APPENDIX B

PRINCIPLES

OF

BENEFIT-COST ANALYSIS

2016

1.0 Introduction

Benefit-cost analysis is required for nearly all FEMA mitigation project grant applications for all FEMA grant programs with only three exceptions:

- Acquisition or relocation of facilities located within FEMA-mapped 100-year floodplains that have been determined to be substantially damaged, and
- Public Assistance mitigation projects with costs less than 15% of repair costs, and
- Several types of Public Assistance mitigation projects that have costs less than 100% of repair costs.

FEMA's definition of substantial damage is "damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50% of the market value of the structure before the damage occurred." The categories of Public Assistance mitigation projects which do not require benefit-cost analysis are listed in FEMA Disaster Assistance Policy 9526.1 (March 30, 2010).

For all FEMA-funded mitigation projects, other than the exceptions noted above, the benefit-cost ratio must be greater than 1.0 for a project to be eligible for FEMA funding. The benefit-cost ratio must be calculated using FEMA's benefit-cost analysis software, with all data inputs consistent with FEMA's guidance and expectations.

The primary references for FEMA benefit-cost analysis are:

BCA Reference Guide (June, 2009), and

Supplement to the Benefit-Cost Analysis Reference Guide (June, 2011).

In addition to the above monographs, there are numerous other FEMA publications related to benefit-cost analysis which are available on the FEMA website:

www.fema.gov/benefit-cost-analysis

Help is also available via:

bchelpline@fema.dhs.gov and at 1-855-540-6744.

2.0 What are Benefits?

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 categories of benefits included in FEMA benefit-cost analysis varies with the type of facility being mitigated, the hazard being addressed and the type of mitigation project. Common categories of benefits include the reductions in: building damages, contents damages, displacement costs for temporary quarters if a building is damaged, the economic impacts of loss of service from a damaged facility and casualties. The economic value of avoided deaths and injuries are calculated using FEMA’s standard statistical values for deaths and injuries.

Some mitigation projects, such as most flood mitigation projects, focus predominantly on reducing future damages and losses. Other mitigation projects, such as most earthquake mitigation projects, focus on reducing casualties as well as reducing damages and losses; in this case, life safety is often the primary motivation for the mitigation project. In some cases, such as tsunami vertical evacuation mitigation projects, life safety is the sole purpose of a mitigation project.

More precisely, a benefit-cost ratio is calculated as the net present value of benefits divided by the mitigation project cost. Net present value means that the time value of money must be considered; benefits that accrue in the future are worth less than those that accrue immediately. The FEMA benefit-cost software discussed in the next section automatically calculates the net present value of benefits from data inputs, including the mitigation project useful lifetime, which varies depending on the type of facility and type of project, and the FEMA-mandated discount rate of 7%.

Because the benefits of a hazard mitigation project accrue in the future, it is impossible to know exactly what they will be. For example, it cannot be known in advance when a future earthquake or other natural hazard event will occur in a given location or how severe the event will be. However, in most cases, it is possible to estimate the probability of future hazard events. Therefore, the benefits of mitigation projects must be evaluated statistically or probabilistically.

Hazard events don’t come in only one size. Rather, the severity of every type of natural hazard event can range from minimal to severe. A benefit-cost analysis always considers a range of severity for hazard events, such as the 10-, 50-, 100- and 500-year floods, and the analysis includes estimates of the expected damages and losses for each level of event.

The FEMA benefit-cost software integrates such data to determine the average annual damages and losses considering the full range of hazard events. The term “average annual” damages and losses doesn’t mean that such damage and losses occur every year, but rather represents the long term average from hazard events of many different severities and probabilities occurring.

3.0 FEMA Benefit-Cost Analysis Software

The current version of FEMA's benefit-cost analysis software (Version 5.0) may be downloaded and installed from the FEMA website noted previously. There are seven benefit-cost modules applicable to different types of hazards and different types of mitigation projects:

- Floods,
- Hurricane Winds,
- Earthquake Structural Projects,
- Earthquake Nonstructural Projects,
- Tornado Safe Rooms,
- Wildfire, and
- Damage Frequency Assessment.

The applicability of most of the above BCA modules is self-evident, with a couple of exceptions:

- The flood BCA module can be used only when a full set of quantitative flood hazard data is available, including first floor elevations of buildings, stream discharge and flood elevation data for four flood return periods (typically, the 10-, 50-, 100- and 500-year events) and stream bottom elevations. For coastal storm surge flooding, the above data are necessary, less the stream discharge and stream bottom elevation data.
- The Damage Frequency Assessment module is applicable for any natural hazard for which a damage-frequency relationship can be defined from historical data and/or engineering analysis/judgment.

All of the BCA modules, except for the Damage Frequency Assessment module, have some built-in data which significantly simplifies the BCA process. However, all of the modules also require a considerable number of user-defined data inputs to complete a benefit-cost analysis.

The Damage Frequency Assessment (DFA) module has no built-in data: all of the data inputs are user-defined. The DFA module is the most flexible module, but also the most difficult to use because it requires the most technical expertise to input FEMA-credible data.

The Damage Frequency Assessment BCA module is used for the following types of hazards and facilities:

- Tsunamis,
- Landslides,

- Flood projects where the quantitative flood hazard data necessary to use the flood BCA module are unavailable,
- Seismic projects for utility or transportation infrastructure,
- All other natural hazards for which a damage-frequency relationship can be defined, including snow storms, ice storms, erosion, avalanches, and others.

Benefit-cost analysis of most hazard mitigation projects is unavoidably complex and requires at least a basic technical understanding of facilities, hazards, vulnerability, risk, and the economic parameters of benefit-cost analysis. For many types of mitigation projects, especially seismic projects, technical support from an engineer is almost always necessary. For some mitigation projects, technical support from subject matter experts with experience in making estimates of damages, casualties, and economic losses for benefit-cost analysis may also be helpful.

4.0 Benefit-Cost Analysis: Use and Interpretation

For FEMA mitigation grants, the immediate use of benefit-cost analysis is to determine whether a project has a benefit-cost ratio above 1.0 and thus meets FEMA's eligibility criterion. However, benefit-cost analysis can also play are larger role in the evaluation and prioritization of mitigation projects.

Districts that are considering whether or not to undertake mitigation projects must answer questions that don't always have obvious answers, such as:

What is the nature of the hazard problem?

How frequent and how severe are hazard events?

Do we want to undertake mitigation measures?

What mitigation measures are feasible, appropriate, and affordable?

How do we prioritize between competing mitigation projects?

Are our mitigation projects likely to be eligible for FEMA funding?

Benefit-cost analysis is a powerful tool that can help districts provide solid, defensible answers to these difficult socio-political-economic-engineering questions. As noted previously, benefit-cost analysis is required for all FEMA-funded mitigation projects under both pre-disaster and post-disaster mitigation programs. However, regardless of whether or not FEMA funding is involved, benefit-cost analysis provides a sound basis for evaluating and prioritizing possible mitigation projects for any natural hazard.

Overall, benefit-cost analysis provides answers to a central question for hazard mitigation projects: "Is it worth it?" That is, are the benefits large enough to justify the costs necessary to implement a mitigation project?

Whether or not a mitigation project is "worth it" depends on many factors, including:

- The level of hazard at a given location,
- The value and importance of the facility being mitigated,
- The vulnerability of the facility to the hazard,
- The cost of the mitigation project,
- The effectiveness of the mitigation project in reducing future damages, economic losses, and casualties.

The best mitigation projects address high risk situations: a high level of hazard for an important facility which has substantial vulnerability to the hazard.

All well-designed mitigation projects reduce risk. 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.

5.0 Benefit-Cost Analysis Example

The principles of benefit-cost analysis are illustrated by the following simplified example. Consider a small building in the town of Acorn, located on the banks of Squirrel Creek. The building is a one story building; about 1500 square feet on a post foundation, with a replacement value of $60/square foot (total building value of $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.

For this BCA, the FEMA flood BCA module is used, because the necessary quantitative flood hazard data are available. The data built into the BCA module, along with user data inputs, allow the module to calculate the annual probability of flooding in one-foot increments, along with the resulting damages and losses shown in Table A2.1.

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 building is expected to average $6,312 per year in flood damages. This expected annual or “annualized” damage estimate does not mean that the building 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 $6,312 per year.

The calculated results in Table A2.1 are the flood risk assessment for this building 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. The owner explores mitigation alternatives to reduce the risk: the example below is to elevate the house 4 feet. These results are shown in Table A2.2.

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 building 4 feet, the owner has reduced the expected annual (annualized) damages from $6,312 to $112 (a 98% reduction) and greatly reduced the probability or frequency of flooding affecting the building. The annualized benefits are the difference in the annualized damages and losses before and after mitigation or $6,312 - $112 = $6,200.

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 guidance for this type of project, we assume that this 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 useful 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 (essential for a correct economic calculation), results in lower benefits than if we simply multiplied the annual benefits times the project's 30-year useful lifetime. Economically, simply multiplying the annual benefits times the project lifetime would ignore the time value of money and thus would yield an incorrect result.

The above discussion of benefit-cost analysis of a flood hazard mitigation project illustrates the basic concepts.

The actual FEMA BCA modules calculate each category of damage or loss separately and the specific built-in data and the specific user-input data vary from module to module, depending on the hazard, type of facility, and type of mitigation project.