

OREGON BENEFIT-COST ANALYSIS TOOL

FOR EVALUATION OF
SEISMIC REHABILITATION GRANT
PROGRAM APPLICATIONS

USER'S GUIDE



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1.0 WHAT IS BENEFIT-COST ANALYSIS?

1.1 Overview

Benefit-cost analysis is a well-established quantitative way of comparing the benefits of a seismic retrofit project with the costs of the project. Benefit-cost analysis results are expressed as a benefit-cost ratio which is simply the calculated benefits of the retrofit project divided by the project costs. When the benefit-cost ratio is greater than 1.0, the seismic retrofit project is deemed to be economically justified or cost-effective.

The benefits of a seismic retrofit project are the reduction in future damages, economic losses, and casualties attributable to the seismic retrofit project. That is, the benefits are the difference in estimated future damages, losses and casualties between the as-is condition of a building and the after-retrofit condition of the building. Thus, benefit-cost analysis requires making quantitative estimates of the future damages, losses and casualties both with and without the proposed retrofit project being implemented.

For the Oregon Seismic Rehabilitation Grant Program, the following categories of damages and losses are considered:

- Building damages,
- Contents damages,
- Displacement costs for temporary quarters,
- Loss of public services, and
- Casualties (deaths and injuries).

Benefit-cost analysis requires several types of input data, which are addressed in more detail in Chapter 4 of this User Guide. Briefly, benefit-cost analysis requires quantitative assessments of the following factors:

- Level of seismic hazard at the building's location,
- Vulnerability of the building and contents to damage in future earthquakes,
- Values of the building and contents,
- Costs for temporary quarters if the building must be vacated for repair of future earthquake damage,
- Value and importance of the public services provided from the building, and
- Average number of occupants in the building.

1.2 Present Value Calculations

Benefit-cost analysis is inherently probabilistic in nature. The timing and severity of future earthquakes cannot be known exactly; rather, the level of earthquake hazard is expressed probabilistically.

For benefit-cost analysis, damages and losses in future earthquakes are evaluated statistically, based on the likelihood of many levels of earthquake ground shaking and the expected damages when such levels of ground shaking occur. The benefits of reduced damages and losses are calculated statistically over the expected useful lifetime of the building.

To compare future benefits with the present costs of seismic retrofits, the calculated future benefits of retrofitting are adjusted to what is known as net present value, taking into account the time value of money. These calculations are done automatically by the Oregon BCA Tool, based on standardized assumptions about the useful lifetime of the project and the “discount rate” which reflects the time value of money.

For benefit-cost analyses of seismic mitigation projects for the Oregon Seismic Rehabilitation Grant Program, a standard useful lifetime of 50-years and a discount rate of 2% are built into the Oregon BCA Tool.

The Oregon BCA Tool does all of the many complicated calculations necessary for benefit-cost analysis automatically. The user must only enter the specified building-specific information in the designated cells in the spreadsheet.

1.3 Engineering Analysis

Benefit-cost analysis of seismic retrofit projects necessarily involves some engineering judgment about the existing building and the proposed retrofit.

Consultation with an engineer knowledgeable about seismic vulnerability and seismic retrofits is necessary to understand the seismic vulnerabilities of the existing building, evaluate the level of risk, develop a credible seismic retrofit scheme and generate an accurate retrofit cost estimate.

The Infrastructure Finance Authority encourages applicants to consult with a knowledgeable engineer throughout the development of the prospective seismic retrofit project. Applications submitted without adequate engineering evaluations are much less likely to receive grant funding.

1.4 Data Documentation

A robust, fully credible benefit-cost analysis requires careful consideration of each of the user-entered data inputs which affect the benefit-cost analysis.

Information on the sources where the data inputs were obtained for the benefit-cost analysis may be requested for verification purposes.

1.5 Interpretation of BCA Results

As noted above, a benefit-cost ratio greater than 1.0 means that the seismic retrofit project is deemed to be economically justified or cost-effective. In this sense, the higher the benefit-cost ratio the better the project is from an economic perspective.

Conversely, a benefit-cost ratio less than 1.0 means that the seismic retrofit project is not economically justified or cost-effective. This conclusion becomes stronger for benefit-cost ratios well below 1.0.

Thus, in narrowly defined economic terms, projects with higher benefit-cost ratios are better projects than those with lower benefit-cost ratios.

However, there are important caveats on the above interpretation of benefit-cost ratios. Most importantly, they are valid only to the extent that the benefit-cost analysis includes all of the significant benefits for a seismic retrofit project.

In some cases, there may be other factors, which are not considered at all or incompletely considered in the benefit-cost analysis. Examples include the historical value of a building, the importance that a given community may place on a particular building or other factors that are difficult to quantify in purely monetary terms.

For the Oregon Seismic Rehabilitation Grant Program, benefit-cost results are an important part of the evaluation and ranking process, but are not the sole determinant of whether or not a given project will be selected for funding. In some cases, projects with benefit-cost ratios below 1.0 may be selected for funding.

2.0 WHAT MAKES A GOOD SEISMIC RETROFIT PROJECT?

2.1 Concepts

Benefit cost analysis is about evaluating risk. In this context, risk means the potential for damages, economic losses and casualties in future earthquakes. The higher the level of risk is for an existing building, the greater the benefits of reducing that risk by retrofitting a building.

The following attributes combine to determine the level of risk for a given building:

- **Seismic Hazard.** The higher the level of seismic hazard is at a given location (the probability and severity of future earthquakes), the greater the level of risk.
- **Vulnerability.** The greater the vulnerability of a building and its contents (the extent of damage expected at various levels of earthquake ground shaking), the greater the level of risk.
- **Value at Risk.** The greater the values of the building and contents, the greater the level of risk.
- **Economic Losses.** The greater the costs of displacement to temporary quarters in future earthquakes and the value of public services provided from the building, the greater the level of risk.
- **Occupancy.** The higher the average occupancy of a building is, the higher the level of risk of casualties (deaths and injuries).

For a given seismic retrofit project, the benefit-cost ratio depends strongly on the level of risk, as noted above, but also depends on the following two factors:

- **Effectiveness.** How effective is the proposed seismic retrofit in reducing the level of seismic risk? The greater the effectiveness, the higher the benefit-cost ratio.
- **Cost.** For a given level of effectiveness in reducing future damages and losses, lower costs for the mitigation project always result in a higher benefit-cost ratio.

2.2 Common Misperceptions

The level of seismic hazard has a substantial effect on benefit-cost ratios. Locations in Oregon with higher levels of seismic hazard will have higher benefit-cost ratios, everything else being equal, than locations with lower levels of seismic hazard.

For reference, Figure 1 on the following page shows the 2008 United States Geological Survey seismic hazard map for Oregon. This map, which shows the ground motions with a 2% chance of being exceeded in a 50-year period, illustrates the relative hazard levels within Oregon with the brown, red, orange and yellow areas having higher levels of hazards than the green and blue areas.

However, there are important caveats to keep in mind which considering seismic hazards, including:

- Seismic hazard also varies with soil type –which is not considered in the following map which is for rock sites. Soft soil sites typically have higher levels of ground motions and thus higher seismic hazard levels.
- Not every prospective seismic retrofit in a high hazard location will have a high benefit-cost ratio. The benefit-cost ratio depends on the combination of all of the risk factors noted above, as well as on the effectiveness and cost of the mitigation project.
- Seismic retrofits in moderate or even relatively low seismic hazard locations may have high benefit-cost ratios if the building has profound seismic vulnerabilities, the building and contents have high values, high potential for economic losses, and a high occupancy.

There are many other common misperceptions about seismic risk, including:

Misperception #1: A building that doesn't meet the seismic provisions in the current building codes is necessarily a high risk building and should be seismically retrofitted.

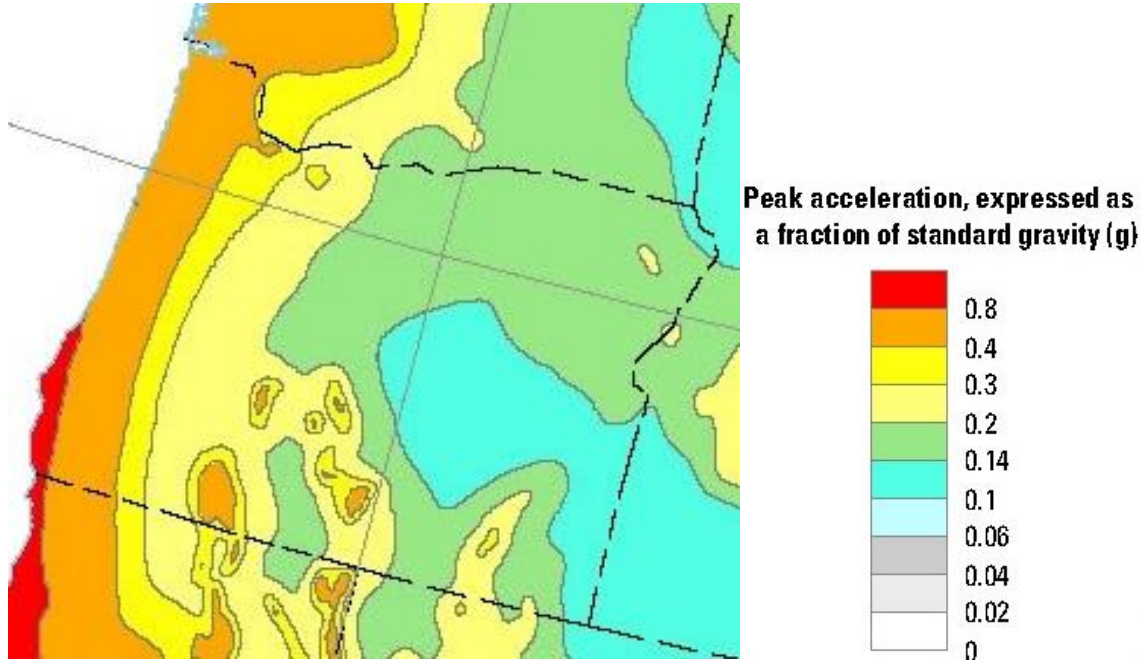
- Not meeting current code does not mean that a building is necessarily high risk or should be seismically retrofitted.
- Rather, a quantitative vulnerability assessment is necessary to determine how poor the building's seismic performance actually is. Many older buildings may have adequate seismic performance, depending on their vulnerability, use, importance and occupancy.

Misperception #2: Buildings home to critical services (emergency response, emergency medical, emergency operations centers and so on) will automatically be a "good" seismic retrofit project.

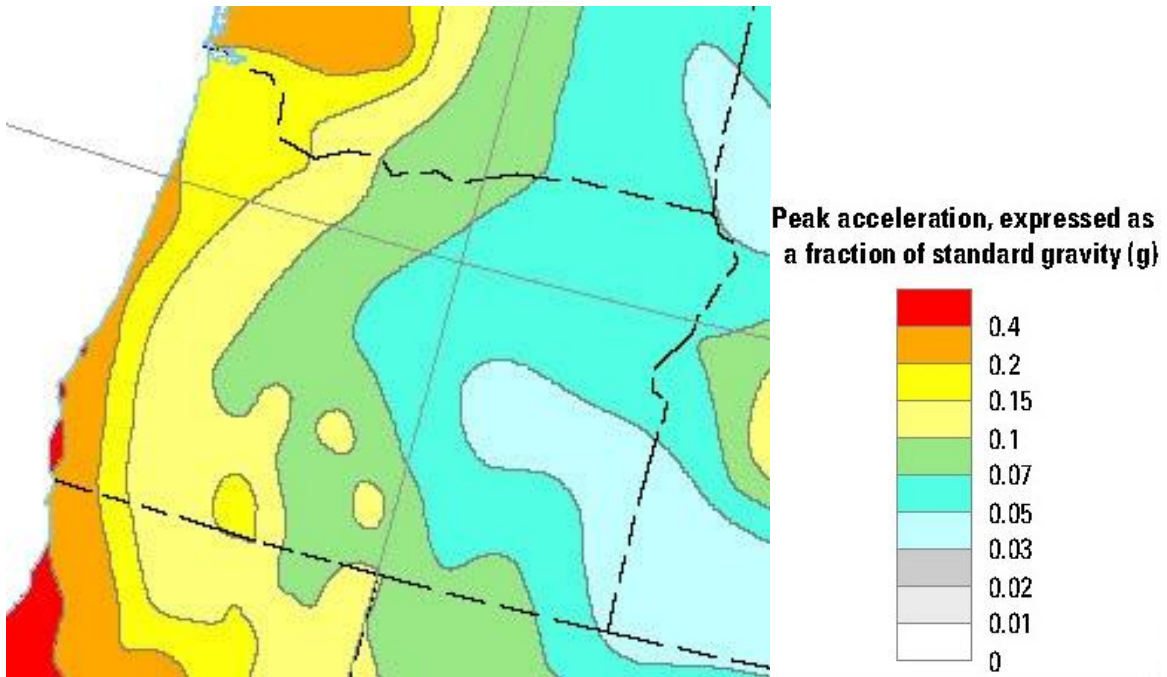
- Seismic retrofits for critical facilities are often given higher priorities than retrofits for ordinary facilities. Whether or not a retrofit for a critical facility is worth doing really depends, as always, on the level of risk.
- Seismic retrofits for critical facilities which have only minor seismic vulnerabilities, or are located in very low seismic hazard areas, may not be necessary or may not have a high priority.

2014 USGS Seismic Hazard Maps for Oregon
Earthquake Ground Motions
Peak Ground Acceleration as a Percentage of "g" the Acceleration of Gravity

2% Chance of Being Exceeded in a 50-Year Time Period



10% Chance of Being Exceeded in a 50-Year Time Period
(Note: Different Scale than the Figure Above)



3.0 OREGON BCA TOOL: OVERVIEW

3.1 Software

3.1.1 Oregon BCA Tool

The **OR-BCAT-Vers7.xlsm** file is the Excel spreadsheet where users enter data for their building and seismic retrofit project. Then, the spreadsheet automatically calculates the benefit-cost analysis results and the benefit-cost ratio.

Note: In last year's version of the software there were two Excel files, one for the BCA and one with the seismic hazard. This year, both have been merged into a single file.

3.1.2 Excel Software

The Oregon BCA Tool was written in **Microsoft Excel 2010** and the file appear to work properly in Excel 2013 but the compatibility has not been exhaustively tested. Operability of the Oregon BCA Tool in earlier versions of Excel has not been evaluated and use of older versions of Excel is not recommended.

Using the OR BCA Tool in Excel 2010 or 2013 is recommended.

3.2 Oregon BCA Tool: Navigation and Use

3.2.1 First Steps and Setup

The OR-BCAT-Vers7.xlsm file has a large number of embedded macros, which **MUST** be enabled for the software to work correctly. To enable the macros, open Excel and go through the following sequence on the Excel tool bar:

- Tools – Macro –Macro Security
- Should be set to Medium Security for macros to work.


When you open the OR-BCAT-Vers7.xlsm file the following message may appear near the top of the screen:

Security Warning:

Some active content has been disabled. Click for more details.

Enable Content

The recommended action is to click on the “Click for more details” text which opens a menu of choices. Click on the “Enable Content” button and then “Enable All Content.” These steps always enable content when you open this file without further actions being necessary.

Alternatively, you may click on the  button each time you open the OR-BCAT-Vers7.xlsm file.

For the BCA Tool to run correctly, you **MUST** click on Enable Content.

The Oregon BCA Tool has the following groups of pages (worksheets):

- The primary user data entry pages:
 - Main
 - Occupancy
 - Budget
- Building Part data entry pages for 1 to 10 building parts:
 - Bldg Part A
 - Bldg Part B...Bldg Part J
 - For a given building the number of Building Part data entry pages matches the number of structurally different building parts in the Bldg Database or as defined by the user on the Main page.
- Bldg Database:
 - This page contains built-in data for all buildings in the database.
 - Users may accept this data or override the data with user entries on the user entry data pages listed above.
 - If your building is not in the database, then you must enter all of the requested information.

Note: In many cases, a BCA for a given “building” must be done in several parts because the “building” has different parts that were built at different times to different seismic design levels and/or have parts with different structural systems with different seismic vulnerabilities. A seismic retrofit may include all parts of a given “building” or may only include some parts of the building if not all building parts have significant seismic vulnerabilities.

3.2.2 Navigation and Use

The basic steps for completing a BCA using the Oregon BCA Tool are summarized below. Further details and guidance are given in Chapter 4.

- Open the OR-BCAT-Vers7.xlsm file.
- **Rename the file with a name indicative of the building for which the BCA is being done, such as BCA-ABC School.xls, using the File Save As menu.**

- Begin by completing the data entries on the MAIN page.
 - The user data entries are in the cells shaded light green.
 - Simplified instructions are in the purple cells at the right hand side of the page.
- Complete the data entries in the cells shaded light green on the following pages:
 - **Main**
 - **Occupancy**
 - **Budget**
 - **Bldg Part A**
 - For buildings with more than one part which differs structurally from other building parts, complete the pages Bldg Part B, Bldg Part C....for the number of building parts for the building under evaluation.
- When the data entries are complete, print reports using the **Print** buttons at the bottom of each page:
 - Print individual pages, if desired, or
 - Print the entire report.

4.0 TECHNICAL GUIDANCE

This chapter contains technical guidance on data entries to supplement the simplified explanations given in the Instructions on each user data entry page in the OR-BCAT-Vers7.xlsx file.

4.1 MAIN PAGE

The MAIN page contains basic information to identify the entity submitting the Oregon Seismic Rehabilitation Grant Program application and the point of contact.

This page also contains the initial building-specific entries.

Building Name

Enter the building name. This entry does not necessarily have to be the same as the building name on the Bldg Database page.

Site ID

The Site ID is a critical entry, which must be unique. If the building is listed on the Bldg Database page you must enter the exact Site ID as shown on the Bldg Database page in Column B. Once the Site ID is entered, the OR BCA Tool automatically looks up data from the Bldg Database page and transfers it to the Building Part data entry pages.

If the building is not listed, enter a unique Site ID which does not duplicate a Site ID listed on the Bldg Database page. The user-entered Site ID can be in the same format as in the Bldg database, with a different number, or any short name that the user desires. For example: Acorn_sch. For the Building IDs, the BCA Tool adds letters to the end of the Site ID. In this example, Building Part A would be shown as Acorn_schA.

NOTE: Changing the Site ID erases all of the user-entered data. Be sure to change the Site ID only when you are starting a BCA for a new building.

Building Use

If the Site ID was not listed on the Bldg Database page, select the appropriate use for this building by left clicking on the green cell to the right of the Building Use label and then select from the drop-down menu.

Is the Building in the Oregon BCA Tool Database?

This question is answered automatically when you enter a Site ID.

How Many Structurally Different Building Parts Are There?

If the building is in the database, the number of building parts in the database is automatically displayed. If the actual number of structurally different parts differs from the number in the database, or if the building is not in the database, enter the number of structurally different parts.

Many buildings have been added on to or otherwise modified over time. For example, an original unreinforced masonry school building may have a later addition which is a wood frame building. In such cases the seismic performance of the two parts of the building may differ markedly. In such situations, the seismic vulnerability and indeed the entire BCA need to be done separately for each building part.

As noted previously in Section 1.3, many aspects of benefit-cost analysis almost always require engineering analysis. Consultation with a knowledgeable engineer to determine how many structurally different parts of the building there are may be required.

Building ID Numbers

Each building has an individual, unique Building ID number. If the building is in the database, these Building ID numbers appear automatically.

If the building is not in the database, Building ID numbers appear automatically when the user enters the User-Defined number of building parts.

Building Parts Square Footages

Users must enter the total building square footage for each building part. Here, as always for benefit-cost analyses, accurate data are desired. For example, a measured value of 4,920 SF is preferred to a rough estimate of 5,000 SF.

For buildings with more than one story, the square footage is the sum of the total square footage of each floor, not just the footprint of the building. not

Percent of Occupancy and Budget

Entering user values in the Percent of Occupancy and Percent of Budget columns is optional. If these columns are left blank, the Oregon BCA Tool automatically allocates occupancy and budget to each building part pro-rata with the percentage of square footage.

Occupancy and budget (annual operating budget for the building) are important inputs for BCA: occupancy is a key input for estimating deaths and injuries; budget is used to place an economic value on loss of function of the building in future earthquakes.

When data are available for the occupancy and budget percentages are available for building parts being retrofitted, entering these values will yield a more accurate BCA than using the automatic allocations by square footage. However, occupancy and budget percentages for building parts not included in the retrofit have no impact on BCA results.

Building Part Being Retrofitted?

The building part(s) included in the proposed seismic retrofit project must be identified in the Building Part Being Retrofit column by clicking on the green cells in each building part row and selecting Yes or No from the drop down menus.

Seismic Retrofit Cost Estimate

The seismic retrofit cost estimate is a critical entry for benefit-cost analysis and must be as accurate as possible and robustly documented

The seismic retrofit cost estimate must include the following elements:

- Conceptual seismic retrofit scheme. A meaningful cost estimate cannot be generated without knowing what retrofit measures are to be implemented. At a minimum, there must be at least a conceptual retrofit scheme summarizing the structural measures to be implemented with a narrative and/or sketches showing where in the building each structural measure will be constructed.
- More formal designs, either preliminary or final, allow more accurate cost estimates to be made. Thus, having such formal designs is certainly helpful and adds to the credibility of the application, but is not required for a grant application.
- Engineering cost estimate which includes:
 - Quantities and unit costs for construction,

- Architectural and engineering fees,
- All of the other typical soft costs, including contractor mobilization, profit and overhead (if not included in the unit costs above), permitting, inspections, insurance, and project management.

An accurate cost estimate for the proposed seismic retrofit is important not only for benefit-cost analysis and for the evaluation and ranking of the proposal, but also for the applicant. Cost overruns for successful applications will not be covered by the Oregon Seismic Rehabilitation Grant Program, but rather will be the responsibility of the applicant.

Documentation of the proposed retrofit scheme and documentation for the retrofit costs are completed by attaching other documents to the grant application (not in the BCA file).

Benefit-Cost Analysis Summary Results

The summary tables at the bottom of the Main page are automatically filled in after the user completes the entries on the Occupancy, Budget and Building Parts pages. There are no user entries in this table. An example of Benefit-Cost Analysis summary results is shown on the following page, for a fictitious school.

Benefit-Cost Analysis: Summary Results			
Acorn Example School			

Building Part	Benefits	Benefits by Category	
		Avoided Damages and Losses	
Bake_sch01A	\$295,348	Building Damage	\$43,618
Bake_sch01B	\$121,848	Contents Damage	\$21,809
		Displacement Costs	\$4,642
		Loss of Function Costs	\$7,350
		Casualties	\$339,777
		Total	\$417,196
Total Benefits	\$417,196		
Total Cost	\$321,321		
Benefit-Cost Ratio	1.298		

See also Section 1.5 of this User Guide, which reviews the interpretation of BCA results.

Seismic Retrofits for Only Part of a Building

In many cases, a seismic retrofit may be for only part of a building. For example, a building may consist of an original part built many decades ago and a newer addition, with the seismic retrofit being proposed only for the original part.

For such cases, follow these steps:

- Enter the square footages, described above, for all building parts. If desired the allocation of occupancy and/or budget to the various building parts can be adjusted by making entries in the occupancy or budget columns.
- On the Occupancy and Budget pages, which are described below in Sections 4.1 and 4.2, enter occupancy and budget data for the entire building including all of the parts whether or not they are being retrofitted.
- Then, complete the Building Part pages, which are described below in Section 4.3, only for the part(s) of the building being retrofitted. Do not make any entries on the Building Part pages for building parts which are not being retrofitted.
- When the benefit-cost analysis is completed, the summary benefit-cost analysis summary information will be displayed at the bottom of the Main page only for the building parts being retrofitted.
- The benefit-cost ratio displayed at the bottom of the Main page will be for the retrofit addressing the specified parts of the building.

4.2 OCCUPANCY PAGES

The average building occupancy on a 24/7/365 basis is an important data entry for benefit-cost analysis because it is used to calculate the expected number of casualties both before and after mitigation. For benefit-cost analysis, the number of casualties is monetized, using the 2015 FEMA statistical values for deaths, major injuries and minor injuries.

The average 24/7/365 occupancy for the building under evaluation is calculated from the data entries on the Occupancy page. The total building occupancy is distributed between the building parts (for buildings with more than one part), per the percentages of occupancy in each building part, which are entered on the Main page.

Especially for high occupancy buildings, the benefit of reducing casualties is typically an important component of the total benefits, and may be the largest category of benefits.

Determining the average occupancy for a building with a complicated pattern of occupancy varying by time of day, day of week, and time of year has historically been difficult for users of benefit-cost analysis software. The difficulty is compounded for buildings with many different types of occupancy, including not only employees or students or patients and visitors, but also other occupancies such as special events or periodic meetings.

In the Oregon BCA Tool, users are not asked to input average 24/7/365 occupancies but rather enter specific occupancies for various types of people. Then, the average 24/7/365 occupancy is calculated automatically.

The data entries required to calculate average 24/7/365 occupancy vary depending on the building use.

There are two columns of data entries on the Occupancy page:

- The left hand column is for buildings with occupancies that don't vary significantly from month to month and for the academic year for schools, colleges and universities.
- The right hand column is intended for the summer months for schools, colleges and universities, but can also be used for other occupancies with seasonal variation.

For hospitals, fire stations, and police stations complete only the entries in the left hand column. Make sure that the number of summer months is entered as zero on the right hand column.

For schools, colleges and universities, complete the entries in both the left and right hand columns.

Enter occupancy data only for the categories that apply for this building. For example, for a school, the patient entries, which apply only to hospitals, would be left blank.

Employees

Enter the typical number of employees in the building for the various combinations of time of day and day of week.

As for all data entries, provide documentation of the source(s) for the occupancy data.

Note that the number of hours for "day", "evening" and night can be adjusted to reflect the actual occupancy patterns for your building.

- A typical Monday-Friday “day” occupancy might be for 7 hours for some schools, 8 hours or 10 hours for some buildings and perhaps 12 hours for buildings that operate on a 12-hour shift basis.
- Similarly, some evening occupancies might be for only a few hours, while others may be for up to 8 hours.

Visitors

The occupancy pattern for visitors may vary markedly from building to building. For visitors, the data entries are for:

- Average total number of visitors in the building each day, and
- The average time (minutes) that each visitor spends in the building.

The average time that visitors spend in a building may vary markedly depending on the building use, ranging from just a few minutes, to several hours or more.

See also, the Meetings, Sports Events and Other Special Events section described below. Do not double count visitors in both places.

K-12 Students

For K-12 students, enter the following data for both the academic year and summer months:

- Average daily number of students
- Hours per day
- Days per year of classes.

College or University Students

For college and university students enter the following data for both the academic year and summer months:

- The duration of typical class periods – such as 1 hour, 1.5 hours, 2 hours and so on.
- The number of class periods per week of each class for a given duration. For example, a class that meets three times per week is three class periods.
- The average number of students for classes of each duration. Estimating this number is somewhat complicated because a given

Meetings, Sports Events and Other Special Events

Many buildings have meetings or other special events that occur on a variable basis. During such events people are in the building who would not be in the building for the normal daily function of the building. Examples include:

- Sports events or music/theater performances,
- Training sessions,
- Committee meetings,
- Community events in public facilities, and
- Any other events that occur from time to time.

Enter the following data for such events:

- Name/type of event,
- Number of events per year,
- People per event, and
- Average duration per event.

Important Note: for events with long durations such as a day-long book sale to benefit a school library, the correct entry for the “duration” is the average time that a typical person spends at the event. For example, if the book sale lasts 8 hours and 1,000 people attend and each person spends about one hour at the event, then the average occupancy for this event is 125 people, not 1,000 people.

Patients

For in-patients, enter the total number of in-patient beds (for reference) and the average daily number of in-patients. For benefit-cost analysis, in-patients are assumed to be in the hospital for each entire day.

For out-patients, enter the average number of out-patients per day and the average time that each out-patient spends in the building.

Occupancy data for hospital employees and visitors, other than patients, are entered in the previous sections for Employees and Visitors.

4.3 BUDGET PAGE

Following methods developed for FEMA, the value of public services provided from a building are valued in proportion to the cost to provide the services. For example, if a given building provides services to the community at a cost of \$5,000 per day, then the daily value of the services, the economic loss if the services are lost for one day because of earthquake damages, and the benefit if the loss of services is avoided for one day because of a seismic retrofit are all assumed to be \$5,000.

The daily cost of service is calculated from the annual operating budget for the building.

The total annual budget for the building under evaluation is calculated from the data entries on the Budget page. The total budget is distributed between the building parts (for buildings with more than one part), per the percentages of budget for each building part, which are entered on the Main page.

For services which provide critical post-earthquake response functions, the services provided are much more important – and thus valued more highly – immediately after an earthquake when the demand for services will be extremely high. For such critical facilities, a post-disaster continuity premium of 10 is applied to the daily cost of service. This means that the services per day are valued at 10-times the normal daily cost of service. This premium reflects the great importance of continuity of service for such critical facilities.

The types of facilities to which this premium is applied includes: police, sheriff and fire stations, emergency operations centers (including public safety answering points and similar services) and hospitals. In the Oregon BCA Tool, this premium is applied automatically, once the user selects the building use on the Main page.

The Annual Operating Budget is calculated automatically from the following user-entered data on the Budget page.

Employee Costs

Employee costs include salaries and all of the benefits paid by the employer. The salary and benefits table allows entries for up to 10 categories of employees in which to enter average annual salaries (or wages, for hourly employees) and benefits as a percentage of salaries (or wages).

Part time employees can be entered as fractional full time equivalents (FTEs). For example, three half-time employees would be entered as 1.5 FTEs.

The costs for contract employees who work in the building can also be entered in this section, either by categories or as a lump sum for a single contract covering multiple contract employees.

Other Building Expenses

Data entry locations are provided for several other common categories of building expenses, including, supplies, building maintenance costs (exclusive of labor costs, which are covered under employees), utilities, insurance and rent.

A data entry location is also provided for annual capital goods costs. In this context, capital goods means items with a long useful lifetime such as furniture and equipment. Capital goods costs may vary markedly from year to year, depending on whether or not expensive items are purchased. In such cases, the average annual costs for several years may be entered.

District Office or Headquarters Costs

The true cost to provide the public services from a given building may include part of the annual costs to operate a district office or headquarters building. For example, the true annual costs for Fire Station #3 in a fire department or district with 7 fire stations and a headquarters building includes not only the specific costs for Fire Station #3 but also a fraction of the costs to operate the headquarters building. Similar considerations apply to a school, college, or university where part of the cost of providing services from an individual building include part of the costs to operate a district office or administration building.

In such cases, enter the percentage of the Annual Operating Budget for the District Office, Headquarters or Administration Building that is attributed to the building for which benefit-cost analysis is being conducted. The determination of the applicable percentage must be determined on a rational basis, which must be documented, such as:

- Proportional to the annual operating budgets for each building. For example, if Fire Station #3's annual operating budget is 17.5% of the total annual operating budget for 7 fire stations, then 17.5% of the annual operating budget for the Headquarters building could be allocated to the cost of services for Fire Station #3.
- Alternatively, District Office, Headquarters or Administration building annual operating budgets could be allocated to a specific building in proportion to the percentage of employees or students in the building under evaluation. For example, if the Lincoln School has 32% of the employees or students in a district with four schools, then 32% of the

District Office annual operating budget could be attributed to the Lincoln School.

Proxy Rent Calculations

For buildings that are rented, annual rental costs are included in the Other Building Expenses categories discussed above.

If the annual rental costs are left blank or entered as zero, the Oregon BCA Tool assumes that the building is owned by the applicant. In this case, a “proxy rent” is calculated automatically and included in the effective Annual Operating Budget for the building. Doing so reflects the economic cost of the capital tied up in the building and thus more accurately values the services provided from the building.

Annual Operating Budget for District Office, Headquarters or Administration Building.

The Annual Operating Budget for a District Office, Headquarters or Administration Building is calculated in the same manner as discussed above for the building under evaluation.

If the District Office, Headquarters or Administration Building is owned (that is, annual rent is zero), then the replacement value of the building must be entered to allow calculation of the proxy rent (as discussed above).

Building replacement value means the cost to construct a new building of the same size, function and level of amenities as the existing building. Building replacement values may be estimated from standard cost estimating guides such as Means SF Costs (and others) or estimated from the costs to construct recent similar buildings (adjusted for size differences) by the entity submitting the application or by nearby entities.

NOTE: Be sure to avoid double-counting. For example, employee costs for the District Office, Headquarters or Administration Building should include only the costs for employees working in the building. The total Annual Budget for all buildings must sum to the Total Annual Budget for the entity.

4.4 BUILDING DATA PAGES

Each structurally different building part has its own data entry page. The number of building part data entry pages to be completed varies from one – for buildings that consist of only one part – to several for many buildings. The Oregon BCA Tool software can handle buildings with up to 10 parts.

Once the user enters the number of building parts on the Main page, the software automatically hides unused building part pages, so only the necessary number of pages is shown.

Latitude and Longitude

Latitude and longitude are important data entries because, in combination with the soil type, they determine the level of seismic hazard at the building location.

For buildings in the database, the default values from the database are shown. Users may correct errors in these data or, for buildings not in the database, enter latitude and longitude in the User-Entered Values column.

Latitude and longitude must be entered in decimal format, such as 44.0524, not in degrees, minutes and seconds. For a given building, data can be found using Google Earth or doing an internet search for web-based address converters. Search example: “Find latitude and longitude by address”.

Do not round the latitude and longitude data – enter data with at least 4 decimal places.

Soil Type

Soil type affects the level of seismic hazard because variations in soil type may amplify or de-amplify earthquake ground motions.

For buildings in the database, the default soil type from the database is shown. Users may correct errors in these data or, for buildings not in the database, enter soil type for the building site. If the soil type is not in the database and is not known for the building site, enter Soil Type D – Firm Soil.

There are four soil types in the Oregon BCA Tool:

- AB – Rock
- C – Soft Rock or Very Dense Soil
- D – Firm Soil
- E – Soft Soil.

Soil type is an important data entry for the benefit-cost analysis. Thus, an accurate determination of the soil type is important.

Accurate determination of soil type requires a geotechnical study for the site or consultation with an engineer knowledgeable about the determination of soil types.

For reference, the technical definitions of soil types from the International Building Code are shown below.

**TABLE 1615.1.1
SITE CLASS DEFINITIONS**

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 FEET, AS PER SECTION 1615.1.5		
		Soil shear wave velocity, \bar{v}_s , (ft/s)	Standard penetration resistance, \bar{N}	Soil undrained shear strength, \bar{s}_u , (psf)
A	Hard rock	$\bar{v}_s > 5,000$	N/A	N/A
B	Rock	$2,500 < \bar{v}_s \leq 5,000$	N/A	N/A
C	Very dense soil and soft rock	$1,200 < \bar{v}_s \leq 2,500$	$\bar{N} > 50$	$\bar{s}_u \geq 2,000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1,200$	$15 \leq \bar{N} \leq 50$	$1,000 \leq \bar{s}_u \leq 2,000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1,000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

Seismic Hazard Data

Seismic hazard data are automatically calculated after entry of latitude, longitude and soil type data.

In most cases, the seismic hazard data are the same for all building parts, but it is possible for different building parts to be on different types of soils and thus to have different seismic hazard data.

The seismic hazard data are displayed as peak ground accelerations (PGA), with the values as fractions of “g”, the acceleration of gravity.

There are two types of seismic hazard data displayed:

- Peak ground accelerations for 2%, 5%, 10% and 20% probabilities of being exceeded in 50 years. These values can be used to compare the level of seismic hazard at different sites.
- Spectral accelerations for both short-period and long-period motions, which are used for the seismic design of new buildings and retrofits. These values are shown for reference only.

Building Structural Data

There are three data entries in this section: Primary Structure Type, Number of Stories and Year Built. If the default values are correct you can leave these as-is. The number of stories for a building excludes basements. For the year built, enter the approximate year built if the exact year is unknown.

The structural building types used in the Oregon BCA Tool follow FEMA definitions. The building structural types are summarized in the table on the following page. See also Appendix 1 for detailed definitions.

The determination of the primary structure type for each building part is a critical step in the benefit-cost analysis. The building types in the database may or may not be correct. Therefore, it is essential to verify the correctness of the primary structural type for each building part.

The determination of the primary structural type is not always easy. For example, a building which appears at first look to be a “brick” building might be any one of several building types, including:

- Unreinforced Masonry (URM),
- Reinforced Masonry (RM1 or RM2),
- Wood Frame (W1 or W2, with brick veneer),
- Concrete Shear Wall (C2, with brick veneer), and
- Other building types or a combination of building types.

Accurate determination of the primary building structural type may require detailed inspection by a knowledgeable engineer, including review of the building drawings (if available).

The building structural types shown in the table on the following page are those used in FEMA’s HAZUS loss estimation software. **Note: most wood school buildings, even those with more than 5,000 square feet are Building Type W1 (Light Wood Frame).**

Building Structural Types

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1	W1	Wood, Light Frame ($\leq 5,000$ sq. ft.)		1 - 2	1	14
2	W2	Wood, Commercial and Industrial (> 5,000 sq. ft.)		All	2	24
3	S1L	Steel Moment Frame	Low-Rise	1 - 3	2	24
4	S1M		Mid-Rise	4 - 7	5	60
5	S1H		High-Rise	8+	13	156
6	S2L	Steel Braced Frame	Low-Rise	1 - 3	2	24
7	S2M		Mid-Rise	4 - 7	5	60
8	S2H		High-Rise	8+	13	156
9	S3	Steel Light Frame		All	1	15
10	S4L	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise	1 - 3	2	24
11	S4M		Mid-Rise	4 - 7	5	60
12	S4H		High-Rise	8+	13	156
13	S5L	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 - 3	2	24
14	S5M		Mid-Rise	4 - 7	5	60
15	S5H		High-Rise	8+	13	156
16	C1L	Concrete Moment Frame	Low-Rise	1 - 3	2	20
17	C1M		Mid-Rise	4 - 7	5	50
18	C1H		High-Rise	8+	12	120
19	C2L	Concrete Shear Walls	Low-Rise	1 - 3	2	20
20	C2M		Mid-Rise	4 - 7	5	50
21	C2H		High-Rise	8+	12	120
22	C3L	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 - 3	2	20
23	C3M		Mid-Rise	4 - 7	5	50
24	C3H		High-Rise	8+	12	120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26	PC2L	Precast Concrete Frame with Concrete Shear Walls	Low-Rise	1 - 3	2	20
27	PC2M		Mid-Rise	4 - 7	5	50
28	PC2H		High-Rise	8+	12	120
29	RM1L	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise	1 - 3	2	20
30	RM1M		Mid-Rise	4 - 7	5	50
31	RM2L	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise	1 - 3	2	20
32	RM2M		Mid-Rise	4 - 7	5	50
33	RM2H		High-Rise	8+	12	120
34	URML	Unreinforced Masonry Bearing Walls	Low-Rise	1 - 3	1	15
35	URM M		Mid-Rise	4 - 7	3	35
36	MH	Mobile Homes		All	1	10

Some buildings do not fit easily into the above building type classification. A building may have a composite structural system with elements combining the structural systems from more than one building type. In this case, assign the structural type as the one which best fits the actual building characteristics.

In atypical structural cases, the default seismic fragility curves used in the Oregon BCA Tool may not accurately reflect the seismic characteristics and building-specific seismic fragility curves may have to be developed by a knowledgeable engineer. See Seismic Fragility Curve section of this guide.

Rapid Visual Screening (RVS) Data

Rapid Visual Screening (RVS) is a FEMA-developed methodology for making a preliminary assessment of the seismic vulnerability of a building: the lower the RVS Final Score for a building, the greater the likelihood that the building has substantial seismic vulnerabilities.

The Bldg Database page in the OR-BCAT-Vers2.xls file contains RVS scores for many, but not all, of the buildings in the database. These scores were compiled by DOGAMI.

The Oregon BCA Tool uses these RVS scores, with modifications following the Enhanced RVS method developed by DOGAMI, as an important part of the algorithms used to estimate the seismic vulnerability of each building.

If the building is in the database and the database contains DOGAMI RVS scores, the RVS scores are displayed in the Default Values column. If not, then user-entered values **MUST** be entered.

RVS scores depend on the structural type of the building, the number of stories, the seismicity region, and on six score modifiers. A summary of these parameters is given below:

- The RVS seismicity region is determined by county.
 - If the county for your building is incorrect or missing, select the correct county from the drop-down menu
 - The correct RVS seismicity region appears automatically.
- The RVS Basic Score is determined by the primary structure type, number of stories and seismicity region. This value appears automatically based on the data entry for these three parameters.
- The RVS Final Score is based on the Basic Score plus the sum of the scores for five score modifiers:
 - Vertical Irregularity,
 - Plan Irregularity,
 - Pre-Code,
 - Post-Benchmark, and
 - Soil Modifier.

Completing a RVS Analysis, including determination of appropriate score modifiers requires specialized engineering experience and should not be attempted by users who are not thoroughly familiar with the FEMA RVS methodology. Thus, in most cases, reviewing RVS scores will require consultation with an engineer familiar with the RVS methodology.

The latest FEMA RVS Methodology is documented in the following two FEMA Publications:

- FEMA 154. Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook. Third Edition, 2015.
- FEMA 155: Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation. Third Edition, 2015..

The RVS Score Modifiers are defined below.

Vertical Irregularity means that a building's dimensions or stiffness and strength vary with elevation in the building. For example, if different stories have different sizes or shapes or differ in strength. A common vertical irregularity is a soft first story which may occur when the first story has larger windows or higher story height than upper stories. FEMA's 3rd Edition RVS considers two levels of vertical irregularity: "moderate" and "severe."

Plan irregularity means that a given story is not regular in shape, but rather may be L-shaped, T-shaped or U-shaped or have large interior openings or large reentrant corners.

Pre-Code means that the building was designed and built prior to the adoption of seismic provisions in the applicable local or state building code.

Post-Benchmark means that the building was designed and built under a building code with seismic provisions generally similar to the current building code.

Soil modifiers are based on the soil types listed previously.

The Oregon BCA Tool is based on the RVS results, but adjusts them using the mathematical principles in the Enhanced RVS methodology. For details of the E-RVS methodology see: DOGAMI Special Paper 39 (2007), Yumei Wang and Kenneth A. Goettel, Enhanced Rapid Visual Screening (E-RVS) Method for Prioritization of Seismic Retrofits in Oregon.

Building Data Section

This section contains basic data about the building and contents, as well as estimates of the displacement costs. For benefit-cost analysis, “displacement” means that a building suffers sufficient damage in a future earthquake so that the functions of the building must be relocated to temporary quarters while repairs are made.

Historical Buildings

The 2015 Oregon BCA Tool incorporates consideration of some buildings’ historical importance by assigning multipliers to buildings’ replacement values. There are five choices from the dropdown menu:

- None
- ES – Eligible, Significant per SHPO (Oregon State Historic Preservation Office)
- NDE – Eligible for listing in the National Register
- NRI – Individually listed in the National Register
- NHL – National Historic Landmark in the National Register.

Consultation with a historic preservation expert is recommended before assigning these historical categories to a building.

Building Square Footage

The square footages for each building part are entered on the Main page, rather than here. This approach is adopted to facilitate checking that the total building square footages matches the sum of the square footages for each part. If this value is incorrect, return to the Main page to enter a correct value.

Building Replacement Value

Building replacement value is the cost to build a new building of the same size, function and level of amenities as the existing building. Building replacement values include construction costs and all of the usual soft costs associated with building construction, including architectural and engineering fees, permitting, insurance, inspections and project management. However, building replacement value does not include land value.

Building replacement values may be estimated from:

- Standard cost estimating guides, such as Means SF Values (and many others), including consideration of the cost factors for various locations, or

- The actual building costs for a recent similar building in the area of the entity submitting the application (or in a nearby area with similar cost factors), adjusted, if necessary, for differences in building square footage.
- Building replacement values are expressed as \$/SF not as the total value of the building. Total values are calculated automatically from the \$/SF and the size of the building.

The reference building replacement values shown in the Default Values column may or may not be applicable to the specific building under evaluation. Users may enter building specific values, with documentation of the basis for the estimate.

Contents Value

Contents value is comprised of the replacement value of the building contents, including furnishings, equipment and supplies. However, contents value excludes building electrical and mechanical equipment which is permanently attached to the building and thus considered under building replacement value.

Contents value must be expressed as a percentage of the building replacement value and may be estimated from inventory data or insured value data, adjusted, if necessary, to reflect replacement value not depreciated value.

Displacement Costs

Displacement costs refer to the expenses of being displaced from the current facility in the event an earthquake results in enough damage so that the building must be vacated for repairs to be made or for the building to be replaced.

Displacement costs are expressed in two parts:

- Monthly costs to rent temporary quarters. Monthly costs are expressed as \$/SF/month, not as \$/month to facilitate comparison with typical values.
- One time displacement costs which include round-trip moving expenses and set-up costs for information technology and other specialized functions.

Local values may be entered based on local rental rates and building-specific one-time displacements costs,.

Average Annual Occupancy

The average annual occupancy for each building part is displayed on the Main page from the total average occupancy of the building, calculated on the Occupancy page, and the percentages of total average occupancy attributed to each building part.

Adjustments to the average annual occupancy of a given building part are made on the Main page by adjusting the percentage of the building's total occupancy attributed to each building part.

Annual Operating Budget

The annual operating budget for each building part is calculated on the Main page from the total operating budget of the building (including one or more building parts) and the percentage of total annual operating budget attributed to each building part.

Adjustments to the annual operating budget of a given building part are made on the Main page by adjusting the percentage of the building's total budget attributed to each building part.

Seismic Fragility Curves

Seismic fragility curves are mathematical expressions of a building's vulnerability to seismic damage in future earthquakes. Fragility curves allow calculation of the expected level of damages as a function of level of earthquake ground motions. For each building part, there are two sets of fragility curves: one for the as-is (before retrofit) condition of the building and one for the after retrofit condition of the building. Seismic fragility curves profoundly affect the calculation of benefits and thus are extremely important inputs for benefit-cost analysis.

Seismic fragility curves facilitate estimating the probability that a building will be in one of four damage states: slight, moderate, extensive or complete, at any given level of ground shaking. There are five mathematical parameters in each seismic fragility curve:

- Median PGA values for the slight, moderate, extensive and complete damage stages, and
- A "beta" value which is a form of standard deviation, reflecting the uncertainty in median PGA estimates. In the Oregon BCA Tool, betas of 0.66 before mitigation and 0.62 after mitigation were used. The

higher beta before mitigation reflects a greater uncertainty in the building's seismic performance.

The mathematics of seismic fragility curves is somewhat complex, involving log-normal probability distributions. However, the concept is straightforward. For example, for a given building, a median PGA of 0.55 g for the extensive damage state means that engineering analysis and judgment indicate that this building has a 50% chance of being in the extensive damage state or a higher damage state at a level of earthquake ground shaking of 0.55 g.

The default values for seismic fragility curves built into the Oregon BCA Tool are based on a combination of the FEMA-HAZUS fragility curves, modified and interpolated based on the RVS (and E-RVS) scores. These default values are largely based on fragility curves for typical buildings of a given structural system and thus may or may not accurately reflect the seismic vulnerability of the specific building under evaluation.

For reference, the HAZUS seismic fragility curves for typical buildings are shown in Appendix 3. There are four sets of fragility curves, for various building types: Pre-Code, Low-Code, Moderate-Code and High-Code. These code variations reflect the prevailing seismic code provisions applicable when the building was designed and built.

A seismic retrofit improves the seismic performance of a building, which is reflected in the after-retrofit seismic fragility curves. After-retrofit seismic fragility curves have higher median PGA values for a given damage state, reflecting a lower probability of being in a given damage state at any PGA level.

For some building types, a system retrofit typically results in strengthening an existing structural system. However, for some building types, a typical seismic retrofit replaces a highly vulnerable structural system with a new, less vulnerable structural system. In the Oregon BCA Tool, the default after-retrofit seismic fragility curves assume replacement of the structural system for the cases in the shaded cells in the following table.

Building Type	Retrofit Bldg
W1	W1
W2	W2
S1	S2
S2	S2
S3	S3
S4	S4
S5	S4
C1	C2
C2	C2
C3	C2
PC1	PC1
PC2	PC2
RM1	C2
RM2	C2
URM	C2
MH	N/A

For the building types with different after-retrofit structural systems, unreinforced masonry or reinforced masonry structural walls are assumed to be replaced with reinforced concrete structural walls.

The 2015 Oregon BCA Tool allows applicants to select the most appropriate after-retrofit structural system for a given building. Ideally, a benefit-cost analysis should include development of building-specific seismic fragility curves for both the as-is and after-retrofit conditions. Building specific fragility curves can incorporate all available information about the existing building's structural characteristics and condition into the as-is fragility curve estimate. Similarly, for the after-retrofit building, a building-specific fragility curve can incorporate the specific structural measures included in the retrofit.

Thus, building specific seismic fragility curves may be more accurate than the default fragility curves built into the Oregon BCA Tool. Nevertheless, developing building-specific seismic fragility curves requires specialized seismic engineering experience and necessarily requires greater resources and more time than using the fragility curves built into the Oregon BCA Tool.

For applicants considering the development of building-specific seismic fragility curves, we offer the follow brief guidance. Such efforts should be undertaken by only engineers with broad experience in seismic risk assessments for existing buildings and in the design of seismic risk retrofits.

The typical steps in developing building specific seismic fragility curves are briefly noted below:

- Site visit to evaluate the building's structural system(s) and condition.

- Examination of as-built drawings (when available).
- Vulnerability assessment, including necessary calculations, typically using the methods in ASCE-41-13, including at least a Tier 1 evaluation and preferably a Tier 2 evaluation.
- Generate building specific seismic fragility curves, starting with the HAZUS fragility curves (for reference) and incorporating the engineering analysis, calculations and judgments from the vulnerability assessment to reflect the building specific seismic vulnerabilities.
- Similarly, for the after-retrofit conditions, start with the building specific fragility estimates for the as-is conditions and the HAZUS fragility curves (for reference) and estimate the after-retrofit vulnerability taking into account the specific details of the structural measures in the retrofit.

For reference, the HAZUS fragility curves for typical buildings are shown in Appendix 3. Depending on its design basis and condition, a given building may have better or worse seismic performance than the typical fragility curves for a given structural type designed to a given code level.

4.5 SUMMARY

The above text completes the technical guidance for user data entries into the Oregon BCA Tool. If you have completed all of the entries noted above, the BCA is complete.

The next step is to return to the Main page and print the entire report.

See also Section 1.5 of this User Guide, which reviews the interpretation of BCA results.