Seismic Retrofit Technical Review

This job aid supplement covers the requirements associated with the technical reviews for seismic retrofit projects funded by Hazard Mitigation Assistance. FEMA will also conduct an Environmental Planning and Historic Preservation review for each project. Refer to the Seismic Retrofit: Information Required for Environmental Review Job Aid.

This Technical Review Supplement provides additional information, examples and potential sources of documentation for items in the job aid to help communities applying for Hazard Mitigation Assistance grants comply with application requirements.

- All Hazard Mitigation Assistance (HMA) applications must comply with the requirements outlined in the HMA Guidance.
- According to the guidance, in addition to a general programmatic review, an EHP review and a technical review will be performed by FEMA for each proposed project.
- The technical review will verify that a project demonstrates feasibility, effectiveness and cost-effectiveness. The document is intended for technical reviews of applications only.
- For assistance completing EHP compliance reviews, see the EHP Supplement Job Aids.

Introduction

The following provides a review of the information that should be provided with the grant application, including recommended documentation and a list of supplementary information, to assist FEMA when conducting technical reviews of the project application. Technical resources are identified throughout this supplement to provide clarifying information on specific project application components. The final section provides a comprehensive list of resources identified throughout this supplement.

It is recommended that the grant applicant consult with a professional structural engineer to assist in preparing the application, as many of the documentation requirements are technical in nature. The engineer will assist with the risk assessment, existing structure evaluation and retrofit recommendations; provide documentation for benefit-cost analysis (BCA) parameters; provide the design of the seismic retrofit; and oversee the implementation of the seismic retrofit to verify the retrofit is effective in achieving mitigation objectives.

Retrofitting buildings requires an evaluation of the existing structure and the as-built construction plans. The evaluation will help determine seismic vulnerability and potential retrofit strategies. For complex seismic retrofit projects, applicants may want to consider Advanced Assistance or a phased project approach. Initial funds may be obtained to produce detailed designs of the project (Phase 1 or Advanced Assistance) for further FEMA review and approval prior to construction (Phase 2). Refer to HMA Guidance Part, VIII, A.12 and A.13 for additional guidance.

The project-specific guidance in this supplement does not provide all the information necessary to apply for funding through an HMA program and must be read in conjunction with other relevant guidance.

Additional Resources

- Hazard Mitigation Assistance Guidance (HMA Guidance)
- Hazard Mitigation Assistance Guidance Addendum
- Benefit-Cost Analysis Reference Guide and Supplement to the Benefit-Cost Analysis Reference Guide
- Hazard Mitigation Assistance Application Development – Seismic Structural and Non-Structural Retrofit Projects
- Sample Engineering Case Study for Structural Seismic Retrofit
- Sample Engineering Case Study for Non-Structural Seismic Retrofit

A list of all resources referenced is provided on the last page of the supplement.

Summary of Steps

- ☐ STEP 1: Provide a Scope of Work
- ☐ STEP 2: Provide Structure-Specific Details
- ☐ STEP 3: Provide Available Technical Data
- ☐ STEP 4: Provide a Project Schedule
- ☐ STEP 5: Provide a Project Cost Estimate
- ☐ STEP 6: Provide a Project Site Map
- ☐ STEP 7: Provide Property Location Information
- ☐ STEP 8: Provide Structure Photographs
- ☐ STEP 9: Determine if Project Location is in a Floodplain
- ☐ STEP 10: Identify Seismic Risk
- ☐ STEP 11: Cost-Effectiveness Analysis
- ☐ STEP 12: Environmental and Historic Preservation Considerations

Important Terms

ASCE/SEI 7-22 (American Society of Civil Engineers/Structural Engineering Institute – Minimum Design Standards and Other Structures, 2022 Edition): This standard is used by engineers and architects to determine design loads for buildings, including seismic loads on buildings.

ASCE/SEI 41-17 (American Society of Civil Engineers/Structural Engineering Institute – Seismic Evaluation and Retrofit of Existing Buildings): This standard provides performance-based principles used by engineers and architects to evaluate and retrofit existing structures to withstand seismic loads using deficiency-based and systemic procedures.

Capacity Parameters: Parameters that are indicative of a building's ability to resist seismic loads and how it responds during an earthquake. The capacity parameters are used to determine damage factors in the Seismic module of the BCA Tool. These parameters include:

- **Elastic Period (Te):** A structure's fundamental period of vibration during elastic response to ground motion, in seconds. The structure's fundamental period is used to estimate the maximum force that an earthquake may demand from the structure if the structure were to remain elastic.
- **Design Strength (Cs):** A fraction (base shear coefficient) of the building's seismic weight that represents the actual capacity of a building to resist lateral loads at load and resistance factor design (LFRD) level.
- **Elastic Damping (%):** Used to express energy dissipation in a structure as a percentage of the critical damping, which is the amount of damping that prevents a structure from oscillating freely.
- **Degradation Factor (Kappa):** A value that represents the detailing of major lateral force-resisting elements in terms of stiffness and ductility. Kappa has a significant impact on damage estimates in the BCA Tool.
- **Complete Structural Damage (STR):** Also known as structural drift-sensitive damage threshold, this is the ratio of interstory drift (lateral displacement) at the complete damage state for lateral load-resisting members.
- **Complete Non-Structural Damage (NSD):** Also known as non-structural drift sensitive damage threshold, this is the ratio of interstory drift (lateral displacement) at the complete damage state for building components such as cladding and full-height partition walls (non-load bearing).
- **Complete Non-Structural Damage (NSA):** Also known as non-structural acceleration-sensitive damage threshold, this is the acceleration at the complete damage state of acceleration-sensitive non-structural components such as mechanical equipment, racks and shelves, elevators and generators.

Design Earthquake: The earthquake effects that are two-thirds of the corresponding risk-targeted maximum considered earthquake (MCER) effects.

Design Earthquake Ground Motion: The earthquake ground motion that buildings and structures are specifically proportioned to resist in the building codes per the IBC 2018.

Maximum Considered Earthquake (MCE) Ground Motion: The MCE is the most severe earthquake for a specific location considered by the building codes (i.e., IBC and ASCE 7). This is typically understood as the event that has a 1% probability of collapse within a 50-year period or a 4,975-year recurrence interval. This term can be further specified by the terms Maximum Considered Earthquake Geometric Mean (MCEG) Peak Ground Acceleration and Risk-Targeted Maximum Considered Earthquake (MCER) Ground Motion Response Acceleration.

Maximum Considered Earthquake Geometric Mean (MCEG) Peak Ground Acceleration: Per ASCE 7, the most severe earthquake effects considered by this standard determined for geometric mean peak ground acceleration and without adjustment for targeted risk.

Non-Structural Retrofit: Modifications to the contents of a building or the elements that are not considered part of the structural load-resisting system of the building with the intended consequence of anchoring and/or bracing them from movement during an earthquake. These elements may be acceleration-sensitive elements, such as mechanical equipment or drift-sensitive elements, such as cladding.

Peak Ground Acceleration Adjusted for Site Effects (PGAM): The MCEG peak ground acceleration adjusted for site effects is used in ASCE 7 to evaluate liquification, lateral spreading, seismic settlements and other soil-related issues.

Risk Category: Per the IBC, this is a categorization of buildings and other structures for determination of flood, wind, snow, ice and earthquake loads based on the risk associated with unacceptable performance.

Risk-Targeted Maximum Considered Earthquake (MCER) Ground Motion Response Acceleration: The most severe earthquake effects considered by this standard determined for the orientation that results in the largest maximum response to horizontal ground motions and with adjustment for targeted risk (ASCE 2016).

Seismicity: The geographic and historical distribution of earthquakes (U.S. Geological Survey [USGS]).

Seismic Design Category: The seismic design category is a classification assigned to a structure based on its risk category and the severity of the design earthquake ground motion at the site (IBC 2018).

Seismic Retrofit Building Assessment: An inspection, performed by a professional engineer or licensed architect, utilizing the methodology provided in FEMA P-154 and ASCE/ SEI 41-13, that is used to determine whether the structure is a good candidate for a seismic retrofit and identifies the retrofits to be performed on the structure that will improve its ability to resist the forces associated with seismic loading.

Site Class: Refers to the classification assigned to a site based on the types of soils present and their engineering properties (IBC 2018). The effect of earthquakes at a site is affected by the surrounding soil and the soil upon which the structure is built; therefore, the soil type needs to be provided.

Spectral Acceleration: The peak response of a single-degree-of-freedom oscillator, subject to earthquake ground motion and is a function of the oscillator natural period and damping.

Structural Retrofit: Modifications to a structural system with the intended consequence of improving the building’s performance when resisting applied loads such as earthquake and wind. The structural system includes elements such as beams, columns, diaphragms, walls, member connections and foundations.

Technical Review Components

To complete a successful project application, a minimum amount of technical information is required for review. The following is a step-by-step approach addressing the major components of a seismic retrofit project. Data collected in these steps will provide reviewers with the necessary information to determine whether a project is feasible and effective.

The data requirements in the following steps should be compiled in an attachment to the project application. If the project impacts multiple structures, this information must be provided for each structure.

STEP 1: Provide a Scope of Work

Description: Provide a project narrative clearly identifying the proposed mitigation action and structure(s) to be mitigated, including a description of the proposed activities and a clear explanation of how the project will mitigate risk. The SOW should include key milestones and correspond with the design information, project schedule and cost estimate. Prior to developing the scoping narrative and application, the seismic retrofit building assessment and an evaluation of the structure's condition to determine if the building is a good candidate for a mitigation project, should be performed.

References: When preparing a SOW, refer to the following:

- HMA Guidance Part IV, Section H: Scoping Narrative: Scope of Work, Schedule, and Cost Estimate
- HMA Application Development – Procedures for Developing Scopes of Work for Seismic Structural and Non-Structural Retrofit Projects
- Sample Engineering Case Study for Structural Seismic Retrofit
- Sample Engineering Case Study for Non-Structural Seismic Retrofit

Approach: A licensed engineer should be consulted when developing the SOW for the mitigation project. The following items are recommended for inclusion in the SOW. Specific details and documentation required to support the narrative will be documented in the subsequent steps:

- Provide a detailed narrative of the seismic risk being mitigated, including seismic hazard information in the project area. The seismic risk is based on the structural and non-structural characteristics of the structure and the seismicity at the structure location. It is highly recommended to evaluate risk as early in the project development process as possible (i.e., prescreen the project) to minimize unnecessary application development work. For example, a structure may have a poor seismic load-resisting system but is in an area with such low seismicity that retrofit is not cost-effective. The BCA Tool, using conceptual capacity parameters, may be used to prescreen projects.
- Describe the existing conditions of the structures(s) to be retrofit. Specific details and documentation to support the narrative are described in **Step 2**.
- The narrative should indicate the type of deficiencies being addressed. For retrofits of buildings, the seismic deficiencies will typically be one or more of the following:
  - **Global strength:** This deficiency relates to the lack of sufficient lateral strength of the vertically oriented lateral force-resisting system (e.g., shear walls, braced frames).
  - **Global stiffness:** This deficiency refers to excessive deflection/drift of the structure owing to lack of stiffness.
  - **Configuration:** This deficiency covers irregularities in the structure such as plan eccentricities that create large torsional demands.
  - **Load path:** This deficiency addresses the connection between different elements of the structure such as the attachment of the walls to the floors and how the loads are transferred from these elements to the foundations and supporting soil.
  - **Component detailing:** This deficiency refers to design decisions that affect a component or system's behavior, often in the non-linear range, such as the expected drift in a concrete column exceeding the flexibility/deformation capacity of the column.

   - **Diaphragms:** Diaphragms are horizontal elements that span lateral force-resisting elements. This deficiency typically covers inadequate share and/or bending capacity stiffness and reinforcing around openings and re-entrant corners.
   - **Foundations:** This deficiency covers the foundation's inability to effectively transfer the loads from the structure to the soil such as inadequate bending capacity in a spread footing or inadequate length/reinforcement in piles or piers.
   - **Other deficiencies:** This deficiency is a broad spectrum that includes deficiencies not already listed above. Examples of such deficiencies are geologic hazards such as liquification, proximity to other structures and the deterioration of construction materials.
- The narrative should indicate the risk to non-structural elements as often damage to non-structural elements is more costly than damage to the structural system; therefore, it is important to evaluate drift-sensitive and acceleration-sensitive non-structural elements during a structural retrofit. If a structural retrofit is proposed, the application should consider combining the building retrofit with non-structural bracing and/or anchoring as this can increase the project benefits and reduce contractor overhead costs associated with developing two separate projects.
- Define the level of protection the mitigation will provide (i.e., this retrofit shall be designed to resist the seismic forces specified by ASCE 7-16, most recent edition). At a minimum, the retrofit design level earthquake should be as specified by the latest edition of the building code.
- Verify that the project will be constructed to the latest edition of codes and standards by including a description of the building code and standards that are to be followed.
- Describe the retrofit/mitigation method and the steps required to implement the structural and non-structural mitigation activities, including a mechanism for retrofitting (e.g., additional lateral force resisting elements, improved diaphragm design, improved ductility of connections, anchoring/bracing of non-structural elements).
- Mitigation project alternatives are required as part of the application development. Document at least two alternatives that were considered during the planning or design phase. Clearly indicate which alternative is the preferred mitigation project and discuss why it is the most practical, effective and environmentally sound alternative. One alternative is often considered the "no-action alternative" and reflects conditions expected to exist if a mitigation project is not completed. This is a key step to verify an efficient EHP review process.
- Clearly explain the proposed mitigation activity, specifying the deliverables, identifying the tasks required to complete the proposed activity and defining the tasks to be accomplished in clear, concise and meaningful terms. All cost elements must match tasks and provide sufficient detail for FEMA to determine whether the application is eligible. The scoping narrative will become part of the conditions of the award.

STEP 2: Provide Structure-Specific Details

Description: It is necessary to demonstrate that a project is feasible and effective at reducing risk; as part of this demonstration, provide detailed information about each structure in the project.

References: For some details, such as capacity parameters, a professional engineer should be consulted. Documentation for most of the required details can be found in as-built drawings, design drawings, tax assessor records, aerial photo assessments, parcel databases, building permit information or the seismic retrofit building analysis.

Approach: Provide the following information about the existing structure(s); if there are multiple structures, this information must be provided and documented for each.

- Photos of the structure from all sides and photos of the structural supporting system and structural connections, where possible
- Date the structure was built
- Date(s) of any upgrades or additions
- Structure type, as defined in ASCE 41-17 (or most recent version) and FEMA P-154, Table 2-3
- Property structure type (e.g., residential, non-residential, utility, critical infrastructure, bridge)
- Building use (e.g., agriculture, hospital, grade school, college/university, emergency response, industrial, general services)
- Describe the average number of occupants (not peak) based on 24 hours per day, 7 days per week, 365 days per year. Provide a description of the methodology used to establish the number of employees and visitors at various times of the day and days per week if included. Sources may include the bundling owner or employment and attendance records.
- Structure size in square feet of the total enclosed area
- Number of stories, including basement, with dimensions and interstory heights
- Describe the construction type (e.g., wood frame, masonry, concrete, manufactured housing, steel-frame)
- Describe floor and roof diaphragm construction materials (e.g., wood, concrete). Construction materials can be determined from the existing drawings or from the information provided by the seismic retrofit building analysis.
- Describe the architectural finishes (e.g., floors, walls, ceilings) and glazing (windows)
- Describe the structural system used to transfer or reduce the transfer of seismic loads to the foundation (load path). The structural system can be determined from the existing drawings or from the seismic retrofit building analysis.
- Building replacement value (BRV) based on the cost per square foot to replace the building with a functionally equivalent building based on the current cost of labor and materials. The BRV is different from the current market value of the structure. The BCA Tool may estimate the BRV based on structure details; however, additional sources can be used to document the BRV, including a letter from a construction or contracting firm or local building inspector, a photocopy of pages from a standard reference manual (e.g., RSMeans) or tax records (if the source is an assessor). This information will need to be distributed among STR, NSD and NSA elements based on percentage of the BRV for the BCA.
- Provide the location of an acceleration-sensitive equipment/non-structural components (e.g., generators and heating, ventilation and air conditioning equipment). Location should specify if they are located at ground level or elevated.

- Describe the existing condition as stated in **Step 1**.
  - The existing condition description should include a narrative with a qualitative assessment of the structure condition.
  - The existing capacity parameters should also be provided. The BCA Tool includes default values for the capacity parameters; however, these should be reviewed and modified to reflect the correct values for the structure. Documentation provided by a licensed professional engineer or credible source must be provided to justify the use of **either default or modified parameters.** Resources for determining the appropriate capacity parameters include a professional engineer with expertise in seismic retrofit, ASCE 7-16 (or most recent version), or FEMA's Hazard U.S. resources such as Multi-Hazard Loss Estimation Methodology – Earthquake Model Technical Manual (HAZUS-MT, 2015) and the FEMA Help Content within the BCA Tool. Parameters that should be included are:
    - Elastic period (Te) – ASCE 7-16
    - Design strength (Cs) – ASCE 7-16
    - Elastic damping (%) – BCA Tool Help Content
    - Degradation factor (Kappa) – Hazus MT Table 5.18
    - Structural drift-sensitive damage threshold (STR) – Hazus MT Table 5.9
    - Non-structural drift sensitive damage threshold (NSD) – Hazus MT Table 5.11
    - Non-structural acceleration-sensitive damage threshold (NSA) – Hazus MT Table 5.12
    - Describe the foundation (see **Figure 1**)

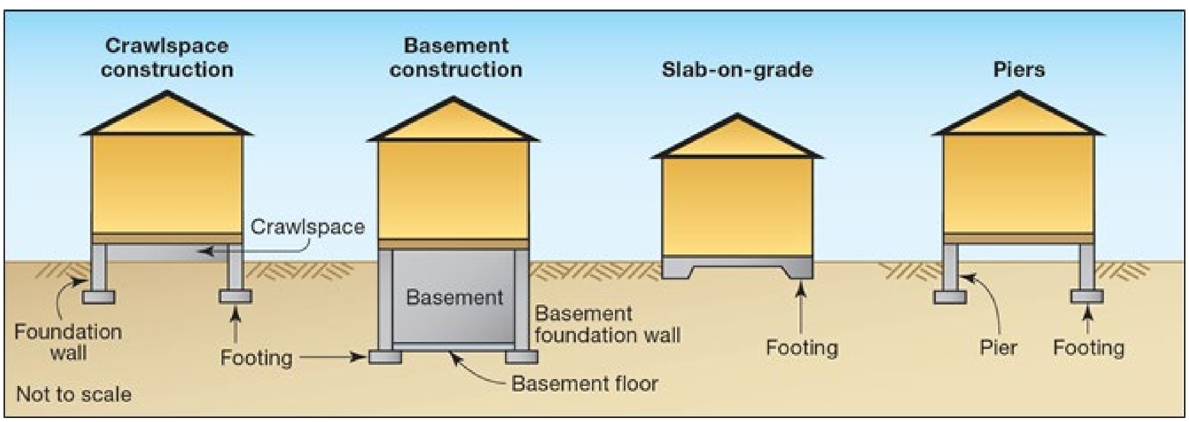


Figure 1. The four foundation types represented in this figure are crawlspace construction, basement construction, slab-on-grade and piers.

STEP 3: Provide Technical Data to Support the Scope of Work

Description: It is necessary to demonstrate that a project is feasible and effective at reducing risk. Provide engineering or design plans; these may be conceptual (e.g., sketches or schematics) with the project application. This information can be further developed following the grant award and should be accounted for in the scoping narrative, schedule and cost estimate, if not available during application development.

An engineer, architect, building official or contractor will be required to assist with collecting or developing the necessary information for the mitigation project.

It must be shown that a proposed structural retrofit project will meet the requirements of the most current, enforced version of the International Existing Building Code (IEBC), IBC, International Residential Code (IRC), ASCE 7 and ASCE 41. Additionally, it must be demonstrated that the proposed retrofits will improve the structure to the desired performance level as described in **Step 1**. For multiple buildings, the information must be provided and documented for each.

References: When preparing technical data, refer to the following resources, as appropriate:

- ASCE 7-16 (or most recent version) – Minimum Design Loads for Buildings and Other Structures
- ASCE 41-17 (or most recent version) – Seismic Evaluation and Retrofit of Existing Buildings
- FEMA 445 – Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings
- FEMA 547 – Techniques for the Seismic Rehabilitation of Existing Buildings
- FEMA E-74 – Reducing the Risks of Non-Structural Earthquake Damage
- FEMA P-58 – Seismic Performance Assessment of Buildings
- FEMA P-787 – Catalog of FEMA Building Science Branch Publications and Training Courses

Approach: Project plans should comply with the latest edition of codes, standards and minimum construction requirements. Providing project plans and specifications will allow reviewers to determine the technical feasibility for the proposed mitigation project and check the validity of the cost estimate against the drawings and specifications. Clearly document how the scope solves the identified seismic risk. Prior to beginning construction, documentation should indicate that the final design drawings and specifications will be signed and sealed by a professional engineer licensed in the state or jurisdiction where the project is located.

In addition to verifying that the project will meet the required codes and standards identified in the narrative (**Step 1**), provide any available information to support the following:

- The proposed retrofit will feasibly meet the required standards, including the IEBC, IBC, IRC, ASCE 7 and ASCE 41.
  - Confirm that the proposed retrofit can be constructed (i.e., there is no physical limitations that will prevent its completion).
  - Provide information that verifies that the seismic retrofit will resist the seismic forces as specified by the IEBC, IBC, IRC, ASCE 7 and ASCE 41.
  - Confirm that the existing foundation, or designed retrofit of the existing foundation, is designed to properly address all loads with a proper load path.
- Provide design plans (as-builts) and specifications for the construction of the existing structure.
  - Condition assessment of the existing structure developed from the findings of the seismic retrofit building assessment, if available.

    - Calculations/engineering assessment of the existing structure's deficiencies. During either the seismic retrofit building assessment or design of the structural retrofit, calculations will be performed to identify deficiencies in the structure that need to be addressed. Additionally, detailed drawings of connections or load paths can be provided to show deficiencies in the design.

- Provide a description of the proposed solution to the identified risk/retrofits of the structure. The description should be accompanied by:
    - Plans, design drawings or sketches of the proposed retrofit(s)
    - Engineering calculations and/or analysis for the proposed retrofit(s)
    - The structure's after-mitigation retrofit capacity parameters, including:
        - Elastic period (Te)
        - Design strength (Cs)
        - Elastic damping (%)
        - Degradation factor (kappa)
        - Structural drift-sensitive damage threshold (STR)
        - Non-structural drift sensitive damage threshold (NSD)
        - Non-structural acceleration-sensitive damage threshold (NSA)

STEP 4: Provide a Project Schedule

Description: Include a detailed project schedule for all tasks identified in the project cost estimate and SOW. The schedule identifies major milestones with start and end dates for each activity. Project schedules must show completion of all activities (including construction period) within the period of performance (POP) allowed by the relevant HMA program. Sufficient detail must be provided so FEMA can determine whether the proposed activities can be accomplished within the POP.

References: HMA Guidance Part VI, Section D.4: Program Period of Performance and Part IV, Section H: Scoping Narrative: Scope of Work, Schedule, and Cost Estimate

Approach: Verify that the information in the schedule supports the SOW and aligns with the project cost estimate.

STEP 5: Provide a Project Cost Estimate

Description: Include a detailed line-item cost estimate for all tasks identified in the project schedule and SOW. Allowable costs are costs that are necessary and reasonable for the proper and efficient performance and administration of the federal award. All costs included in the application should be reviewed to verify they are necessary, reasonable and allocable consistent with the provisions of 2 Code of Federal Regulations Part 200. Include sufficient detail so that FEMA can determine whether costs are reasonable based on proposed activities and level of effort. Costs incurred prior to award may be considered pre-award costs and may be eligible for reimbursement. Eligibility may depend on the date they occurred and the grant program. Refer to HMA guidance and the Notice of Funding Opportunity for specifics.

References: HMA Guidance Part IV, Section H: Scoping Narrative: Scope of Work, Schedule, and Cost Estimate

Approach: Verify that the information in the cost estimate supports the SOW and aligns with the schedule. Source materials used to support the cost estimate should be referenced.

Allowable costs are costs that are necessary and reasonable for the proper and efficient performance and administration of the federal award. They may include, but are not limited to:

- Engineering services for design, structural feasibility analysis and cost estimate preparation
- Project administration and construction management
- Surveying and inspection
- Soil sampling
- Completion of a title search and deed recording fees
- Permitting and/or legal fees
- All construction activities required for seismic retrofitting
- Disconnecting and reconnecting utilities and extending lines and pipes, as necessary
- Debris disposal and erosion control
- Costs for repair of lawns, landscaping, sidewalks or driveways, if damaged by retrofits

It is important to verify using appropriate methods that an annual maintenance cost has been determined. The annual maintenance cost is necessary to address those costs associated with maintaining the effectiveness of the mitigation measures. Although the costs will not be funded by FEMA, they are required to be included in the BCA.

STEP 6: Provide a Project Site Map

Description: Provide a map showing the project location. If the project includes multiple structures, show the project boundaries, including staging area. **Figure 2** provides an example of a project site map.

Reference: Supplement to the Benefit-Cost Analysis Reference Guide, Section 5: Available Technology Aids

Approach: Provide a map showing the project location, including structures, map scale and location information. For any maps provided, verify that a scale bar is shown, and the map is clearly labeled to identify the project boundaries.

Potential Sources: Official site survey, assessor maps, topographic maps obtained from the project engineer or planner, maps created using a web-based service such as Google Maps

Figure 2. Example of a project site map. Map clearly shows the buildings to be retrofitted, the project area and the staging area. The map includes a north arrow and a scale.

STEP 7: Provide Property Location Information: Address and Latitude and Longitude

Description: Provide the physical address(es) and the latitude and longitude of each structure in the project application. For projects with multiple properties, tables containing all relevant information by property can be helpful.

PROPERTY ADDRESS

Approach: Provide property address(es) of each structure involved in the mitigation project. This includes street name and number; city, county or parish; state; and zip code. A post office box number is not an acceptable address. If the address provided does not clearly match up with the structure(s) to be retrofit, provide pictures or a site map with the structure(s) footprint(s) clearly identified.

Potential Sources: Property owner, local building inspector, tax assessor records, deed to the property, engineering plans

Example: 456 Terremoto Road, San Francisco, San Francisco County, CA 94102

LATITUDE AND LONGITUDE

Approach: Provide the latitude and longitude of each structure involved in the mitigation. The latitude and longitude should be taken at the center of the property. The latitude and longitude can be provided in either decimal degrees (e.g., 27.9807, -82.5340) or degrees, minutes and seconds (27° 58’ 50.5’’ N, 82° 32’ 2.4’’ W).

Potential Sources:

- GPS device
- Free online map tools or search engines that generate latitude and longitude when an address is supplied

Example: 27.9807, -82.5340 or 27° 58’ 50.5’’ N, 82° 32’ 2.4’’ W

STEP 8: Provide Structure Photographs

Description: Provide photographs of the property, or properties, and structure(s) that are proposed to be retrofitted from all sides of the structure and photographs looking outward from each side of the building (see **Figure 3**).

Approach: Provide photographs of all sides of the structure.

- For each photograph, provide a descriptive caption explaining what the photo shows, the direction it was taken (e.g., “looking east” or “east side of building, looking west”), side of the structure shown (e.g., front, back) and other relevant details.
- When a structure has multiple levels, it is important to provide photographs that provide different views of the structure.
- For structures that are raised (or partially raised) owing to surrounding ground level changes or other circumstances, provide photographs of different sides and angles of the foundation.

Potential Sources: Use a cell phone, tablet, or camera to take clear, good quality photos for inclusion in the application.

Example:

Figure 3. Photos showing the structure to be retrofitted.
Photos include all sides of the building from different cardinal directions.

STEP 9: Determine if Project Location is in a Floodplain

Description: Provide a Flood Insurance Rate Map (FIRM) showing the project location. Include a description of the flood zone in which the existing structure is located and whether the site is in a regulatory floodway. An example is provided in **Figure 4**.

References: To identify flood risk, refer to FEMA’s Flood Map Service Center and FEMA’s How to Find Your FIRM and Make a FIRMette.

Approach: If a FIRM is available for the project area, provide a copy of the map with the project location(s) and structure(s) footprint clearly outlined on the map. Include a description of the flood zone in which the existing structure is located and whether the site is in a regulatory floodway.

Example:

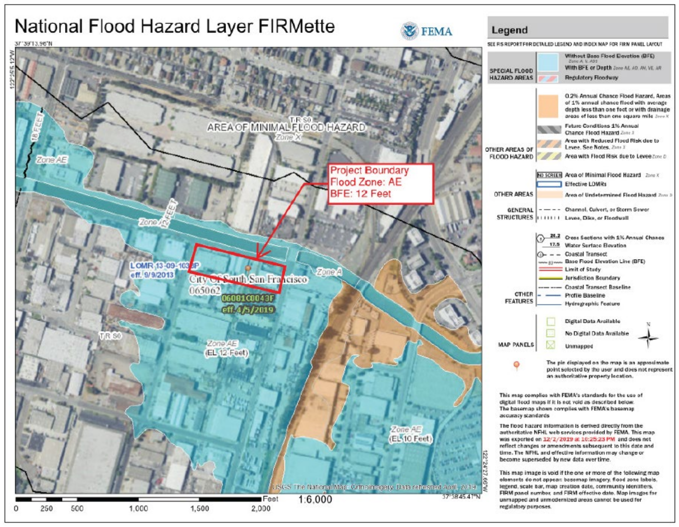


Figure 4. FEMA FIRMette with dry floodproofing project boundary identified.

STEP 10: Identify Seismic Risk

Description: The seismic risk of a structure is dependent on the structural and non-structural characteristics of the building and the earthquake ground motion. The ground motion depends on the seismicity and the soil conditions (site class) at the structure location.

Potential Sources: The USGS Earthquake Hazard Program and U.S. Seismic Design Maps can be utilized for additional information based on project location (entered in web portal) or the ground acceleration contours are available in ASCE 7 or the IBC.

Approach: The FEMA BCA Tool will generate risk information based on the latitude and longitude provided when creating a new structure within the tool as shown in **Figure 5** and **Figure 6.**

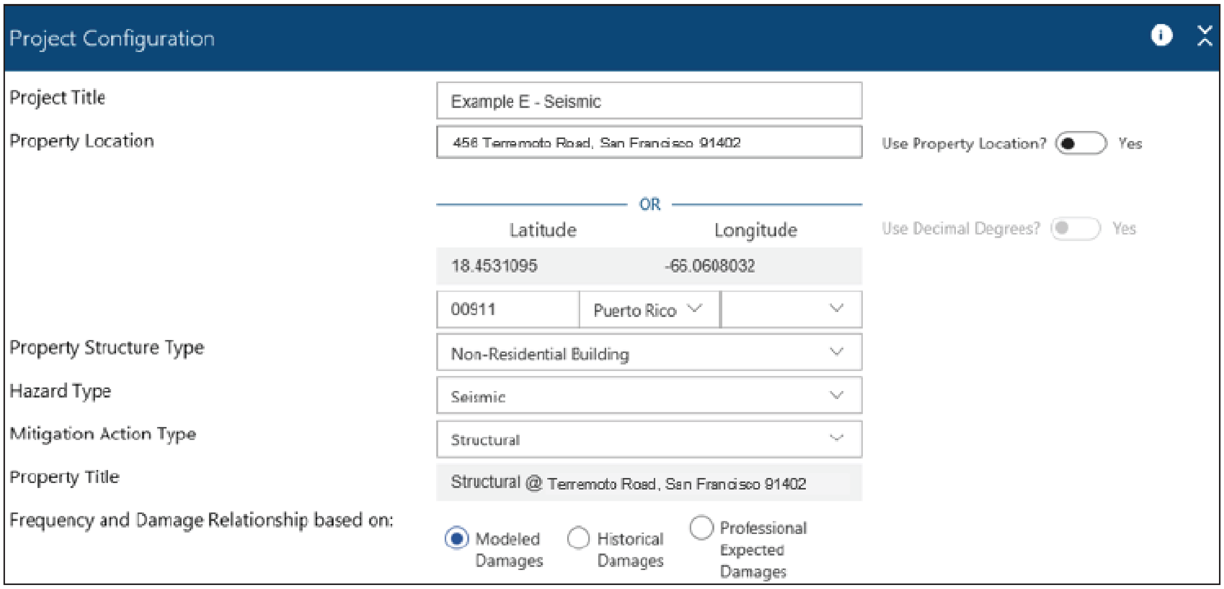


Figure 5. Project latitude and longitude in BCA Tool v6.0.

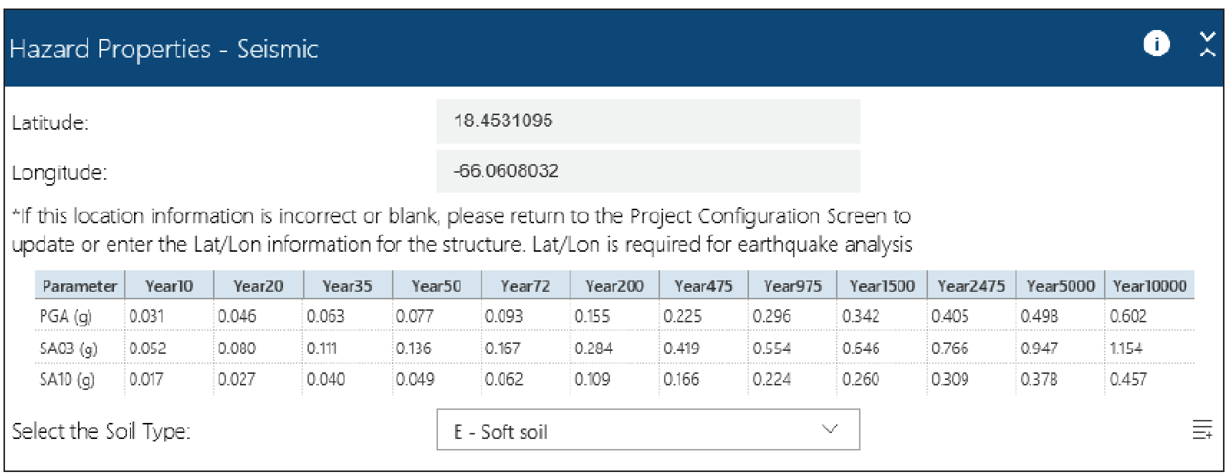


Figure 6. BCA Tool-generated seismic hazard properties.

STEP 11: Cost-Effectiveness Analysis

Description: Cost-effectiveness of a seismic retrofit project must be demonstrated to obtain FEMA funding. Cost-effectiveness is determined through a BCA. A BCA is a quantitative procedure that assesses the cost-effectiveness of a hazard mitigation measure over the useful life of the project by comparing potential avoided damages (benefits) associated with the mitigation measure to the cost of a project in current dollars.

FEMA will only consider applications that use a FEMA-approved methodology to demonstrate cost-effectiveness. FEMA provides a BCA Tool that allows applicants to calculate a project's benefit-cost ratio (BCR). The BCR is a calculation of the project benefits divided by the project costs. Projects for which the benefits exceed costs (a BCR of 1.0 or greater) are considered cost-effective. FEMA requires the use of the BCA Tool to verify calculations are consistent with Office of Management and Budget Circular A-94 Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. Benefits may include avoided damage, loss of function and displacement.

All BCA inputs must be **justified and documented**. When appropriate FEMA standard values are used, they should be clearly stated.

In the case of seismic projects, these include:

- Avoided physical damage to the structure and contents
- Avoided displacement costs – the costs required to move and reside in a temporary location while repairs are performed on the structure
- Avoided life safety damages (injuries or casualties)
- Avoided loss of rental income
- Avoided volunteer labor time that typically supports cleanup and repair work
- Avoided loss of business income or net revenue (for commercial properties)
- Avoided loss of public services (for public properties)
- Avoided loss of service (for utilities)
- Avoided loss of function (for roads and bridges)

There are several benefits that could be counted for a project, and any or all the benefits can be included in a BCA when analyzing cost-effectiveness. The approaches outlined in **Step 11A** and **Step 11B** of this supplement are focused primarily on avoided physical damage (structure and contents), loss of service/function and displacement costs. It is recommended that the applicant start on a BCA using these types of benefits as they are typically the largest benefits for seismic retrofit projects.

If the BCR does not exceed 1.0, or is slightly over 1.0, after following **Step 11A** or **Step 11B**, move to **Step 11C** to find additional methods for calculating potential benefits for the project.

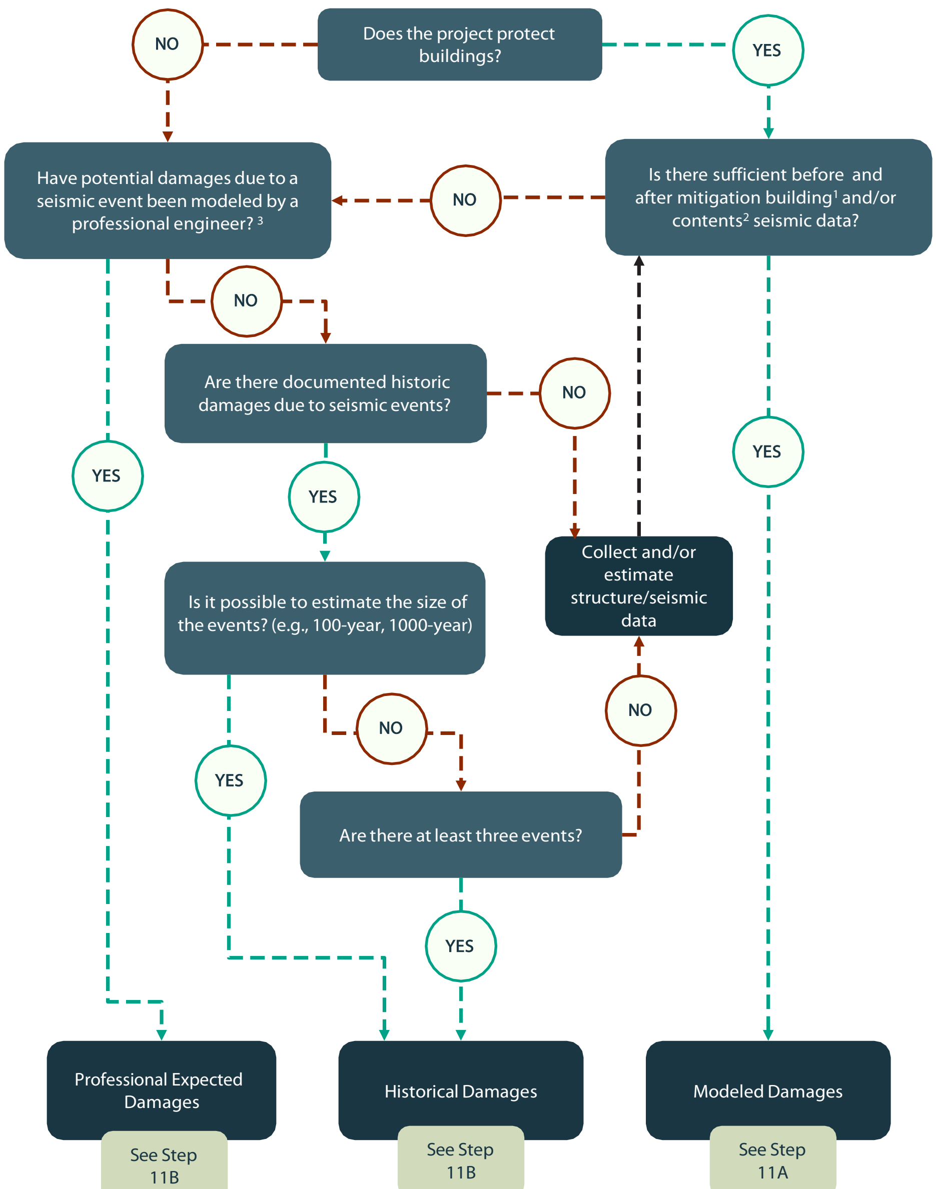
A seismic retrofit project can reduce risk to several facilities, including roads, bridges and utilities. The approach to the BCA depends on the facilities being protected and the data available.

- Modeled damages can only be used to evaluate avoided losses to residential and non-residential structures. To use modeled damages, detailed information about the structure and the soil condition must be available for before- and after-mitigation conditions (**Step 11A**).
- If data for historical damages or professional expected damages is available, the BCA Tool provides a Damage Frequency Assessment (DFA) module (**Step 11B**) to evaluate any type of facility, including structures.
- A combination of modeled, historical and estimated damages can be used when evaluating structures and other infrastructure together.

This supplement only provides a recommended approach to documenting cost-effectiveness. For detailed guidance on using the FEMA BCA Tool, refer to the FEMA BCA Reference Guide and FEMA Supplement to the BCA Reference Guide. For additional questions, contact ***BC Helpline:*** **bchelpline@fema.dhs.gov** or at ***1-855-540-6744***. Provide a .pdf of the BCA report and an export of the BCA .zip file.

The FEMA BCA Tool includes embedded Help Content. Click on the information button within the tool to access the Help Content.

Approach: There are several methods to evaluate cost-effectiveness. The method used will depend on the data collected in the previous steps of this supplement. Use the flowchart in **Figure 7** to analyze the data available for the project site and determine the recommended approach.



NOTES

[1] Building data refers to structural building data for before- and after-mitigation conditions. See **Step 2** and **Step 10**.

[2] Building data refers to nonstructural contents data for before- and after-mitigation conditions. See **Step 10**.

[3] If professional expected damages is used, the application must include the recurrence interval in the models and the model results must be included as documentation.

Figure 7. Flowchart for determining the appropriate BCA frequency and damage relationship in the FEMA BCA Tool.

STEP 11A: Benefit-Cost Analysis Tool – Modeled Damages

Description: Using modeled damages is suitable when the project is primarily protecting structures as it only calculates damages to structures. The Seismic module within the BCA Tool analyzes proposed mitigation projects using the previously defined capacity parameters and earthquake ground motions at the site to estimate damages before and after the seismic retrofit. The software uses the input of the structure address or latitude/longitude coordinates to determine ground motions from the USGS Seismic Hazard Mapping Project. The site class (A through F) is selected in the software, which is used to modify the ground motions to better represent the site. For soil type F, remediating the site or relocating to a new site (with site class E or better) is recommended prior to pursuing an earthquake mitigation project for a structure.

Table 1. Soil site classifications.

Class	Description
A	Hard rock
B	Rock
C	Very dense
D	Stiff soil
E	Soft soil
F	Liquefiable

Ground motions are determined for recurrence intervals ranging from 10 to 10,000 years and are used in conjunction with the capacity parameters to computer-estimated damages before and after mitigation. Ground motions and capacity parameters are calculated for drift-sensitive and acceleration-sensitive elements for both structural and non-structural seismic projects. For projects that include both structural seismic retrofits and non-structural seismic retrofits, it is beneficial to include both within a single project, but they must be added as separate mitigation actions as shown in **Figure 8**.

References: FEMA's Benefit-Cost Analysis Reference Guide, Supplement to the Benefit-Cost Analysis Reference Guide, FEMA BCA Tool (including Help Content within the tool)

Approach: The following describes the essential seismic data required to estimate avoided damages using modeled damages in the BCA Tool. If **Step 1** through **Step 10** of this supplement are followed and all data gathered, there should be minimal additional data collection needed to complete the Modeled Damages BCA. To verify the information entered in the BCA software, the following supporting information must be provided.

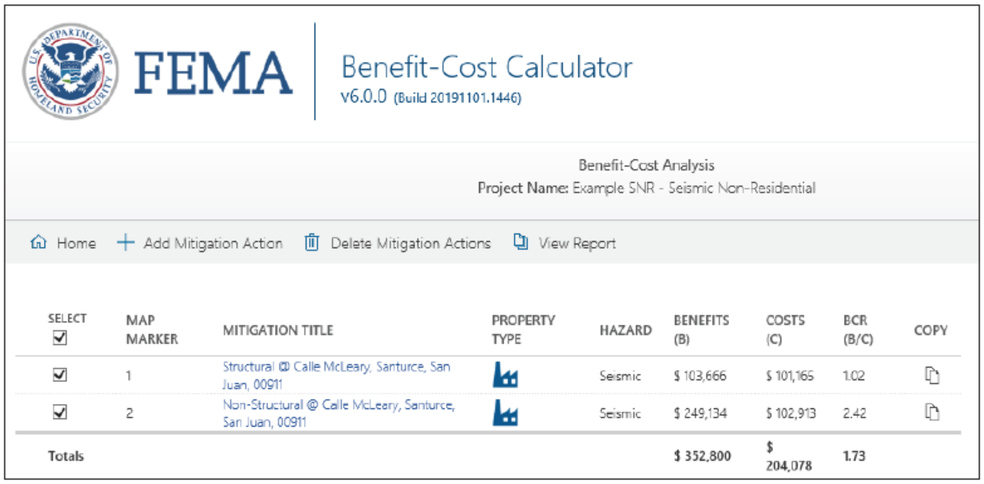


Figure 8. Example of combining structural and non-structural mitigation actions in a single BCA project.

1. Project useful life (PUL) – FEMA standard values can be found in the BCA Reference Guide or within the BCA Help Content
2. Project Cost – Refer to **Step 5**
3. Provide the annual maintenance cost associated with maintaining the effectiveness of the components installed as part of the mitigation project.
4. Seismic hazard information – Refer to **Step 10.**
    a. Provide the location of the structure to be retrofitted (address or latitude/longitude).
    b. Provide the soil site class (e.g., rock, stiff soil).
    Note: If a geotechnical report indicating the soil site class has not been developed for the project site, soil type D, "Stiff Soil," should be utilized.
5. Structural information – Refer to **Step 2.**
    a. Provide the total structure area.
    b. Provide the total BRV.
    c. Provide the average number of occupants based on occupancy 24 hours per day, 7 days per week, 365 days per year.
    d. Specify the structure use (e.g., hospital, college/university, single-family dwelling).
6. Before and after mitigation building parameters for each of the following – Refer to **Step 2.**
    a. Specify the building model type (e.g., steel moment, concrete shear wall, unreinforced masonry bearing walls).
    b. Specify the number of stories in the building.
    c. Specify the total structure height in feet.
    d. Provide the capacity parameters: elastic period (Te), design strength (Cs), elastic damping, degradation factor (kappa), STR, NSD, NSA and the location of any acceleration-sensitive components.

STEP 11B: Benefit-Cost Analysis Tool – Historical or Professional Expected Damages

Description: The BCA Tool Damage Frequency Assessment (DFA) module calculates project benefits and costs for proposed mitigation projects for any hazard. The DFA module compares user-entered damages/losses and the frequency that they occur in the before-mitigation scenario versus the after-mitigation scenario to calculate benefits based on avoided damages. The DFA module is used when the user has hazard data for historical damages or professional expected damages. For seismic projects, the DFA module is generally used when conducting a BCA for seismic retrofit of a non-building structure, for non-structural retrofit of components not specified in the Seismic module or when sufficient building and/or contents seismic data are not available.

References: FEMA's Benefit-Cost Analysis Reference Guide, Supplement to the Benefit-Cost Analysis Reference Guide, FEMA BCA Tool (including Help Content within the tool)

Approach: The DFA module calculates project benefits for proposed hazard mitigation projects based on either documented historical damages (such as physical damages or loss of function) or professional expected damages (estimated damages that have not yet occurred or that occurred but not to the extent possible) from at least one known frequency event. If recurrence intervals are not known and there are historical damage data from at least three events from different years, the DFA module can estimate a recurrence interval. Otherwise, additional data collection or analysis will be needed. The calculation compares before- and after-mitigation conditions. An example calculation is shown in **Table 2.**

- **Before-mitigation:** Based on existing conditions at the site. To demonstrate the current risk, actual historical damages or professional expected damages for certain severity events (e.g., mean recurrence interval of 1,000 years) can be entered in the DFA module to perform a BCA. Both structural and nonstructural damages may be considered when using the DFA module.
- **After-mitigation:** The same scenario seismic events (i.e., before- and after-mitigation scenarios for a 1,000-year mean recurrence interval seismic event) should result in reduced damages due to the mitigation project. The after-mitigation damages should be estimated based on the level of protection provided by the project (i.e., the seismic retrofit will resist the seismic forces as specified by the IEBC, IBC, IRC, ASCE 7 and ASCE 41). For example, seismic retrofit that meets the aforementioned standards should generally achieve a level of protection of 1% probability of collapse within a 50-year period or a 4,975-year recurrence interval seismic event. In this case, for earthquakes of smaller magnitudes or characteristic earthquakes, there may be negligible or minor structural damages and minor non-structural damages.

Table 2: Before- and after-mitigation estimated damages.

RI	Before-Mitigation Damages			After-Mitigation Damages		
	Building (Structural)	Contents (Non-structural)	Loss of Function	Building (Structural)	Contents (Non-structural)	Loss of Function
100-year	$25,000	$50,000	$175,000	$0	$1,250	$0
500-year	$50,000	$80,000	$250,000	$5,000	$7,500	$10,000
4975-year	$1,500,000	$2,250,000	$3,000,000	$75,000	$120,000	$150,000

Potential Sources:

- Insurance claims, receipts from repair of seismic damages, FEMA Public Assistance projects, documentation of lost service from a utility provider, Public Works department.
- Results of structural models developed and certified by a professional engineer

STEP 11C: Additional Benefits for a Benefit-Cost Analysis

Description: There are several benefits that could be counted for a project. Any or all the benefits can be used to demonstrate that a project is cost-effective or, in other words, has a BCR greater than 1.0. Once the initial BCA information is collected and a preliminary analysis is performed, additional benefits may be analyzed if needed.

Approach:

Answer the following questions:

1. Do the services that the structure provides have to be temporarily relocated? Displacement costs are based on the length of time the building is out of service, a one-time cost for setting up and moving to a temporary facility to continue operations and monthly costs for occupying the temporary facility (rent). The BCA Tool will use FEMA standard values to automatically calculate the avoided losses to contents and avoided displacement costs. If different values are used, supporting documentation must be provided.
2. Does the building include any rental property for which the owner receives income? What is the cost of rent income per month? Including rental income and displacement costs, the user should be cautious to avoid double-counting benefits. For example, including both the loss of rental income for the owner and the displacement cost for the residents in the BCA would be double-counting damages for the property because both costs represent the same loss.
3. Is there a business run out of the building? How much income does that business bring in per month?
4. Does the project prevent loss of service to a utility?
5. Are there any non-critical government services provided from the building such as a permit office or library?
6. Are there any critical services provided from the building such as police, fire, or medical services?

STEP 11D: Loss of Service to Critical Facilities

Description: The BCA Tool will account for the loss of service for critical facilities such as fire stations, hospitals, police stations and other facilities. Under each facility type, specific information is required to determine the monetary damages incurred if the facility is closed because of seismic damage. The following is a list of information that will allow the loss of service to be calculated.

References: Supporting documentation for loss of service calculations can include census data, local maps, mapping programs or GIS programs, facility operations management reports, emergency plans for the facility or documents such as annual reports.

Approach: To calculate loss of service, provide the following information for each facility type:

- **Fire Stations**
  - Type of service area served by the fire station (e.g., urban, suburban, rural, wilderness)
  - Number of people served by the fire station
  - Distance to the next closest fire station that would provide fire protection to the jurisdiction normally served by this fire station (in miles)
  - Distance in miles to the next closest fire station that would provide emergency medical services for the jurisdiction normally served by this fire station (in miles), if applicable
- **Hospitals**
  - Number of people served by the hospital
  - Distance to the next closest hospital (alternate hospital) that would treat the population served in the event this hospital was inoperative (in miles)
  - Number of people served by the alternate hospital
- **Police Stations**
  - Type of area served by this police station (e.g., metropolitan, city, rural)
  - Number of people served by this police station
  - Number of police officers working at the police station
  - Number of police officers that would serve the same area if the station were shut down due to a disaster
- **Other Facilities**
  - Service name (type of service)
  - Total annual operating budget (must be provided with supporting documentation)

STEP 12: Environmental and Historic Preservation Considerations

Description: Environmental and, particularity, historic preservation compliance will need to be considered as part of the application process for seismic retrofit mitigation. The assistance of a licensed professional engineer, architect or contractor may be required to help obtain the necessary information about environmental and historic preservation compliance. Refer to the EHP Supplement Job Aids.

Resources

Below is a comprehensive list of resources identified throughout this supplement. Not all these resources are necessary for every seismic retrofit project but are provided to ease identification of source material.

PROGRAM AUTHORITIES

- The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, 42, U.S.C. 4001 et seq.

- [44 Code of Federal Regulations, Part 206, Subpart N]
- [2 Code of Federal Regulations, Part 200]

PROGRAM GUIDANCE

- FEMA Hazard Mitigation Assistance Guidance (and Hazard Mitigation Assistance Guidance Addendum)
- Benefit-Cost Analysis Reference Guide and Supplement to the Benefit-Cost Analysis Reference Guide

TECHNICAL GUIDANCE AND STANDARDS

- American Concrete Institute (ACI), Building Code Requirements for Structural Concrete and Commentary. (ACI 318-14)
- ACI/ASCE/The Masonry Society (TMS), Building Code Requirements and Specifications for Masonry Structures. (ACI 530-13/ASCE 5-13/TMS 402-13)
- American Iron and Steel Institute (AISI), Cold-Formed Steel Design Manual. (AISI S100-16)
- American Iron and Steel Institute (AISI), North American Specification for the Design of Cold-Formed Steel Structural Members. (AISI S100-12)
- American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC), Specifications for Structural Steel Buildings. (ANSI/AISC 360-16)
- ANSI/AISC, Seismic Provisions for Structural Steel Buildings. (ANSI/AISC 341-16)
- ANSI/American Forest & Paper Association (AF&PA), National Design Specification for Wood Construction. (NDS-2018)
- American Society of Civil Engineers (ASCE) Structural Engineering Institute's (SEI) ASCE/SEI 7-16,
- Minimum Design Loads for Buildings and Other Structures (or latest version)
- American Society of Civil Engineers (ASCE) Structural Engineering Institute's (SEI) ASCE/SEI 41-17, Seismic Evaluation and Retrofit of Existing Buildings (or latest version)
- Cost Estimating Principles for Hazard Mitigation Assistance Applications
- FEMA E-74, Reducing the Risks of Nonstructural Earthquake Damage
- FEMA P-58, Seismic Performance Assessment of Buildings
- FEMA P-154, Rapid Visual Screenings of Buildings for Potential Seismic Hazards
- FEMA P-224, Seismic Vulnerability and the Impact of Disruptions of Lifelines in the Conterminous United States
- FEMA P-420, Engineering Design Guidelines for Incremental Seismic Rehabilitation
- FEMA P-424, Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds
- FEMA 445, Next-Generation Performance-based Seismic Design Guidelines: Program Plan for New and Existing Buildings
- FEMA P-543, Design Guide for Improving Critical Facility Safety from Flooding and High Winds
- FEMA 547, Techniques for the Seismic Rehabilitation of Existing Buildings

- FEMA P-577, Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds
- FEMA P-787, Catalog of FEMA Building Science Branch Publications and Training Courses
- FEMA's Hazard US (HAZUS) Program
- International Building Code (IBC) 2018 (or most recent version)
- International Existing Building Code (IEBC) 2018 (or most recent version)
- International Residential Code (IRC) 2018 (or most recent version)
- Multi-hazard Loss Estimation Methodology, Earthquake Model, HAZUS-MH2.1
- Resilience-based Earthquake Design Initiative for the Next Generation of Buildings REDiTM Rating System, October 2013
- USGS United States Seismic Design Maps
- USGS Seismic Hazard Maps and Site-Specific Data

ADDITIONAL TOOLS AND RESOURCES

- FEMA's How to Find Your FIRM and Make A FIRMette
- FEMA's Map Service Center
- FEMA Benefit-Cost Analysis (BCA) Tool
- Cost Estimating Principles for Hazard Mitigation Assistance Applications
- FEMA's National Flood Hazard Layer
- Hazard Mitigation Assistance Application Development Scope of Work Examples
- Hazard Mitigation Assistance Application Development Engineering Case Studies
- EHP Review Supplements
- FEMA Hazard Mitigation Assistance Job Aids