shut down because of flood damages once every five years).

All well-designed mitigation projects reduce risk (badly designed projects can increase risk or simply transfer risk from one community to another). However, just because a mitigation project reduces risk does not make it a good project. A $1,000,000 project that avoids an average of $100 per year in flood damages is not worth doing, while the same project that avoids an average of $200,000 per year in flood damages is worth doing.

The principles of benefit-cost analysis are briefly summarized here. The benefits of a hazard mitigation project are the reduction in future damages and losses, that is, the avoided damages and losses that are attributable to a mitigation project. To conduct benefit-cost analysis of a specific mitigation project the risk of damages and losses must be evaluated twice: before mitigation and after mitigation, with the benefits being the difference.

The benefits of a hazard mitigation project are thus simply future damages and losses which are avoided because a mitigation action was implemented.

Because the benefits of a hazard mitigation project accrue in the future, it is impossible to know exactly what they will be. For example, we do not know when future floods or other natural hazards will occur or how severe they will be. We do know, however, the probability of future floods or other natural hazards (if we have appropriate hazard data). Therefore, the benefits of mitigation projects must be evaluated probabilistically and expressed as the difference between annualized damages before and after mitigation.

To illustrate the principles of benefit-cost analysis, we consider a hypothetical single family home in the town of Acorn, with the home located on the banks of Squirrel Creek. The home is a one story building; about 1500 square feet on a post foundation, with a replacement value of $60/square foot (total $90,000). We have flood hazard data for Squirrel Creek (stream discharge and flood elevation data) and elevation data for the first floor of the house. Therefore, we can calculate the annual probability of flooding in one-foot increments, as shown below.

Table A2.1
Damages Before Mitigation

Flood Depth (feet)	Annual Probability of Flooding	Scenario Damages and Losses Per Flood Event	Annualized Flood Damages and Losses
0	0.2050	$6,400	$1,312
1	0.1234	$14,300	$1,765
2	0.0867	$24,500	$2,124
3	0.0223	$28,900	$673
4	0.0098	$32,100	$315
5	0.0036	$36,300	$123
Total Expected Annual (Annualized) Damages and Losses			**$6,312**

Flood depths shown above in Table A2.1 are in one foot increments of water depth above the lowest floor elevation. Thus, a “3" foot flood means all floods between 2.5 feet and 3.5 feet of water depth above the floor. We note that a “0" foot flood has, on average, damages because this flood depth means water plus or minus 6" of the floor; even if the flood level is a few inches below the first floor, there may be damage to flooring and other building elements because of wicking of water.

The Scenario (per flood event) damages and losses include expected damages to the building, content, and displacement costs if occupants have to move to temporary quarters while flood damage is repaired.

The Annualized (expected annual) damages and losses are calculated as the product of the flood probability times the scenario damages. For example, a 4 foot flood has slightly less than a 1% chance per year of occurring. If it does occur, we expect about $32,100 in damages and losses. Averaged over a long time, 4 foot floods are thus expected to cause an average of about $315 per year in flood damages. Note that the smaller floods, which cause less damage per flood event, actually cause higher average annual damages because the probability of smaller floods is so much higher than that for larger floods. With these data, the house is expected to average $6312 per year in flood damages. This expected annual or “annualized” damage estimate does not mean that the house has this much damage every year. Rather, in most years there will be no floods, but over time the cumulative damages and losses from a mix of relatively frequent smaller floods and less frequent larger floods is calculated to average $6312 per year.

The calculated results in Table A2.1 are the flood risk assessment for this house for the as-is, before mitigation situation. The table shows the expected levels of damages and losses for scenario floods of various depths and also the annualized damages and losses.

The risk assessment shown in Table A2.2 shows a high flood risk, with frequent severe flooding which the owner deems unacceptable. He explores mitigation alternatives to reduce the risk: the example below is to elevate the house 4 feet.

Table A2.2
Damages After Mitigation

Flood Depth (feet)	Annual Probability of Flooding	Scenario Damages and Losses Per Flood Event	Annualized Flood Damages and Losses
0	0.2050	$0	$0
1	0.1234	$0	$0
2	0.0867	$0	$0
3	0.0223	$0	$0
4	0.0098	$6,400	$63
5	0.0036	$14,300	$49
Total Expected Annual (Annualized) Damages and Losses			**$112**

By elevating the house 4 feet, the owner has reduced his expected annual (annualized) damages from $6312 to $112 (98% reduction) and greatly reduced the probability or frequency of flooding affecting his house. The annualized benefits are the difference in the annualized damages and losses before and after mitigation or $6312 - $112 = $6200.

Is this mitigation project worth doing? Common sense says yes, because the flood risk appears high: the annualized damages before mitigation are high ($6,312). To answer this question more quantitatively, we complete our benefit-cost analysis of this project. One key factor is the cost of mitigation. A mitigation project that is worth doing at one cost may not be worth doing at a higher cost. Let’s assume that the elevation costs $20,000. This $20,000 cost occurs once, up front, in the year that the elevation project is completed.

The benefits, however, accrue statistically over the lifetime of the mitigation project. Following FEMA convention, we assume that a residential mitigation project has a useful lifetime of 30 years. Money (benefits) received in the future has less value than money received today because of the time value of money. The time value of money is taken into account with present value calculation. We compare the present value of the anticipated stream of benefits over 30 years in the future to the up-front out-of-pocket cost of the mitigation project.

A present value calculation depends on the lifetime of the mitigation project and on what is known as the discount rate. The discount rate may be viewed simply as the interest rate you might earn on the cost of the project if you didn’t spend the money on the mitigation project. Let’s assume that this mitigation project is to be funded by FEMA, which uses a 7% discount rate to evaluate hazard mitigation projects. With a 30-year lifetime and a 7% discount rate, the “present value coefficient” which is the value today of $1.00 per year in benefits over the lifetime of the mitigation project is 12.41. That is, each $1.00 per year in benefits over 30 years is worth $12.41 now. The benefit-cost results are now as follows.

Table A2.3
Benefit-Cost Results

Annualized Benefits	$6,200
Present Value Coefficient	12.41
Net Present Value of Future Benefits	$76,942
Mitigation Project Cost	$20,000
Benefit-Cost Ratio	3.85

These results indicate a benefit-cost ratio of 3.85. Thus, in FEMA’s terms the mitigation project is cost-effective and eligible for FEMA funding. Taking into account the time value of money, which is essential for a correct economic calculation, results in lower benefits than if we simply multiplied the annual benefits times the 30 year project useful lifetime. Economically, simply multiplying the annual benefits times the lifetime would ignore the time value of money and thus gives an incorrect result.

Summary

The above discussion of benefit-cost analysis of a flood hazard mitigation project illustrates the basic concepts. Similar principles apply to mitigation projects for earthquakes or any other natural hazards. However, for earthquake mitigation projects, one of the major benefits is life safety. For purposes of benefit-cost analysis, the statistical values for deaths and injuries must be included in the benefit-cost analysis. For reference, the current FEMA statistical value for human life is $5.8 million. Given this high value, many seismic mitigation projects are deemed cost-effective and thus eligible for FEMA hazard mitigation grant funding.

The role of benefit-cost analysis in prioritizing and implementing mitigation projects in Multnomah County is addressed in Chapter 5 (Plan Adoption, Maintenance and Implementation). Although benefit-cost analysis is a powerful tool for helping to evaluate and prioritize mitigation projects, and a requirement for all FEMA hazard mitigation grants, benefit-cost analysis should not be considered the sole determinant for mitigation actions. In some cases, the potential for negative effects from a particular natural hazard may simply be deemed unacceptable, such as the potential for deaths and injuries, and thus mitigation may be undertaken without benefit-cost analysis.