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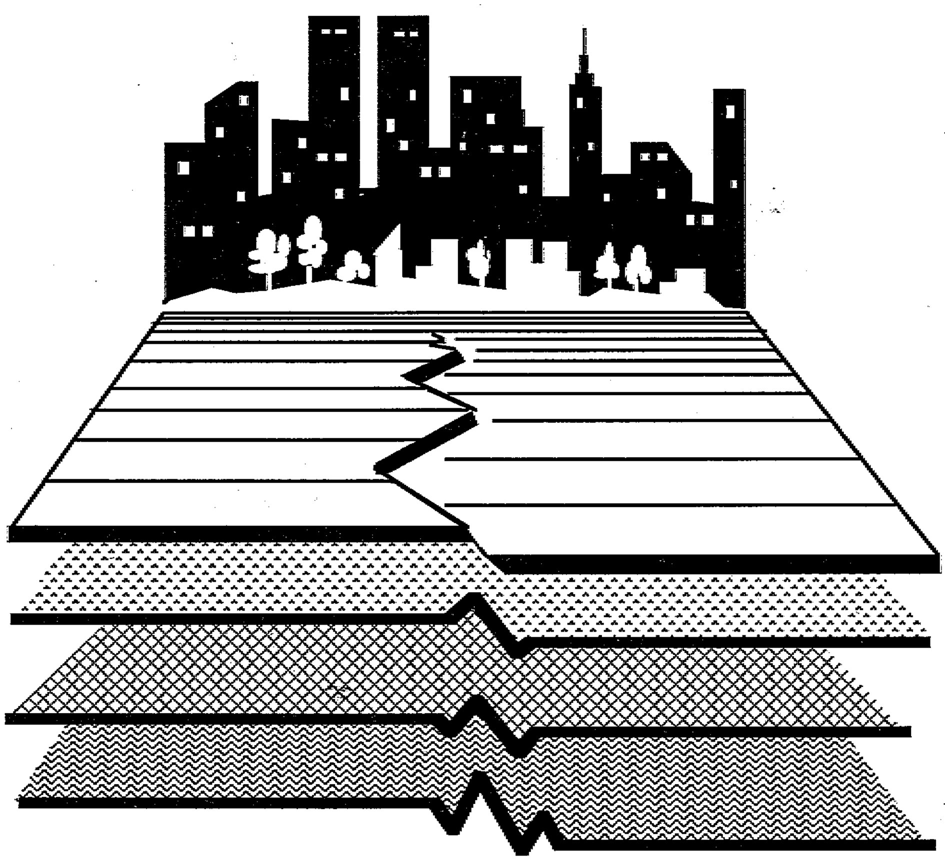
Seismic Rehabilitation of Federal Buildings: A Benefit/Cost Model

Volume 1 - A User's Manual



Issued by FEMA in furtherance of the Decade for Natural Disaster Reduction.

NATIONAL EARTHQUAKE HAZARDS

REDUCTION PROGRAM

SEISMIC REHABILITATION

OF FEDERAL BUILDINGS:

A BENEFIT-COST MODEL

VOLUME 1
A USER'S MANUAL

Prepared for the Federal Emergency Management Agency
Under Contract No. EMW-92-6-3976

by

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For further information regarding this document, additional copies, or the software to operate the model, contact the Federal Emergency Management Agency, Mitigation Directorate, Washington, DC 20472.

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FEMA FORWARD

FEMA is pleased to have sponsored the development of these two new publications (Seismic Rehabilitation of Federal Buildings: A Benefit-Cost Model. Volume 1: A User's Manual and Volume 2: Supporting Documentation), and the associated software, for inclusion in the series of documents dealing with the seismic safety of existing buildings. In this endeavor, FEMA gratefully acknowledges the expertise and efforts of VSP Associates, Inc., its consultants, the Advisory Panel, and Ms. Diana Todd of the National Institute of Standards and Technology, Technical Advisor to FEMA.

The Federal Emergency Management Agency

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EXECUTIVE SUMMARY

FEMA's program for reducing seismic hazards in existing buildings includes development of a body of consensus engineering criteria on how to evaluate and reduce the seismic vulnerability of existing buildings. This comprehensive program is also concerned with the societal and economic aspects of the seismic rehabilitation of existing buildings. This report and accompanying software present a benefit-cost model for the seismic rehabilitation of Federal buildings.

Is it worth it? This is the primary question about seismic rehabilitation projects which are designed to reduce expected damages and casualties from future earthquakes. Decision making about the prospective seismic rehabilitation of existing Federal buildings may be difficult because of the myriad of complex and often contentious engineering and public policy issues involved. In many cases, life safety (avoiding casualties) is the principal motivation for implementing seismic rehabilitation programs, while in some instances property protection or continued functionality of important government services may be the driving economic force.

Benefit-cost analysis is a powerful tool which can help determine whether the future benefits of a prospective seismic rehabilitation are sufficient to justify the present costs of the project. The benefit-cost methodology in this report (and accompanying software) provides estimates of the benefits (i.e., avoided future damages, losses and casualties) of the seismic rehabilitation of Federal government buildings. The benefit-cost model is also applicable to state and local government buildings.

There are two primary intended applications for this methodology: first, to roughly screen or prioritize a large list of buildings and second, to evaluate in detail one or more specific alternatives on a single building for which detailed engineering analysis exists. To screen a large list of buildings, a rough analysis could be made using typical or default data built into the computer program, although incorporation of more detailed building specific information would improve the validity of the results. To evaluate one or more specific rehabilitation options for a single building, detailed engineering analyses of the alternatives are essential.

The benefit-cost methodology presented in this report is intended for use by facility managers, design professionals (engineers and architects), and others involved in decision making about the seismic rehabilitation of Federal buildings. A technical background is <u>not</u> a prerequisite for using the methodology. However, a working knowledge about the general principles and terminologies relevant to the seismic performance of buildings, and some basic personal computer skills are necessary.

The benefit-cost model performs the necessary calculations to determine how the expected future benefits of a specific seismic rehabilitation project compare to the costs. The model also generates detailed scenario damage estimates of expected damages, other economic losses, and casualties per earthquake event (as a function of Modified Mercalli Intensity, MMI, and effective peak ground acceleration, PGA). These scenario damage, loss, and casualty estimates may prove useful to decision makers.

Benefit-cost analysis does not provide an absolute answer about whether or not to undertake the seismic rehabilitation of a building because decisions about rehabilitations usually depend on a great many factors and policy decisions well outside the confines of benefit-cost analysis. For example, basic policy decisions about what level of life safety and what level of post-earthquake performance are desired cannot be decided by a benefit-cost program. Furthermore, the quality of input data and the resulting uncertainty in benefit-cost results must be considered in all decision making using the results of benefit-cost analysis. Notwithstanding these limitations, the benefit-cost model presented in this report is a powerful tool to assist decision-makers concerned with the seismic rehabilitation of Federal buildings.

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CHAPTER 1: INTRODUCTION

It is widely recognized that the greatest hazards to life loss, injury, property damage and other economic losses from earthquakes are posed by existing buildings that were not designed and constructed to resist strong ground motions. Therefore, one of the objectives of the Earthquake Hazards Reduction Act of 1977 (P.L. 95-124) was "...the development of methods for...rehabilitation, and utilization of manmade works so as to effectively resist the hazards imposed by earthquakes..." The National Earthquake Hazards Reduction Program submitted to the Congress by the President on June 22, 1978, stressed that "...it is important that hazards be reduced from those (substandard) structures presenting the greatest risks in terms of occupancy and potential secondary impact."

FEMA's Program for Reducing Seismic Hazards in Existing Buildings

Since 1984, the Federal Emergency Management Agency (FEMA) has had underway a comprehensive, closely coordinated program to develop a body of engineering practices to increase the ability of existing buildings to withstand the forces of earthquakes. Societal implications and economic issues related to the use of these improved practices have also been examined. The first project was the formulation of a comprehensive 5-year plan on what needed to be done and what the required resources would be. This plan was completed in 1985 and published under the title <u>An Action Plan for Reducing Earthquake Hazards of Existing Buildings</u> (FEMA 90). This plan identified priority actions to be taken by the public and private sectors. FEMA has used this plan as the basis for developing a multi-volume, continuing series on the seismic rehabilitation of existing buildings.

At a cost of about $15 million, two dozen publications and a number of software programs and audio-visual training materials have already been produced and distributed for the use of design professionals, buildings regulatory personnel, educators, researchers, and the general public. The program has proceeded along separate, but parallel approaches in dealing with private-sector buildings and Federal buildings.

Private-Sector Buildings

The "technical platform" of consensus criteria on how to deal with some of the major engineering aspects of seismic rehabilitation of buildings is already available to private-sector practitioners and other interested parties. This technical material is contained in a trilogy, with supporting documentation, completed in 1989: 1) a method for rapid visual screening of buildings that might be hazardous in future earthquakes that can be conducted without gaining access to the buildings themselves; 2) a methodology for a more detailed evaluation of a building that identifies structural flaws that have caused collapse in past earthquakes and might do so again in future earthquakes; and 3) a compendium of the most commonly used techniques of seismic rehabilitation.

In addition to these engineering topics, the program has also been concerned with the societal and economic implications of seismic rehabilitation. The costs of seismically rehabilitating buildings were first reviewed in 1988 and have just recently been updated, expanded in scope, and improved in accuracy. Two benefit-cost models and associated software for application to both private-sector buildings and Federal buildings have also been developed. Further, for the use of decision makers at the local level, a series of volumes present an array of socio-economic issues that are likely to arise in a locality that undertakes seismic rehabilitation of its building stock; ways to identify problems and methods to analyze them; and means to stimulate interest in seismic rehabilitation of buildings in appropriate localities.

The culminating program activity for private-sector buildings will be the completion in the fall of 1997 of a comprehensive set of nationally applicable guidelines with commentary, on how to rehabilitate buildings so that they will better withstand earthquakes. This is a multi-year, multi-million dollar effort that represents a first of its kind in the United States. The guidelines will allow practitioners to choose design approaches consistent with different levels of seismic safety as required by geographic location, performance objective, type of building, occupancy, or other relevant considerations. Before being issued, the two documents will be given consensus review by representatives of a broad spectrum of users, including the construction industry, building regulatory organizations, building owners and occupants' groups academic and research institutions, financial establishments, local, State and Federal levels of government, and the general public. This process is intended to insure their national applicability and encourage their widespread acceptance and use by practitioners once the documents are completed. It is expected that, with time, this set of guidelines will be adopted by model building code organizations and standards-setting groups, and thus will diffuse widely into the building practices of the United States.

Significant corollary products of this activity are also expected. Principal among them will be improved seismic rehabilitation cost data; an engineering applications handbook; a plan for a structured transfer of the technology embodied in the guidelines; and an identification of the most urgent research and development needs.

Federal Buildings

A set of technical criteria intended to provide Federal agencies with minimum standards for both the seismic evaluation and the seismic rehabilitation of buildings in their inventories is in advanced stages of preparation. The performance level established in these standards is life-safety for building occupants and the general public. To facilitate the application of the standards by users, a commentary has also been prepared. In addition, an Executive Order to promulgate the standards has been drafted. These materials were given consensus approval by the Interagency Committee on Seismic Safety in Construction (ICSSC) which represents 30 Federal Departments and Agencies, and are expected to be ready for submission to the Executive Office of the President for consideration by the summer of 1994.

Publications

By the end of 1993, the following publications in this series had been published:

- A handbook (and supporting documentation) on how to conduct a rapid, visual screening of potentially hazardous buildings - Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154 and 155).
- The first collection (and supporting documentation) of typical costs for the seismic rehabilitation of buildings - Typical Costs for Seismic Rehabilitation of Existing Buildings (FEMA 156 and 157).
- An engineering report which identifies the generally accepted techniques for the seismic rehabilitation of hazardous buildings - Techniques for Seismically Rehabilitating Existing Buildings (FEMA 172).
- A handbook (and supplemental readings) on establishing priorities for the seismic rehabilitation of buildings - Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings (FEMA 173 and 174).
- A handbook (and supporting documentation) on a methodology for evaluating the seismic safety of existing buildings - Handbook for Seismic Evaluation of Structures (FEMA 175 and 178).
- An evaluation of existing and potential financial incentives in the private and public sectors that would encourage a locality to undertake a seismic rehabilitation program - Financial Incentives for Seismic Rehabilitation of Hazardous Buildings - An Agenda for Action (FEMA 198 and 199).
- A methodology (and accompanying software) for conducting benefit-cost analysis of private sector buildings - A Benefit-Cost Model for the Seismic Rehabilitation of Buildings (FEMA 227 and 228).

- An examination of most significant technical and societal issues likely to confront the writers of the planned set of guidelines on the seismic rehabilitation of buildings with suggested solutions - Seismic Rehabilitation of Buildings - Phase I: Issues Identification and Resolution (FEMA 237).

The Role of Benefit-Cost Analysis in the Seismic Rehabilitation of Existing Buildings

What Is Benefit-Cost Analysis?

Benefit-cost analysis provides estimates of the "benefits" and "costs" of a proposed seismic rehabilitation project. This methodology estimates the seismic performance of a building before and after the proposed rehabilitation project, including expected damages to the building and contents, casualties, and extent of loss of functionality of the building. Estimated future expected benefits are reduced to their net present value and summed. When benefits are greater than costs the benefit-cost ratio is greater than one and the proposed project is economically sound.

Is it Worth it?

This is the primary question about seismic rehabilitation projects which are designed to reduce expected damages and casualties from future earthquakes. Decision making about the prospective seismic rehabilitation of existing Federal buildings may be difficult because of the myriad of complex and often contentious engineering and public policy issues involved.

Benefit-cost analysis is a powerful tool which can help determine whether the future benefits of a prospective seismic rehabilitation are sufficient to justify the present costs of the project. The benefit-cost methodology in this report (and accompanying software) provides estimates of the benefits (i.e., avoided future damages and losses) of the seismic rehabilitation of Federal government buildings. The model is also applicable to state and local government buildings.

The Benefit-Cost Model

Benefit-cost analysis provides estimates of the "benefits" and "costs" of a proposed seismic rehabilitation project. The benefits considered are avoided future damages and losses which are expected to accrue as a result of the rehabilitation project. Costs considered are those necessary to implement the specific rehabilitation project under evaluation. Costs are generally well determined for specific projects for which engineering design studies have been completed. Benefits, however, must be estimated probabilistically because they depend on the improved performance of the building in future earthquakes, the timing and severity of which must be estimated probabilistically. In the present model, the benefits included are: avoided damages to the building and contents, avoided rental income losses, avoided relocation costs, avoided loss of government services, and avoided casualties.

The "benefits" calculated by the methodology are expected future benefits which are calculated over a "planning horizon" (i.e., the useful lifetime of the rehabilitation project). To account for the time value of money, a net present value calculation must be performed. This calculation is done automatically in the program, using the discount rate and project useful lifetime entered by the user.

Results of benefit-cost calculations are presented two ways: first, the benefit-cost ratio (benefits divided by costs) and second, the present value criterion (benefits minus costs). A benefit-cost ratio above one, or, equivalently, a positive present value indicates that benefits exceed costs and that the rehabilitation is economically justified, <u>under the assumptions made in the calculation</u>. The validity of a benefit-cost calculation and the robustness of conclusions drawn therefrom depend entirely on the validity of the data used in the calculations. Calculations based on detailed, building-specific engineering analysis will be much more accurate (and correspondingly more useful), than calculations based largely on typical or default values of input parameters. Therefore, decisions should not be made solely on the basis of benefit-cost results. Rather, prudent decision making must include assessment of the reliability of the benefit-cost results.

What Data Are Needed to Run the Model?

For any benefit-cost analysis, basic information about the building under consideration is required, including: building type (structural system) of the building (e.g., unreinforced masonry), floor area, replacement value, occupancy, use and function and others. Most importantly, estimates of the buildings seismic performance both in its existing condition and post-rehabilitation must be made. Default or reference values are provided for most of the input parameters (based on the building type). However, more reliable analyses are obtained when additional building-specific information, including expected seismic performance, is available.

Probabilistic Seismic Risk Assessment

Seismic risk assessment for benefit-cost analysis must be probabilistic because the timing and severity of future earthquakes is unknown. The benefit-cost program uses the expected annual probability of earthquakes in each "bin" or level of seismic ground motions (expressed as Modified Mercalli Intensity, MMI, and effective peak ground acceleration, PGA) to perform an expected value calculation. For example, if at a site under consideration, the annual probability of earthquakes of MMI VIII is 1%, then there is a one percent chance per year of such an earthquake. If each such earthquake causes $1,000,000 in damages, then on average (over a long time period) there will be $10,000 per year in damages. The $10,000 per year in average damages is the "expected" or statistical average damages per year. If these damages are avoided by a rehabilitation project, then the expected or statistical average damages avoided (i.e., the benefits) are $10,000 per year. To count fully the benefits of a seismic rehabilitation, the expected benefits of avoiding damages from the full range of damaging earthquakes must be counted, rather than simply considering one scenario or design earthquake.

What Are the Intended Applications?

There are two primary intended applications for this methodology: first, to roughly screen or prioritize a large list of buildings and second, to evaluate in detail one or more specific alternatives on a single building for which detailed engineering analysis exists. To screen a large list of buildings, a rough analysis could be made using typical or default data, although incorporation of more detailed building specific information would improve the validity of the results. To evaluate one or more specific rehabilitation options for a single building, detailed engineering analyses of the alternatives are essential.

Who Are the Intended Users?

The benefit-cost methodology presented in this report (and accompanying software) is intended for use by facility managers, design professionals (engineers and architects), and others involved in decision making about the seismic rehabilitation of Federal buildings. A technical background is not a prerequisite for using the methodology. However, a working knowledge about the general principles and terminologies relevant to the seismic performance of buildings, and some basic personal computer skills are necessary.

What the Benefit-Cost Model Can Do

The benefit-cost model performs the necessary calculations to determine how the expected future benefits of a specific seismic rehabilitation project compare to the costs. The model also generates scenario damage estimates of expected damages, other economic losses, and casualties per earthquake event (as a function of Modified Mercalli Intensity, MMI, and effective peak ground acceleration, PGA). These scenario damage, loss, and casualty estimates may prove useful to decision makers.

What the Benefit-Cost Model Cannot Do

The benefit-cost model cannot make a decision about whether or not to undertake the seismic rehabilitation of a building because decisions about rehabilitations usually depend on a great many factors and policy decisions well outside the confines of benefit-cost analysis. For example, basic policy decisions about what level of life safety and what level of post-earthquake performance are desired cannot be decided by a benefit-cost program. Similarly, seismic rehabilitations are frequently done in combination with other building renovation, such as interior refurbishing, upgrading electrical, mechanical, and plumbing systems, or hazardous material (e.g., asbestos) abatements. The seismic benefit-cost model cannot evaluate such projects as a whole because the model only considers seismic benefits and costs. In addition, decisions about whether or not to rehabilitate a building frequently depend on other factors such as budgets available, priorities for seismic safety vs. other program needs. As with new construction, decisions about rehabilitation of existing buildings may also be made partially on factors such as building location, desirability, availability of alternative space, and so on. Therefore, while the model can determine how the benefits of specific rehabilitation alternatives compare to the costs, it does not provide an absolute answer as to whether or not to undertake the seismic rehabilitation of a building.

CHAPTER 2: GETTING STARTED

This chapter describes the computer hardware and software required to run the program and how to install the benefit-cost program on your computer. Chapter 3 (Program Basics) describes the basics of using Quattro Pro for Windows (QPW), how to get around in the program, and how to enter the data requested. Chapter 4 (Tutorial - Worked Example) provides a fully worked example with guidance for the novice user.

QPW works very much like other spreadsheet programs such as Lotus 1-2-3, or Excel, so that experience with any of them is almost 100% transferrable to QPW. However, even if you have little or no experience with spreadsheet programs, the benefit-cost program is self-contained and easy to use.

HARDWARE AND SOFTWARE REQUIRED

Computer Hardware

This program requires an IBM-compatible computer (PC). The CPU must be a 386 or higher; the program will run faster with a 486 or Pentium CPU. In addition, the computer must have:

1. At least 4 megabytes of memory (RAM).
2. A hard drive with at least 15 megabytes of free disk space.
3. A high density (HD) 3.5" floppy disk drive.

The benefit-cost program files require a large amount of disk space, about 2 megabytes per file saved. Therefore, it is desirable to have a large hard disk if you anticipate saving a substantial number of files. Alternatively, files can be saved on high density (HD) floppy disks. However, because of the file size, the files must be compressed using utilities available on recent versions of DOS or as separate utility programs (such as PKZIP).

Computer Software

This program is a Windows program; therefore, your computer must have Windows (Version 3.1 or higher) installed.

Windows

To install Windows:

1. Turn on your computer.

2. Insert the **Windows Disk 1** in the drive you want to use for the installation and close the drive door.
   Windows Setup lets you use any active disk drive.

3. To make the installation drive active, type the drive letter followed by a colon (A: or B:) and press **Enter**.

4. Type **setup** and press **Enter**.

5. Follow the instructions on the screen.

   The Setup program's instructions should be self-explanatory. But, if you do have questions about any of the procedures or options, you can request on-line Help by pressing the F1 key. For more information, see **Microsoft Windows User's Guide**.

   HINT: The installation routine will ask if you want to choose a "custom" installation or allow Windows to perform a "standard" installation. Most computers will operate well if you allow Windows to self-install, i.e., select the "standard" installation, not the "custom" installation.

The benefit-cost program runs as templates in QUATTRO PRO FOR WINDOWS (QPW). You must have QPW (Version 5.0) installed on your computer.

Quattro Pro for Windows

To install QPW:

1. Be sure you are in WINDOWS (i.e., install WINDOWS first): open WINDOWS if it does not automatically come up when you turn on your computer. To open WINDOWS, at the DOS prompt, **C:>** type **WIN**
2. Insert the **QPW Disk 1** in the drive you want to use for the installation and close the drive door.
3. With your mouse, point the cursor on **File** on the menu bar (at the top of your screen), press and hold the left button of your mouse. This will highlight the selected item. While holding down the left mouse button, move the mouse until **Run** is highlighted.
4. On the **Command Line**, i.e., inside the box which will appear next on your screen, type

   a:install.exe

   or **b:install.exe**

   depending on which drive the QPW disk is in. Be sure to type the command exactly as written: **do not** add spaces or change punctuation. Then left-click the mouse on **OK**.
5. Enter the requested information in the Installation dialog box which will appear on your screen. Accept the default choice of QPW for the Quattro Pro directory.
6. Quattro Pro will ask you for various information during the installation. Simply type the response and press **Enter** or click the mouse on **OK**. The default setting are usually suitable for your first installation of Quattro Pro.
7. After entering the information requested in the Installation Dialog Box (e.g., your name), click on **Install** to continue.
8. Follow instructions (e.g., change from Disk 1 to Disk 2) as they appear.
9. Your QPW installation is complete!

INSTALLING THE PROGRAM

Network Systems

Computer networks may be set up and managed in many different ways. Therefore, this manual cannot give detailed instructions for installing the program on a specific network system. To install the benefit-cost program on computer which is connected to a network system, give the program disk and the User Guide to your computer system operator. After installation is completed, go to the Start QPW section on page 1 of Chapter 3.

Stand-Alone Computers

1. Turn on your computer.

2. If you are not at a DOS prompt (such as **C:\>**) either exit from WINDOWS to DOS, or select a DOS prompt from within WINDOWS. To exit from WINDOWS, highlight **File** on the menu, hold down the mouse button and highlight **Exit**. The program will display: "This will end your Windows Session." Click on **OK**. Your screen should show: **C:\>**

If your hard disk drive is designated **D**, or some other letter, that letter will appear in place of **C**;

3. Insert the Benefit-Cost Program diskette (3.5") in either the A or B drive of your computer (whichever floppy drive is the high density 3.5" drive);

4. At a DOS prompt (**C:\>**),
If the Program diskette is in the **a** drive, type: **a:install**
If the Program diskette is in the **b** drive, type: **b:install**

5. The install program will automatically create a new subdirectory on your C drive: **C:\FB**

6. Two files will be loaded into the **C:\FB** directory:

A. An example file with all data entries filled in:
BC_EXAMP.WB1

B. A blank file, for user data input:
BC_BLANK.WB1

7. **PROGRAM INSTALLATION IS COMPLETE!**

CHAPTER 3: PROGRAM BASICS

This chapter provides basic information about starting and running Quattro Pro and the benefit-cost program, along with helpful hints.

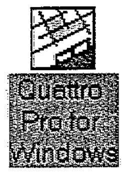
STARTING QUATTRO PRO (QPW)

Start Windows

Quattro Pro is a WINDOWS program; therefore you must first start WINDOWS before starting Quattro Pro. If you are not already in Windows, type WIN at a DOS prompt to start Windows.

Start QPW

After starting WINDOWS, click the left mouse button on the symbol (the "icon") or the group window labeled Quattro Pro for Windows (QPW). Then, double-click the left mouse button on the QPW icon within the window.



> In this tutorial, when you read "click on" it is a short way to say "click on the left mouse button."

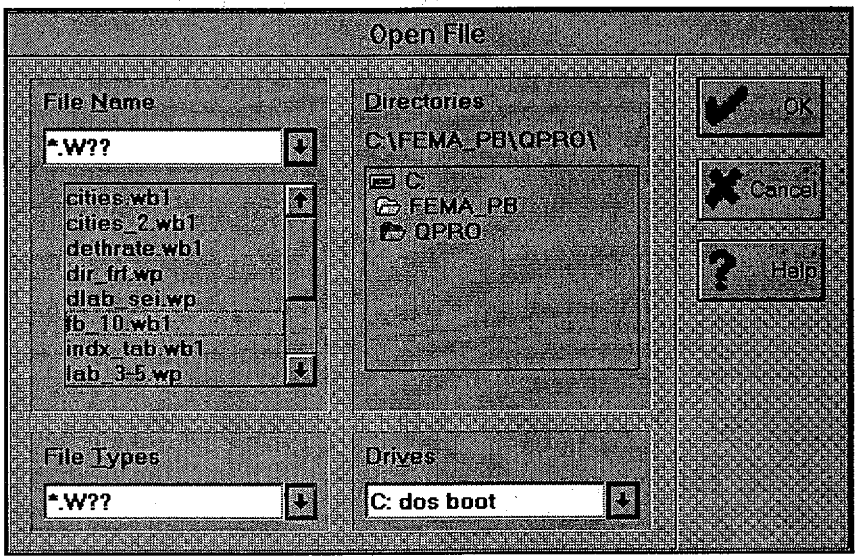
Quattro Pro for Windows works very much like any other Windows spreadsheet or any other Windows program, including word processors. Quattro Pro commands are initiated by clicking on pull-down menus at the top of the screen or by clicking on the speed buttons below the menu lines.

To use the Benefit-Cost Program, you need to know only a little about Quattro Pro. Once the Benefit-Cost Program is loaded, the data entry, calculations, and printing of results can be accomplished entirely within the program, with minimal use of Quattro Pro commands.

Opening Files

The menu bar along the upper edge of the QPW window will display a **File** command at the left side. Click on the **File** command. When the menu opens, click on the **Open...** line.

The screen will display two boxes side by side: **File Name** and **Directories.**



Click on the **C:** in the **Directories** box on the right side of the screen. Use the mouse to move the cursor to the **FB** directory where the benefit-cost model is located, and double click.

Double click on the **BC_EXAMP.WB1** line to load a completed example, or on **BC_BLANK.WB1** to load a blank spreadsheet. Or, click once on the file you wish to open, then click on **OK**.

The computer will load the benefit-cost model. Loading will take only a few seconds on a fast computer, but may take up to several minutes on a slow computer. The bottom right corner of the screen (Status line) will display **WAIT** while the model is loading and **READY** when the model is loaded.

As you continue to use the Benefit-Cost Program and save files, the **File Name** box will contain the names of all of your files which have the **.WB1** ending. Double-clicking on the desired file will open any of these files. Please see **NAMING AND SAVING FILES** on page 3-7.

Screen Display

When the Benefit-Cost Analysis program is loaded, the first screen visible is the **Sign-On Screen.**

Benefit-Cost Analysis of the

Seismic Rehabilitation of Federal Buildings

Version 1.0
June 15, 1994

Building Name:	Court House
Address:	123 I St
City, State, Zip:	Ekalaka, MT 21345
Analyst:	GLH
Rehabilitation Project:	Install shear walls
Run Identification:	123456

If the words extend past the right-hand side of your computer screen or if the image is too small, change the **Zoom List** by following these steps:

1. Click on the **Zoom List** arrow, located in the first row of symbols (the "SpeedBar") at the top of the screen;

2. While holding down the left-hand mouse button, move the mouse until the correct value (e.g., 80) is highlighted. It may take a little trial-and-error to determine the best value for your screen.

Moving Around in the Program

There are several easy ways to move around the Benefit-Cost Program:

1. Use the mouse to place the cursor wherever you want to be on a page and click on that location.
2. To move **left-right** on a page, use the cursor arrows on the keyboard, or the horizontal scroll bar at the bottom right of the screen.
3. To move **up-down** on a page, use the cursor arrows on the keyboard, or the vertical scroll bar at the right hand edge of the screen.
4. To move to the top of any page in the program, press the **Home** button on the keyboard.
5. To move to a specific location within the program, use the custom **Menu Tree** (described next) which appears at the top of the screen. Click on the desired menu item; the submenu (a list of available choices) appears. Click on the desired submenu item.

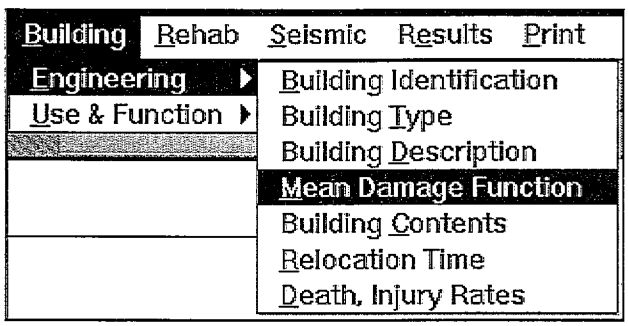
Benefit-Cost Menu Tree

The benefit-cost model is driven from a customized menu tree. The menu appears at the top of the display screen (after the model is loaded):

The underscored letter of the name indicates that this menu item can be accessed by clicking on the menu **or** by the **/X** keyboard command, where "**X**" indicates the underscored letter in the menu name. For example, **Rehab** can be accessed by typing **/R**.

In addition to the main menu, there are submenus which appear when the main menu heading is clicked on. Submenus are accessed in the same manner as the main menu heading.

For example, to move to the **Mean Damage Function** screen, click on **Building**. The **Engineering** submenu appears, and displays seven choices, including the **Mean Damage Function**. Move the cursor down until **Mean Damage Function** is highlighted.



The complete Benefit-Cost Menu Tree is given on the following page.

Menu Tree

CUSTOMIZED BENEFIT-COST MENU TREE

- File
  - Save
  - Save As...
  - Quit
- Model
  - Version
- Building
  - Engineering
    - Building Identification
    - Building Type
    - Building Description
    - Mean Damage Function
    - Building Contents
    - Relocation Time
    - Death, Injury Rates
  - Use & Function
    - Occupancy Data
    - Value of Lost Gov't Services
    - Functional Downtime
    - Rental Income
- Rehab
  - Project Description
  - Costs
  - Effectiveness of the Rehab
  - Death, Injury Rates
- Seismic
- Results
  - Damages
  - Benefit Cost Results
  - Injuries & Deaths
  - Summary
- Print
  - Model Version
  - Building Engineering
    - Facility Class
    - Mean Damage Function
  - Building Use & Function
    - Occupants
    - Rental Income
  - Rehab
  - Seismic Information

Results

Damages

Benefit-Cost Results

Death & Injuries

Summary

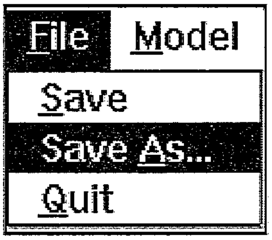
All Data Tables

All Tables

Naming and Saving Files

Each benefit-cost analysis file must be saved with a new name to avoid overwriting previous files. **Each file that you want to save MUST have a unique name.**

New names can be entered, as a file is saved, by using the **Save As** command. To enter a new name for an open file, click on **File** (in the menu on the second line of the screen), then click on **Save As**, and enter a new name in the file name box. Names can have up to eight letters or numbers, then a period, followed by three letters or numbers: e.g., **TUTORIAL.WB1**

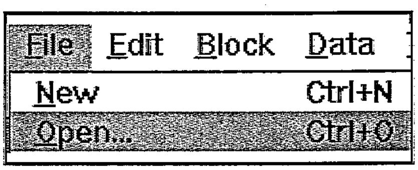


HELPFUL HINT:

Save benefit-cost program files with an extension of **.WB1**

For example: if you want to save a file as **Run17**, save the file as **Run17.WB1**.

When you use the **File|Open** command, Quattro Pro automatically lists all files in which the extension (the three letters after the period) begin with **.W** and thus your program files will be easy to find.



Oops!

If you accidentally overwrite one of the original program files by saving a file with user-entered data without changing the name, the original program file will be lost (overwritten by the new file).

To recreate the original program file, check to see if a backup copy exists: it will have the same name, followed by a **.bak** extension (ending), e.g., **sample.bak** or **example.bak**. Copy this file to the original.

1. Click on the **File** menu at the top of the screen.

2. Next, **Open** the **.bak** file (see page 6 for instructions on opening a file).

3. Select **Save As** and save the file with a new name, as described on page 3-7, **Naming and Saving Files.**

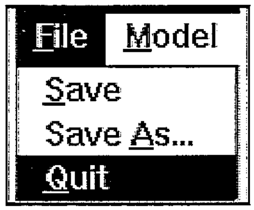
Helpful Hint: If all else fails, reinstall the file from the original floppy disk as described in Chapter 2, **Installing the Program**.

To Start A New Analysis

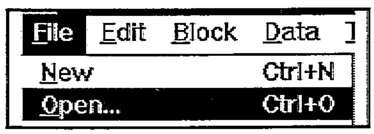
If you want to do another analysis:

1. First, save the existing open file with a new name (see **NAMING AND SAVING FILES**, page 3-7).

2. Quit the Quattro Pro file which you have been using: with the cursor highlight **File** and **Quit**, since the file is already saved under a new name.



3. Next, click on **File**, then click on **Open** to start a new analysis (see **Opening Files**, page 3-2).



To Exit From the Program

First, save your work with a new name, by using the **File]Save As** command described above.

Click on **File**, then click on **OK** to leave Quattro Pro.

Cell Colors

Before you begin the data entry process, note that all areas (cells) of the program screens are color coded to remind the user what type of information each cell contains.

The cell type appears in the Style List window when the cursor is clicked on a cell. The Style List window is in the upper SpeedBar.

There are six cell colors which indicate different types of entries:

Cells are color coded to inform the user what the cell contains. The cell format name appears in the center Style List window of the first speedbar when the cell is activated by the cursor.

Green cells require the user to enter data concerning the building or project. Green cell data entries directly affect the calculated results. Style List Title: Data Input

Pink cells contain information about the building or project. Pink cell entries do not affect the calculated results. Style List Title: Information.

Purple cells contain information that was entered by the user in other screens. Style List Title: Carry Over.

Orange cells contain default data. The values cannot be changed. Style List Title: Default.

Blue cells can be used to override default data with project specific data. Style List Title: Override Default.

Yellow cells contain calculated results from the model. Style List Title: Results.

Data Entry

To enter data into a cell (block) in the program, first move the cursor to the cell where you want to enter the data. Then, type the desired information. As you type, the characters appear in the input line below the menus and speed buttons.

Only when you press ***Enter*** or an arrow key or click the check mark button (✓) does Quattro Pro move the characters into the program cell.

> Helpful Hint: User data entries can be made only in the GREEN, BLUE, or PINK data entry cells (blocks).

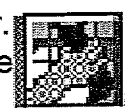
If you attempt to enter data in cells which are not GREEN, BLUE, or PINK, you will see a "protected cell" error message. Other cells are "protected" to prevent inadvertent changes to the program. As with other error messages, click on **OK** or press the **Esc** key to return to data entry.

Correcting Errors

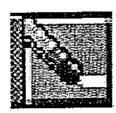
If you make a mistake while typing, press ***Backspace*** to erase. To clear the entire entry, click the **X** box to the <u>left</u> of the input line or press the ***Esc*** button on the keyboard.

After pressing ***Enter***, if you find you made a typing mistake or want to change an entry, type the entry over again or click inside the text on the input line and edit it there. To delete an entry without replacing it, just select the cell (by clicking on the mouse in the selected cell) and press the ***Del*** button on the keyboard.

Another option is to use the ***Erase*** button to delete the entry. Move the cursor to the mistake, then move the mouse to the ***Erase*** button (on the SpeedBar) and click.

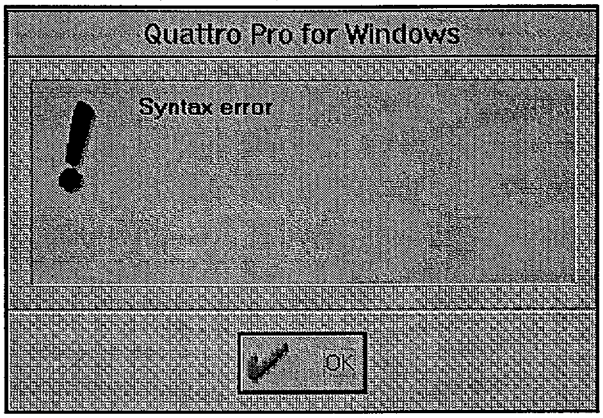


To ***Undo*** any entry or change, move the cursor to the item, then highlight and click on the pencil eraser icon (on the SpeedBar).



Commas, Dollars

QPW won't accept number entries which include a dollar sign ($) or commas (,). Thus, twenty thousand square feet should be entered **20000** and a cost of $10,000 should be entered as **10000**: **$** and **,** are inserted automatically. If you forget and include a "$" or a "," the model will respond with a "Syntax error" message. Click on the **OK**, or press the **Esc** keyboard button, then enter correctly the information requested.



CHAPTER 4: TUTORIAL - WORKED EXAMPLE

The purpose of this chapter is to guide you through a sample data entry exercise. This example is provided for the convenience of the less experienced computer user.

STARTING THE WORKED EXAMPLE

Step One

Start Quattro Pro for Windows (QPW). See instructions in Chapter 3.

Step Two

Open the desired Benefit-cost program file. See instructions in Chapter 3. For the worked example, open the **BC_EXAMP.WB1** file.

Step Three

The **Sign-On** Screen appears after the benefit-cost program is loaded. Adjust the zoom factor if necessary. See instructions in Chapter 3.

Step Four

Proceed through the Data Input process, as outlined below in the tutorial example. This example leads you through a sampling of the data input process.

DATA INPUT

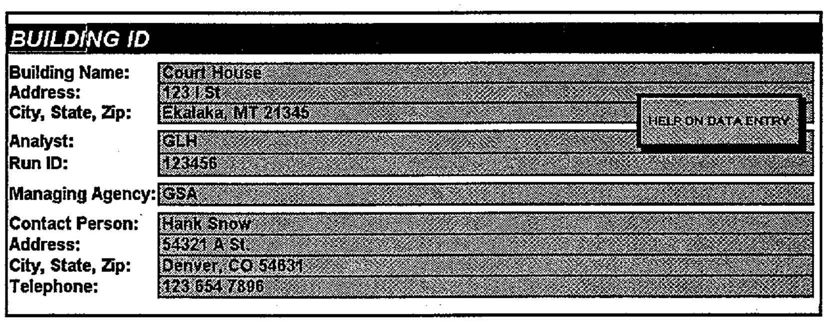
This tutorial will lead you through part of the data entry process for a sample project.

BUILDING ID

Begin Data Entry

Click on **Building** in the menu at the top of the screen. Then click on **Engineering**, and finally, click on **Building Identification**.

The following screen appears:



Building Name

PINK BLOCKS (information only): With your mouse, move the cursor to the first pink-colored block, **Building Name**, and click on the cell. Type the name of the building, e.g., **Federal Building**. Press the **Enter** key.

> **IMPORTANT:** the cursor must be **in the first space on the left inside the pink box**.

Address

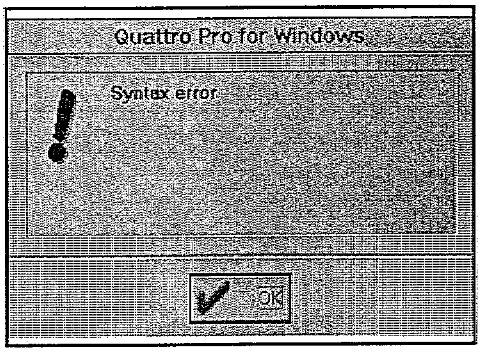
Then, with the mouse or the arrow keys, move the cursor to the street **Address** and enter it in the following way:

'1000 First St

OOPS!

If you forget to start your entry with an apostrophe, ', an error message will be displayed.

Error Message:



Help

The address (and all combinations of numbers and letters **which begin with a number**) **MUST** be entered with a single apostrophe, ', preceding the address, e.g., **'1000 First St**. If not entered this way, a "syntax error" message will appear: click on the **OK** of the error message or press the **Esc** key. Add the apostrophe, then press **Enter.**

City, State, Zip Code

PINK BLOCK (information only): Enter the city, state and zip code for the building: **San Jose, CA 90000**.

Analyst

PINK BLOCK (information only): Enter the name of the person performing this analysis. Enter: **A. Analyst.**

Run ID

PINK BLOCK (information only): Enter a name or number to distinguish this rehabilitation scheme from others which may be analyzed.

Managing Agency

PINK BLOCK (information only): Enter the name of the agency which owns or manages the building.

Contact Person

PINK BLOCK (information only): Enter the name and other information about the building's manager.

BUILDING TYPE

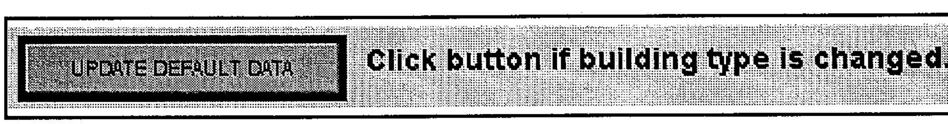
Building Type

GREEN BLOCK (Data input): Enter **P** (as a CAPITAL letter) in the left **GREEN** block. The screen will display the corresponding building description (Unreinforced Masonry Bearing Wall) from the list.

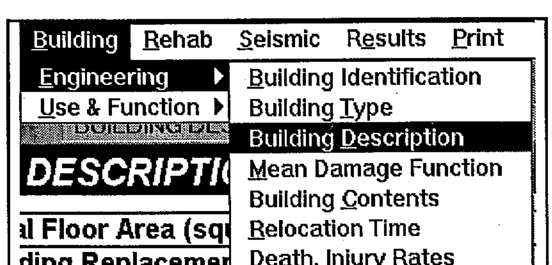
If you make a mistake, use the backspace key to erase, and enter the information correctly. If you have already pressed the **Enter** key, use the mouse to point the cursor at the **GREEN** cell and click. Then enter the correct letter.

Update Default Data

You **MUST** click on the **UPDATE DEFAULT DATA** button to update the default data presented later in the model. **Otherwise, incorrect default data will be presented for your review, and if not overridden (see below), will be used in the benefit-cost calculation.**



Use the mouse to highlight the **Building|Engineering|Building Description** in the menu, or click on the **BuildID** tab at the screen bottom.



BUILDING DESCRIPTION

BUILDING DESCRIPTION

		Calculated
Total Floor Area (square feet):	20,000	
Building Replacement Value per square foot	$150	$150
Total Building Replacement Value	$3,000,000	$3,000,000
Number of Stories Above Grade:	3	
Date of Construction	1955	
Historic Building Controls?	NO	

Floor Area

GREEN block (Data entry): Enter **20000** as the total floor area of the building in square feet.

Helpful Hint: The program won't accept numbers which include a dollar sign ($) or commas. Thus, twenty thousand square feet should be entered **20000** and a cost of $10,000 should be entered as **10000**: **$** and **,** appear automatically. If you forget and include a "$" or a "," the model will respond with a "syntax error" message. Click on the **OK**, then enter correctly the information requested.

Building Value (per Sq. Ft.)

GREEN block (Data entry): Enter **150** as the building replacement value per square foot.

Total Building Value

GREEN block (Data entry): Enter **3000000** as the total building replacement value. The model will display **$3,000,000.**

Stories

PINK block (Information): Enter **3** as the number of stories above ground in this building.

Date

PINK block (Information): Enter **1955** as the year the building was constructed.

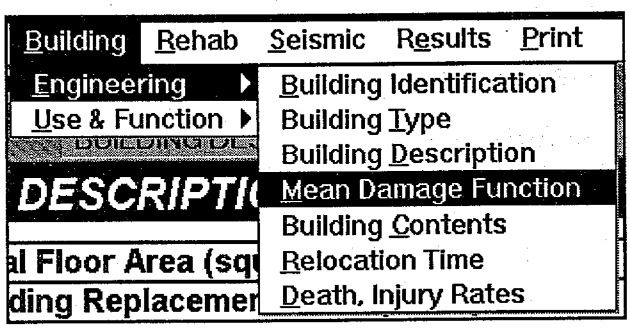
Historic Building

PINK block (Information): Enter **NO**, no historic building controls exist for this structure.

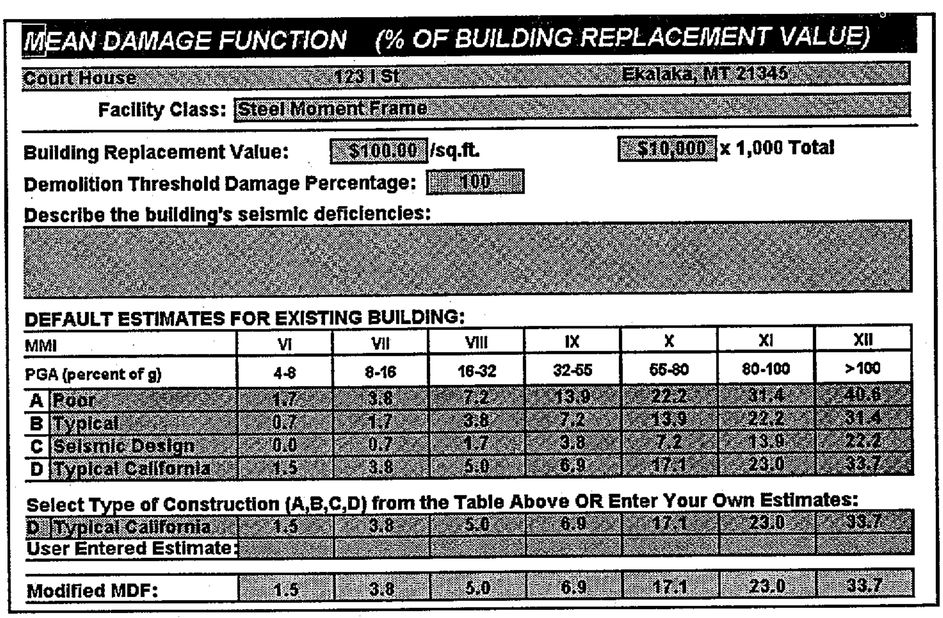
MEAN DAMAGE FUNCTION (% OF BUILDING REPLACEMENT VALUE

Mean Damage Function

Use the mouse to move the cursor to **Building** on the menu at the top of the screen. Click the left mouse button on **Engineering** and again on **Mean Damage Function**, or click on the **MDF** tab at the screen bottom.



The following screen will appear:



MEAN DAMAGE FUNCTION (% OF BUILDING REPLACEMENT VALUE)

Court House 123 I St Ekalaka, MT 21345

Facility Class: Steel Moment Frame

Building Replacement Value: $100.00 /sq.ft. $10,000 x 1,000 Total

Demolition Threshold Damage Percentage: 100

Describe the building's seismic deficiencies:

DEFAULT ESTIMATES FOR EXISTING BUILDING:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (percent of g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
A Poor	1.7	3.8	7.2	13.9	22.2	31.4	40.8
B Typical	0.7	1.7	3.8	7.2	13.9	22.2	31.4
C Seismic Design	0.0	0.7	1.7	3.8	7.2	13.9	22.2
D Typical California	1.5	3.8	5.0	6.9	17.1	23.0	33.7

Select Type of Construction (A,B,C,D) from the Table Above OR Enter Your Own Estimates:

D Typical California	1.5	3.8	5.0	6.9	17.1	23.0	33.7
User Entered Estimate:							
Modified MDF:	1.5	3.8	5.0	6.9	17.1	23.0	33.7

PURPLE BLOCKS (Carry over): The model displays information entered on the first screen in **PURPLE** blocks. If any of this information is incorrect, return to the data entry screens, **Building ID** and **Building Description** and make necessary changes there.

Demolition Threshold

GREEN block (Data input): Enter **65** as the percentage of damage, relative to the building replacement value, at which the structure would be demolished and replaced rather than repaired.

Building Seismic Deficiencies

PINK block (Information): Enter **See Smith & Brown report for seismic performance engineering evaluation.** This comment box can be used to annotate building deficiencies or to reference information sources about the building.

Default Estimates

ORANGE BLOCKS (Default): The model displays default estimates for the estimated damage, as a percentage of the building replacement value, expected to occur in various MMI bins. For reference, four different mean damage functions are shown.

Construction Type

GREEN BLOCK (Data input): Enter **B**, for typical construction, in the **GREEN** block. This selects "typical" as the default mean damage function most appropriate for the building under consideration.

User Entered Estimate

BLUE BLOCKS (Override default): In this example, leave these blocks empty.

> However, when entering information on actual projects, the model will produce better results with building-specific information.

Modified MDF

YELLOW Blocks (Results): The model displays calculated values for the mean damage function modified for the demolition threshold entered above.

Tutorial Note

To perform a complete benefit-cost analysis of a real project, additional data entries are required. These entries are accessed, like those described above, by clicking on the menu headers and filling in the requested information.

Each data entry is described in detail in Chapter 5. However, this tutorial covers only a sample of the total data entries.

The following section of this tutorial describes the **Results** section, with the remaining data entries already completed.

BENEFIT-COST RESULTS

Click the mouse on **Results**, then click on **Benefit-Cost Results** to view the results calculated by the model.

BENEFIT COST RESULTS

Federal Building | 1000 First Street | San Jose, CA 90000

Facility Class: Unreinforced Masonry Bearing Wall

Project Description: 0

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	30	years
Present Value Coefficient:	12.41	

A. ECONOMIC PARAMETERS

Discount Rate

GREEN block (Data input): Enter **7** for the discount rate.

Planning Period

GREEN block (Data input): Enter **30** years for the planning period.

Present Value Coefficient

YELLOW block (Calculated results): The model displays **12.41** as the **Present Value Coefficient**, the present value of $1 per year in benefits received over the project useful lifetime period.

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES (excluding the value of life)

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$47,679	$32,504	$15,174	$403,346
Contents Damages	$7,870	$5,392	$2,478	$66,908
Relocation Expenses	$0	$0	$0	$0
Rental Income Losses	$7,549	$3,736	$3,813	$46,360
Value of Lost Services	$10,806	$7,936	$2,870	$98,475
Total Damages and Losses	$73,904	$49,568	$24,336	$615,090

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$615,090
TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT:	$560,000
TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS:	$55,090
BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS:	1.10

YELLOW blocks (Calculated results): The model displays calculated values for the annual expected, annual avoided, and annual residual damages and losses; and the present value of damages avoided for building and contents damages, relocation expenses, rental income losses and the value of lost services.

Avoided Losses

In the individual **YELLOW** blocks, the model displays the calculated results of the model. The first amount, **$615,090**, is the present value of the damages and economic losses excluding the value of life, which would be avoided if the proposed rehabilitation project is undertaken. **This value is the calculated benefits of the seismic rehabilitation project.**

Project Cost

The second amount, **$560,000**, is the total cost of the proposed rehabilitation project.

Net Benefits

The third amount, **$55,090**, is the value of the net benefits of the proposed project (total benefits minus total costs).

Benefit-Cost Ratio

The last number, **1.10**, is the ratio of net benefits to net costs, excluding the value of life, for the proposed rehabilitation project.

C. VALUE OF INJURIES AND DEATHS

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	5.66E-02	5.09E-02	5.66E-03	$632
Serious Injuries	1.72E-02	1.70E-02	1.72E-04	$2,111
Deaths	7.08E-03	7.07E-03	7.08E-06	$149,136
			Total Value	$151,879

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED:	$766,969
TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS:	$206,969
BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS:	1.37

Minor Injury

GREEN block (Data input): The model displays **$1,000** as the value of a minor injury. In this example, do not change this value.

Major Injury

GREEN block (Data input): The model displays **$10,000** as the value of avoiding a serious injury. Do not change this value.

Statistical Life

GREEN block (Data input): The model displays **$1,700,000** as the value of a statistical life. In this example, do not change this value.

YELLOW blocks (Calculated results): The model displays calculated values for the annual expected, annual avoided, and annual residual costs; and the present value of damages avoided for minor injuries, major injuries, and statistical life.

Avoided Losses

In the individual **YELLOW** blocks, the model displays the calculated results of the model. The first amount, **$766,969**, is the present value of the damages and economic losses including the value of life, which would be avoided if the proposed rehabilitation project is undertaken. **This value is the calculated benefits in the benefit-cost model of the seismic rehabilitation project when the value of casualties avoided is included.**

Project Cost

The second amount, **$206,969**, is the total net benefit of the project (benefits minus costs) including the value of life.

Benefit-Cost Ratio

The third number, **1.37**, is the **benefit-cost ratio** including the value of life.

To Exit From the Tutorial

To exit from the tutorial, click on **File**, then click on **Quit**.

CHAPTER 5: DATA ENTRY

This chapter describes the input data parameters and the data entry process. For guidance on moving around within data entry screens, entering data, erasing mistakes, etc., see the Chapter 3, Program Basics, and Chapter 4, Tutorial - Worked Example, or see the Quattro Pro Manual.

Menu Trees

The benefit-cost model is driven from a customized Quattro Pro menu tree. The main menu headings appear at the left of the menu line at the top of the display screen (after the model is loaded).

The main customized menu tree for the benefit-cost model is integrated with the normal Quattro-Pro screen and appears as follows:

File	Model	Building	Rehab	Seismic	Results	Print

The underscored letter of the menu indicates that, in addition to clicking on the menu word, that this menu can be accessed by an /X keyboard command, where X is the underscored letter in the menu label.

The first seven menu labels above are custom labels for the benefit-cost software. Each menu accesses a range of information about the model:

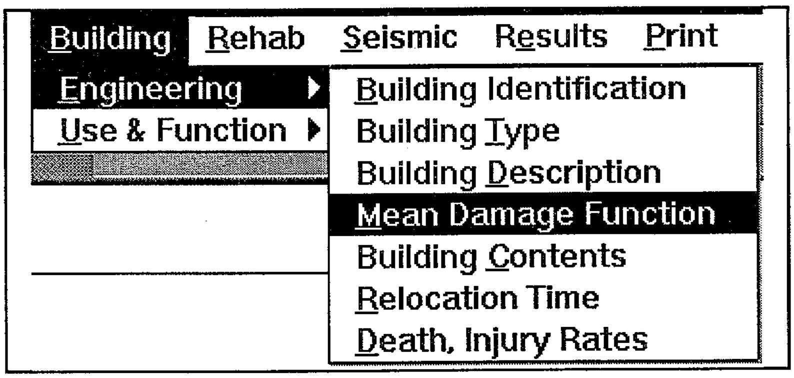
File	controls saving and naming files and closing the current analysis
Model	model version, date and authors
Building	data about the existing building
Rehab	data about a specific rehabilitation project
Seismic	seismic risk data for the site under consideration
Results	summary of damages and losses, casualties, benefit cost results and summary of all data input parameters
Print	controls printing of all data and results pages

Model Menu

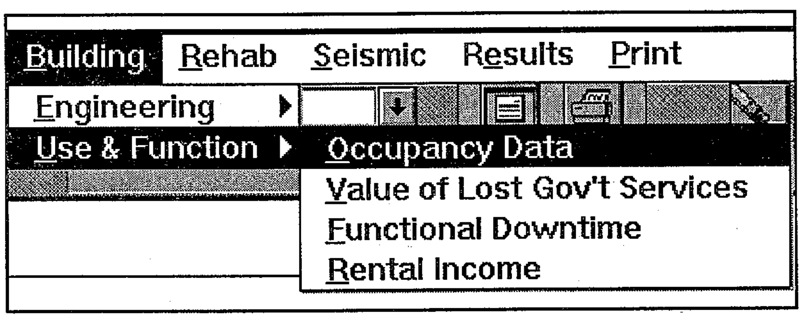
Clicking on **Model** brings up the **Version** submenu header. Clicking on **Version** brings up the title screen of the benefit-cost model. The title screen identifies the version number, date of the version being run, and author identification.

Building Menu

The Building menu label accesses data entry screens for the existing building (before seismic rehabilitation). There are two submenus: Engineering and Use & Function. The Engineering menu has seven submenus: Building Identification, Building Type, Building Description, Mean Damage Function, Building Contents, Relocation Time, and Death, Injury Rates:



The Use & Function menu has four submenus: Occupancy Data, Value of Lost Government Services, Functional Downtime, and Rental Income:



Engineering Menus

BUILDING ID

Building Information

Building Name
Address
City, State, Zip

Enter the basic identifying information about the building under consideration: building name, address, city, state and zip code.

Analyst

PINK BLOCK (information only):
Enter the name of the analyst(s) conducting the benefit cost analysis.

Run Id

PINK BLOCK (information only): Enter a name or number to distinguish this rehabilitation scheme from others which may be analyzed.

Managing Agency

PINK BLOCK (information only): Enter the name of the agency which owns or manages the building.

Contact Person

PINK BLOCK (information only): Enter the name, address, complete address, and telephone number for the building's manager.

BUILDING TYPE

Building Type
Building type denotes the primary structural systems of buildings. Select the building type most appropriate for the building under consideration from the building type table by entering the appropriate capital letter in the shaded box.

Building type: enter CAPITAL letter code in the green box.

C Steel Moment Frame

UPDATE DEFAULT DATA Click button if building type is changed.

FEMA 178	Letter Code	Common Building Types
W1	A	Wood Light Frame
W2	B	Wood (commercial or industrial)
S1	C	Steel Moment Frame
S2	D	Steel Braced Frame
S3	E	Steel Light Frame
S4	F	Steel Frame with Concrete Shear Walls
S5	G	Steel Frame with URM Infill
C1	H	Concrete Moment Frame
C2	I	Concrete Frame with Concrete Shear Wall
C3	J	Concrete Frame with URM Infill
PC1	K	Precast Concrete Tilt-up w/ Flexible Diaphragm
PC2	L	Precast Concrete Frame w/ Concrete Shear Walls
none	M	Precast Frame w/o Shear Walls
RM1	N	Reinforced Masonry w/ Flexible Diaphragm
RM2	O	Reinforced Masonry w/ Precast Concrete Diaphragm
URM	P	Unreinforced Masonry Bearing Wall
none	Q	Mobile Homes
	R	OTHER (Please specify

The designation of building type is a very important data input for the benefit-cost analysis because many of the default parameters in the analysis, including the building's damage function, depend on building type. Therefore, unless building-specific input parameters are entered later in the data entry process, designation of building type will markedly affect the results of the analysis.

If none of the listed building types are appropriate for the building under consideration, enter select the "OTHER" option by entering "R" in the building type selection box. If the "OTHER" option is selected, then default values cannot be provided by the program and all data parameters must be user-entered.

UPDATE DEFAULT DATA **Click button if building type is changed.**

The model will recalculate after you enter your selection **only if** you either click on the button underneath the Green box where you entered your selection. However, if you have split the screen to display both this and the Results pages, you **must** click on this button to see the recalculated results.

BUILDING DESCRIPTION

This section contains additional descriptive information about the building. Enter the total floor area of the building, the building replacement value per square foot and the total building replacement value. The program calculates the building replacement value and if it is inconsistent with the entered value, displays an error message. Re-enter the correct values so that the calculated values (in the yellow blocks) and the entered values agree. If the total square feet and total building replacement value are entered, the model will calculate and display (in the yellow blocks) the replacement value per square foot.

			Calculated
Total Floor Area (square feet):	520,000		
Building Replacement Value per square foot	$150		$150
Total Building Replacement Value	$78,000,000		$78,000,000
Number of Stories Above Grade:	10		
Date of Construction	1910		
Historic Building Controls?	Yes		

Replacement building value (per square foot) is the cost of replacing a building with a new building of equivalent function. Seismic damages are estimated as percentages of replacement value. In some cases, a distinction may be made between "reproduction" which is duplication of the previous building, and "replacement" which refers to duplicating a building's function with another (generally more modern) construction type. In most cases, however, the costs to replace a destroyed building with a similar building are readily identifiable. This value is for the building only, excluding contents.

For historic buildings, reproduction value, rather than replacement value, may be a more appropriate measure of building value. If desired, the reproduction value of a historic building can be entered in the "replacement value" data entry box.

The last three data entries under the Building Description section are for informational purposes only (i.e., they are intended to help guide the user in analyzing the building, but entries in these boxes do not affect the benefit-cost results calculated). These entries include: number of stories, date of construction, and historic building controls? (yes or no).

MEAN DAMAGE FUNCTION (% OF BUILDING REPLACEMENT VALUE)

Purple cells contain information carried forward after being entered earlier in the model.

Demolition Threshold Damage Percentage

The demolition threshold damage percentage reflects the fact that many buildings will be demolished rather than repaired when the cost of repairing seismic damage exceeds some percentage of the replacement cost. For older, somewhat substandard buildings, the demolition threshold may be quite low (e.g., 20 or 30%). For typical, relatively modern buildings, the demolition threshold will be higher (e.g., circa 50%). For some particularly important historical buildings, the demolition threshold may approach 100%. The demolition threshold damage percentage may substantially affect the benefit-cost results when the threshold is set lower than the percentage damages expected in earthquakes. For example, if in a given MMI or PGA bin, the MDF is 70% damage and the threshold is 50%, then this MDF bin is adjusted to show 100% damage because the building will be demolished if 70% damage occurs.

The demolition threshold damage percentage, an important policy parameter, may significantly affect the benefit-cost results.

Enter the Demolition Threshold Damage Percentage in the green cell.

Demolition Threshold Damage Percentage: 100

Describe the building's seismic deficiencies:

Comment Box

The pink comment box is intended for a brief synopsis of the seismic evaluation of the building or for any other comments relevant to the building's seismic performance. If a detailed engineering analysis is available for the building, this comment box may also be used to identify reports or other sources of information on the building.

Mean Damage Functions

Building mean damage functions (MDF) indicate a building's seismic vulnerability by showing the expected levels of damage (as a percentage of building replacement value) for each MMI/PGA bin. For reference, up to four typical building mean damage functions are provided for the building type of the building under consideration.

DEFAULT ESTIMATES:						
MMI		VI	VII	VIII	IX	X
PGA (percent of g)		4-8	8-16	16-32	32-55	55-!
A	Poor	5.7	16.1	20.8	44.9	66.
B	Typical	1.5	5.7	16.1	20.8	44.
C	Seismic Design	0.0	1.5	5.7	16.1	30.
D	Typical California	3.0	6.8	15.7	30.2	45.
Select Type of Construction (A,B,C,D) from the Table Above OR Enter Y						
D	Typical California	3.0	6.8	15.7	30.2	45.
	User Entered Estimate:					

The user may select one of these "default" mean damage functions by entering the appropriate letter in the green box or may enter a user-determined, building-specific MDF for the building. For some building types, the model will display blanks and inconsistencies in the data because these values are taken directly from the original data sources.

The "poor," "typical," and "seismic design" default estimates are from Earthquake Loss Evaluation Methodologies and Databases for Utah, Technical Report: Task 7, Appendix E and F, dated March 10, 1994, prepared by the Applied Technology Council, Redwood City, California, for the Federal Emergency Management Agency (unpublished). These data have neither been tested nor evaluated. Furthermore, these damage functions are specifically for Utah. These damage functions may approximately represent buildings in other states without a long history of seismic design requirements (i.e., most states other than California).

"Typical" indicates a structure of normal or common construction for the building type. "Poor" indicates a building with substantially worse than normal seismic performance due to poor design and/or poor condition. "Seismic design" indicates a building specifically engineered to resist lateral forces.

The "Typical California" default damage functions are for California buildings and are taken from ATC-13 (Earthquake Damage Evaluation Data for California, Applied Technology Council, 1985).

For the MDF, as for all other data input parameters, better data input means better results and, therefore, users are strongly encouraged to enter building-specific data whenever possible. In entering a building-specific MDF, the user should consider the full range of engineering information about the building, including plan and vertical irregularities and any other seismic deficiencies. The program can handle any type of building accurately, as long as a MDF commensurate with the building is entered.

Individual buildings may have <u>much</u> worse seismic performance than typical buildings (or even poor buildings), depending on the details of the design and construction. Building irregularities, such as soft first stories, may profoundly affect building performance. A truly poor building, in which full or partial collapse is expected in moderate earthquakes would be a prime candidate for seismic rehabilitation. If the benefit-cost results are to reflect accurately the true seismic vulnerability of such a building (and thus to reflect accurately the benefits of rehabilitation) the irregularities and other deficiencies of a building MUST be reflected in the MDF. Thus, engineering judgement and analysis must be used to ensure that the MDF entered for a specific building accurately reflects the expected seismic performance of the building.

> Mean Damage Function (MDF) is one of the **critical** input parameters. The selected MDF **must** be a reasonable representation of the building under evaluation or else the results will be inaccurate. Use **building-specific** values **whenever possible** to produce valid results!

Modified Mean Damage Function

Modified mean damage functions (MMDF) reflect the impact of the demolition threshold as shown below:

Select Type of Construction (A,B,C,D) from the Table Above OR Enter Your Own Estimates:							
D Typical California	1.5	3.8	5.0	8.9	17.1	23.0	33.7
User Entered Estimate:							
Modified MDF:	1.5	3.8	5.0	8.9	17.1	23.0	33.7

In this case, these is no difference between the MDF and the MMDF because the demolition threshold percentage is higher than the highest damage percentage in the MDF. If, for example, the demolition threshold were 20%, then damage percentages in the MMI XI and XII bins in the MMDF would both become 100%, because the damage percentage in the MDF for these bins exceeds the demolition threshold percentage.

BUILDING CONTENTS (Damage as a % of replacement value)

In the pink box enter a brief description of the building's contents.

First, enter the estimated value of total building contents (per square foot) in the $/sf box. The total building contents value is calculated automatically.

Second, an estimate for the contents mean damage function must be made. The default assumption is that the contents MDF is the same as the building MDF. The building MDF (entered previously) is shown for reference.

Users may either accept the default contents MDF estimate, or enter a building-specific estimate. Because the seismic fragility of contents may differ significantly (either higher or lower) than the building fragility, users are strongly encouraged to enter building-specific contents MDF estimates.

RELOCATION TIME (due to seismic damage)

Seismic damage to a building may necessitate relocation while the building is repaired. Default estimates of the number of days of relocation necessary, based on the building MMDF, are provided for reference.

Users may accept the default relocation estimates or enter a building-specific estimate. As always, users are strongly encouraged to enter building-specific estimates whenever possible.

Total relocation costs (dollars per square foot per month) are calculated as the sum of the added costs of relocation per day plus the costs of renting alternative space. The costs of relocation per day include extra operating costs (transportation, communications, etc.) incurred as a result of a forced relocation due to seismic damage. Such costs are highly locality-specific and agency-specific and thus no default values are provided.

DEATH & INJURY RATES (Per 1,000 Occupants) EXISTING BUILDING

Life safety concerns are often one of the prime drivers of seismic rehabilitation projects. Therefore, estimating the life safety threat in the existing building and the efficacy of the rehabilitation in reducing expected future casualties are particularly important data input decisions. For reference, default death and injury (minor and major) rates per 1,000 occupants are shown in this section. These values are from ATC-13 (interpolated) for the building mean damage function selected or entered.

Default Minor Injury Rate	1.65E-01	6.60E-01	2.28E+00	1.38E+01
User Entered Estimate:				
Default Major Injury Rate	2.20E-02	8.80E-02	3.04E-01	1.84E+00
User Entered Estimate:				
Default Death Rate	5.50E-03	2.20E-02	7.60E-02	4.60E-01
User Entered Estimate:				

Users may accept the default values or enter user-specified estimates in the appropriate green boxes. Users are strongly encouraged to enter building-specific estimates.

The importance of entering building-specific estimates for death and injury rates when possible cannot be overestimated. User-entered casualty rates must be consistent with the mean damage function estimates entered previously. The life safety threat posed by specific buildings may vary drastically from "typical" values, depending on the seismic damage pattern, the prevalence of falling object hazards and the age and health of building occupants.

User-entered casualty rates should be consistent with the mean damage function estimates entered previously.

A comment box is provided at the end of the Death and Injury section for user comments and/or references to supporting documentation for casualty estimates.

USE & FUNCTION MENUS

The Use and Function submenu of the Building menu contains information on occupancy, value of government services, functional downtime, and building rental income.

OCCUPANCY DATA

Occupancy

Enter the average number of persons (employees and visitors) for both daytime and nighttime, along with the days per week and hours per day for which these day and night occupancy averages apply. The program calculates the average building occupancy over a 24-hour, 7-days per week period.

OCCUPANCY:	Day	Night	
Average Number of Occupants:	25	1	
Days per Week:	5	5	
Hours per Day	9	9	
Average Occupancy (24 hours, 7 days per week):			6.96

VALUE OF GOVERNMENT SERVICES LOST

The value of government services, which may be lost due to seismic damage, is determined using the Quasi-Willingness To Pay (QWTP) model, which is described more fully in Chapter 1 of Volume 2. Briefly, QWTP assumes that government services are worth what it costs to provide them. For example, if an agency spends $1,000,000 per month to provide services from a given building, then the loss of these services for one month is valued at $1,000,000. For QWTP evaluation, the full costs of providing government services must be counted, including salaries and benefits, utilities and other non-wage operating costs, and either rent or a rent-proxy (if the building is agency owned). Rent proxy is an approximate equivalent to rent for owner-occupied buildings (described below).

QWTP assumes that government services are worth what it costs to provide them.

HELP

Complete EITHER Section 1 or 2 (they are equivalent):

1a. Total annual operating budget of government functions in this building. (DO NOT count pass through funds such as social security payments.)	
1b. Does this include rent? (1=yes, 2=no)	2
2a. Number of full-time-equivalent persons working in the building:	25
2b. Average annual salary-plus-benefits paid to the above:	$50,000
2c. Average annual utilities, and other non-wage operating expenses :	$100,000
Rental Values For Support of Agency Functions	
3a. Amount of floor space occupied by government tenants (sq. ft.):	50,000
3b. Proxy annual rent estimate (if 1a. does not include rent):	$350,000
Daily cost of providing services from this building:	$4,658
Post-Earthquake Continuity Premium	
Based on the nature of the services in this building, how much extra cost per day would the tenant agencies be willing to spend to maintain agency functions after an earthquake:	$2,000
TOTAL VALUE OF LOST SERVICES PER DAY:	$6,658

In compiling costs for the QWTP evaluation, pass through costs such as Social Security payments or other transfers should **not** be counted. Only the direct costs of providing the government services should be counted.

Enter **either** the total annual operating budget for the building (in box 1a) **or** the more detailed breakdown in boxes 2a, 2b, and 2c (number of fulltime equivalent employees, average wages and benefits, average annual utilities and other non-wage operating costs). If total annual operating costs are entered in Box 1a, it is not necessary to fill in Boxes 2a, 2b, and 2c. If all boxes are filled in, the program uses the more detailed values from Boxes 2a, 2b, and 2c.

Rental Values for Support of Agency Function

The proxy annual rent is calculated from the building's replacement value and the discount rate; this value (shown in Box 3a) is used unless the annual operating costs in Box 1a includes rent. If a value for total operating costs is entered in Box 1a, and a "1" is included in Box 1b (total operating costs includes rent), and Boxes 2a, 2b, and 2c are not filled in then the proxy rent value in Box 3b is not used to calculate the daily cost of providing government services from the building.

Post-Earthquake Continuity Premium

The above QWTP calculation is for "normal" government services (i.e., not in the post-earthquake environment). Some government services, such as emergency response or emergency medical care, may be more valuable than normal in the post-earthquake time period. If desired, a post-earthquake continuity premium, the dollar amount agencies would be willing to pay to maintain agency functions after the earthquake, can be included. The QWTP value of government services is the sum of the normal cost to provide government services plus the continuity premium.

FUNCTIONAL DOWNTIME

Functional Downtime

For the QWTP evaluation of the value of lost government services, it is necessary to estimate how long government services will not be provided as a result of seismic damage. Default estimates are provided, based on the building's Mean Damage Function. The default functional downtime estimates are capped at 30 days, because it is assumed that government services will be reestablished within 30 days, in temporary quarters if necessary.

MMI	VI	VII	VIII	IX	X	XI
PGA (percent of g)	4-8	8-16	16-32	32-55	55-80	80-1
Building Damage (%)	3	7	16	30	46	62
Default Downtime (Days)	3	7	16	30	30	30
User Entered (days)						

Analyst: Joe Blow

Users may accept the default estimates of functional downtime, or enter user-specified estimates in the blue boxes provided.

Functional downtime is distinct from relocation time (see Relocation Information section). Estimates for each time will generally be quite different. Relocation time refers to the amount of time that agencies will be relocated out of a damaged building, and, thus, relocation time may be significantly longer than functional downtime.

Functional downtime is distinct from relocation time.

BUILDING RENTAL INCOME

This data entry screen enables the user to enter building-specific rental income information for non-Government tenants. Rental income from Government tenants is considered a transfer payment and not included as a loss in true income.

On this data entry screen, enter the amount of rental space and the rental rate.

Rehabilitation Menus

REHABILITATION PROJECT DESCRIPTION

All of the previously discussed input data are applicable to the **existing building**, and thus are applicable to any rehabilitation project(s) under consideration. The following rehabilitation project data, however, are project-specific (i.e., they apply to a specific project with defined objectives, engineering design and construction, and costs). A range of alternative rehabilitation schemes can be analyzed sequentially by entering appropriate data and obtaining benefit-cost results for each in turn.

This section provides spaces for a brief description of the rehabilitation project under evaluation and a statement of the objective of the rehabilitation.

risk reduction: any measure to lower seismic risk;

collapse prevention: the minimum structural strengthening to avoid collapse;

substantial life safety: collapse prevention and ensuring post-earthquake access and egress;

damage control: limiting the extent of seismic damage; and

immediate occupancy: denotes virtually no disruption of function.

If more than one rehabilitation project is being considered, user must be careful to ensure that all of the inputs which apply to the rehabilitation project are commensurate with the specific rehabilitation under evaluation (i.e., costs and effectiveness in avoiding building damages, contents damage, and casualties).

REHABILITATION PROJECT COSTS

This section allows input of the full range of rehabilitation project costs. Data entry boxes are provided for: direct construction costs, indirect costs such as architectural and engineering fees, testing, permits, etc. and for project management. For reference, a data entry box is provided for the base year of costs.

To estimate relocation costs associated with the rehabilitation project (which are included in the total costs of the project), the user must enter the estimated number of months of relocation necessary. Relocation costs are then calculated automatically from relocation cost information entered previously.

Total project costs are calculated from a summation of the above costs.

Default values are <u>not</u> provided for costs because costs are project- and locality-specific. Rehabilitation project cost estimates are readily obtainable using standard construction cost estimating methods.

EFFECTIVENESS OF THE REHABILITATION

The effectiveness of a seismic rehabilitation project is the extent to which the project reduces expected future damages and losses. Effectiveness is characterized by the percentage reduction in expected damages. Five effectiveness estimates must be entered, for: building damages, contents damages, and casualties (minor injury rate, major injury rate and death rate).

Effectiveness in Avoiding Building Damage

The effectiveness of a specific rehabilitation project in avoided future building damages may be viewed from two perspectives. One perspective is to consider the mean damage function (MDF) of the rehabilitated building compared to the MDF of the existing building. Several MDFs for the building type under consideration are shown for reference. The user may select one of these or enter a user-specified, building-specific estimate of the MDF for the rehabilitated building. Percentage effectiveness of the prospective seismic rehabilitation project are calculated from the MDFs for the existing and rehabilitated building.

The effectiveness of seismic rehabilitation projects in avoided future damages may vary markedly from very small percentages for minor risk reduction projects to nearly 100% for projects designed to ensure continued functionality and immediate occupancy in the largest earthquake considered. In general, the effectiveness of many types of rehabilitation projects declines as the intensity of ground shaking increases.

All benefits depend on the estimated effectiveness of the rehabilitation.

The estimated effectiveness in reducing building damages is an extremely important input parameter because avoided building damages typically constitute the largest component of benefits (without the value of life). Furthermore, all of the other benefits (avoided contents damages, avoided rental income losses, avoided relocation costs, avoided loss of government services, and avoided deaths and injuries) depend on the expected building mean damage function after rehabilitation. Therefore, all of the estimated benefits of the rehabilitation project depend on the estimated effectiveness of the rehabilitation in avoiding building damages.

Effectiveness in Avoiding Contents Damage

The effectiveness of the proposed rehabilitation project in avoiding contents damage must also be estimated. The default assumption is that the effectiveness for contents is the same as the effectiveness for the building.

Users may accept this default assumption (which may not always be a good assumption) or enter building- and contents-specific estimates in the appropriate data entry boxes. As always, users are strongly encouraged to enter building-specific estimates whenever possible.

DEATH AND INJURY RATES (per 1,000 occupants): REHABILITATED

Effectiveness in Avoiding Casualties

The effectiveness of the proposed rehabilitation project in avoiding casualties (deaths, major injuries and minor injuries) must also be estimated. For reference, the casualty rates for the existing building (entered previously) are shown. Default estimates are provided based on the assumption that the rehabilitation project reduces minor injuries by a factor of 10, major injuries by a factor of 100, and deaths by a factor of 1,000. These default casualty reduction factors are based on the premise that life safety is the driving force for most seismic rehabilitations.

The effectiveness of rehabilitation projects in avoided casualties may vary markedly depending on the type of building and on the objective and implementation of the rehabilitation. Therefore, it is very important to enter building-specific, project-specific estimates whenever possible.

In some cases, where occupancy is high and a building is expected to undergo partial or full collapse at moderate levels of ground shaking, benefit-cost results may be predominantly determined by the casualties avoided by the rehabilitation. Therefore, estimation of expected casualty rates for the existing building and the reduction in expected casualty rates for the rehabilitated building are among the most important data input decisions.

Seismic Menus

SEISMIC RISK

Seismic risk, the expected annual number (or probability) of earthquakes for the range of MMI/PGA bins, is the single most important determinant of benefit-cost results. Seismic risk may vary by several orders of magnitude from one location in the United States to another. All other factors being equal, benefit-cost results are directly proportional to seismic risk. A more technical review of seismic risk is given in Technical Issues chapter of Volume 2.

Soil Type

Specify the soil type in the green box provided.

The expected level of ground shaking in any given earthquake event depends on the soil type at the site. Site-specific soil conditions may markedly impact the actual ground shaking experienced during earthquakes. Therefore, to model seismic risk it is essential to consider the effects of soils at each site. Soil effects are modeled using a five step soil classification from NEHRP.

For the Default Method (seismic risk based on two pairs of input data) the user must classify the site on a simple five point scale (S0, S1, S2, S3, and S4). Seismic risk estimates at a site are adjusted according to the consensus soils multipliers compiled by the Design Values Panel (1993) which is currently reviewing proposed NEHRP 1993 standards. Because of soil amplification effects, the expected annual number of earthquakes in a given MMI/PGA bin depends on the soil type. The soil multipliers used are shown below:

		% of g			
Soil Description	Class	25	50	75	100
Hard rock	S0	0.6	0.6	0.7	0.8
Rock	S1	0.7	0.8	0.9	1.0
Very dense soil	S2	1.0	1.0	1.0	1.0
Stiff Soil	S3	1.2	1.1	1.0	1.0
Soft soil	S4	1.5	1.3	1.1	0.9

If Option 2 (the Site-Specific Geotechnical Estimate, below) is chosen, then soil effects are assumed to be incorporated into the geotechnical estimate and the soil multipliers shown above are <u>not</u> used.

Seismic Risk Assessment

Seismic risk, the expected annual number of earthquakes as a function of the MMI/PGA bins, for a specific site may be estimated in two ways in the model:

1) DEFAULT METHOD: from tabulated values for about 300 cities in the Seismic Risk Table (below), or by entering values of acceleration and exceedance probability from the 1991 NEHRP appendix maps; or

2) SITE-SPECIFIC GEOTECHNICAL METHOD: enter data from a site-specific geotechnical study.

The user must estimate seismic risk in only one of the above ways.

1) Default Method

The first method provides approximate estimates of seismic risk, based on regional seismicity contours. This method requires entering two pairs of data for spectral acceleration (as a percentage of g, the acceleration of gravity) with a 10 percent chance of exceedance in two time intervals (e.g., 50 years and 250 years). More accurate estimates can be obtained from a site-specific geotechnical study. Therefore, users are strongly encouraged to use site-specific geotechnical data whenever possible.

a) Tabulated Values

The Seismicity Estimates for Major Cities Table (Table 3.1) contains seismic risk data for approximately 260 cities in the United States. These cities include the 200 largest cities, plus an additional smaller cities in higher seismicity areas. For cities in this table, the user can copy the two tabulated spectral acceleration data points into the appropriate boxes on the Seismic Risk data entry screen. These data points were obtained from the spectral acceleration contours on the 1991 NEHRP maps (as described below). From these data points, the program automatically calculates the expected annual number of earthquakes shown in the "default estimate" line of the Seismic Risk Table.

Using the tabulated values in the Cities Tables is convenient; however, seismic risk estimates derived from these tables are subject to two significant uncertainties. First, the spectral acceleration contours on which the tabulated values may not fully reflect all local faults. Second, particularly for cities of large geographic extent, the average values for a city may not reflect important local differences, depending on the location of the major fault(s).

b) NEHRP Maps

Another option is to enter spectral acceleration contour data (i.e., as shown in Table 3.1) for the city of interest. This option may be useful for cities not shown in Table 3.1 or cities of large geographic extent where it may be possible to read the contours to a higher precision than the average city values shown in Table 3.1. This option is still, of course, subject to uncertainties in the contours, which may not accurately reflect all local faults.

The 1991 NEHRP Appendix maps showing contours of spectral acceleration for a period of 0.3 seconds are used to estimate the expected annual numbers of earthquakes for each bin of effective peak acceleration. For cities outside California, Maps 5 and 9, 10% exceedance probabilities in 50 and 250 years are used. For cities within California, Maps 6 and 10 are used.

When using the default seismic risk method, you must click on the Update Seismic Button if any of the seismic values are changed.

2) Site-Specific Geotechnical Method

The second option is to enter site-specific data in the blue blocks. If available, this is by far the preferred option, because it incorporates detailed site-specific information and analysis of local faults and is thus likely to produce more accurate results than the default method.

The preferred option is to have the expected annual numbers of earthquakes in each MMI/PGA bin calculated directly as part of the detailed site-specific geotechnical seismic evaluation.

Table 5.1
Seismicity Estimates for Major U.S. Cities

State	City	50 yr	250 yr
AK	Anchorage		
AK	Juneau		
AL	Birmingham	20	45
AL	Huntsville	15	30
AL	Mobile	1	6.5
AL	Montgomery	11	28
AR	Fayetteville	4	11
AR	Fort Smith	5	14
AR	Little Rock	13.5	29
AR	Pine Bluff	15	35
AZ	Flagstaff	15	40
AZ	Glendale	8	22
AZ	Mesa	7	19
AZ	Phoenix	8	21
AZ	Scottsdale	7.5	19
AZ	Sierra Vista	15	35
AZ	Sun City	8.1	22
AZ	Tempe	7.5	21
AZ	Tucson	8.5	28
AZ	Yuma	25	50
CA	Anaheim	95	200
CA	Bakersfield	50	110
CA	Berkeley	150	250
CA	Chula Vista	110	300
CA	Citrus Heights	18	40
CA	Concord	100	200
CA	East Los Angeles	110	250
CA	El Monte	110	290
CA	Escondido	75	150
CA	Fremont	130	300
CA	Fresno	18	38
CA	Fullerton	90	175
CA	Garden Grove	110	275
CA	Glendale	105	250
CA	Hayward	130	275
CA	Huntington Beach	110	300
CA	Inglewood	110	300
CA	Irvine	105	240
CA	Long Beach	120	300
CA	Los Angeles	110	250
CA	Modesto	20	38
CA	Moreno Valley	100	175
CA	Oakland	130	275
CA	Oceanside	105	275
CA	Ontario	90	180
CA	Orange	90	190
CA	Oxnard	120	180
CA	Pasadena	110	250
CA	Pomona	90	190
CA	Rancho Cucamonga	100	200
CA	Riverside	90	175
CA	Sacramento	19	37
CA	Salinas	150	220
CA	San Bernardino	200	300
CA	San Diego	110	300
CA	San Francisco	200	300
CA	San Jose	185	250
CA	Santa Ana	95	225
CA	Santa Clarita	90	200
CA	Santa Rosa	78	175
CA	Simi Valley	80	165
CA	Stockton	25	40
CA	Sunnyvale	190	300
CA	Thousand Oaks	95	200
CA	Torrance	120	300
CA	Vallejo	85	190
CO	Aurora	2.5	10.5
CO	Colorado Springs	3	12.5
CO	Denver	3	11
CO	Lakewood	3	11
CO	Pueblo	4	12.5
CT	Bridgeport	38.5	85
CT	Hartford	36	82
CT	New Haven	40	86
CT	Stamford	38	85
CT	Waterbury	38.5	83
DC	Washington	14	28
DE	Dover	15	34
FL	Fort Lauderdale	1	2
FL	Hialeah	1	2
FL	Hollywood	1	2
FL	Jacksonville	8	22
FL	Miami	1	2
FL	Orlando	6	20
FL	St. Petersburg	1	4
FL	Tallahassee	5	17.5
FL	Tampa	1	6.5
GA	Atlanta	19	44
GA	Columbus	11	28
GA	Macon	10	27
GA	Savannah	14	30
HI	Honolulu		
IA	Cedar Rapids	2	7
IA	Des Moines	2	2
ID	Boise City	9	22
ID	Coeur d'Alene	8	19
ID	Idaho Falls	10	25
ID	Lewiston	7.5	15

State	City	50 yr	250 yr
ID	Pocatello	22	50
ID	Twin Falls	8.6	25
IL	Chicago	5.5	18.5
IL	Peoria	7	16
IL	Rockford	6	19
IL	Springfield	7	17.5
IN	Evansville	21	50
IN	Fort Wayne	7.5	17.5
IN	Gary	5	15
IN	Indianapolis	15	40
IN	South Bend	5	15.5
KS	Kansas City	7	18
KS	Overland Park	7	18
KS	Topeka	10	23
KS	Wichita	10	25
KY	Lexington-Fayette	16	34
KY	Louisville	15	30
LA	Baton Rouge	1	8.5
LA	Metairie	1	8
LA	New Orleans	1	8
LA	Shreveport	2	10
MA	Boston	36	89
MA	Lowell	37.5	70
MA	Springfield	35	88
MA	Worcester	40	82
MD	Baltimore	15	30
ME	Augusta	20	50
ME	Portland	30	58
MI	Ann Arbor	8	22
MI	Detroit	8.5	23
MI	Flint	6	17
MI	Grand Rapids	5	16
MI	Lansing	6.5	16.5
MI	Livonia	8.5	22
MI	Sterling Heights	8.5	20
MI	Warren	9	21
MN	Minneapolis	2.5	11
MN	St. Paul	2	10
MO	Independence	6	18
MO	Jefferson City	7.5	17.5
MO	Kansas City	7	18
MO	Springfield	6	17
MO	St. Louis	27	61
MS	Jackson	3.5	10
MT	Billings	2	5.5
MT	Bozeman	37	93
MT	Butte	20	65
MT	Great Falls	6	13
MT	Helena	32	83
MT	Kalispell	45	125

State	City	50 yr	250 yr
MT	Missoula	12	27
NC	Charlotte	14	29
NC	Durham	10	24
NC	Greensboro	12	28
NC	Raleigh	9.5	22
NC	Winston-Salem	13	29
ND	Bismarck	1	2
NE	Lincoln	15.5	33
NE	Omaha	14	25
NH	Concord	30	50
NH	Manchester	32	53
NJ	Elizabeth	38	85
NJ	Jersey City	38	85
NJ	Newark	38	85
NJ	Paterson	38	85
NJ	Trenton	37.5	83
NM	Albuquerque	28	55
NM	Santa Fe	7.5	20
NV	Carson City	65	155
NV	Las Vegas	13	32
NV	Paradise	13	35
NV	Reno	62	155
NY	Albany	25	50
NY	Buffalo	23	58
NY	New York	38	84
NY	Rochester	23	83
NY	Syracuse	9	20
NY	Yonkers	38	85
OH	Akron	15	40
OH	Cincinnati	15.5	33
OH	Cleveland	15	40
OH	Columbus	13	30
OH	Dayton	15.5	30
OH	Toledo	13	30
OK	Oklahoma City	10.5	22
OK	Tulsa	8.5	20
OR	Albany	33	80
OR	Corvalis	37	87
OR	Eugene	31	82
OR	Grants Pass	24	80
OR	Klamath Falls	15	40
OR	Medford	19	60
OR	Portland	42	82
OR	Salem	39	80
OR	The Dalles	25	50
PA	Allentown	32	80
PA	Erie	15	30
PA	Harrisburg	27	60
PA	Philadelphia	37	84
PA	Pittsburgh	6	14

State	City	50 yr	250 yr
RI	Providence	40	83
SC	Columbia	30	65
SD	Pierre	7.5	21
SD	Sioux Falls	4	14
TN	Chattanooga	21.5	48
TN	Knoxville	23	53
TN	Memphis	60	150
TN	Nashville-Davidson	14	30
TX	Abilene	1	6.6
TX	Amarillo	7.5	20
TX	Arlington	4	12.5
TX	Austin	1	7.2
TX	Beaumont	1	7.8
TX	Corpus Christi	1	7.5
TX	Dallas	5	14
TX	El Paso	2.5	15
TX	Fort Worth	3.5	12.5
TX	Garland	5	14
TX	Houston	1	8
TX	Irving	5	13
TX	Laredo	1	5
TX	Lubbock	2	7
TX	Mesquite	5	12.5
TX	Pasadena	1	8.5
TX	Plano	6	18
TX	San Antonio	1	7.2
TX	Waco	1	7
UT	Logan	48	100
UT	Ogden	37	85
UT	Provo	37	90
UT	Salt Lake City	35	75
UT	Tooele	25	64
VA	Alexandria	13.8	29
VA	Arlington	14	29
VA	Chesapeake	12.5	27
VA	Hampton	15	35
VA	Newport News	14	34
VA	Norfolk	13	28
VA	Portsmouth	12.5	25
VA	Richmond	20	74
VA	Virginia Beach	10	20
VT	Montpelier	14.5	28
WA	Bellevue	83	141
WA	Bellingham	64	110
WA	Bremerton	83	150
WA	Everett	74	140
WA	Longview	50	85
WA	Olympia	75	136
WA	Richland	18	32

State	City	50 yr	250 yr
WA	Seattle	84	150
WA	Spokane	11	21
WA	Tacoma	85	147
WA	Vancouver	45	82
WA	Yakima	28	58
WI	Madison	5	16
WI	Milwaukee	5.5	17
WV	Charleston	8	18
WY	Casper	3	12
WY	Cheyenne	2	11
WY	Laramie	2	12
WY	Sheridan	2.5	10

Other Data Inputs

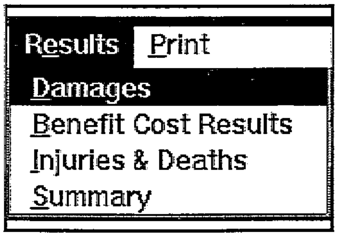
There are five additional data inputs required: discount rate, planning horizon, and three value of life amounts for deaths, minor injuries, and major injuries. These data inputs are discussed in Chapter 6 (Results) in the Benefit-Cost Results section because they are independent of either the existing building or the rehabilitated building.

These economic inputs strongly affect any benefit-cost calculation. For consistency, we suggest that decisions about these economic inputs should probably be made at the agency level, rather than on a building-by-building basis. Agency-wide consistency is essential if benefit-cost results are to be used as part of the decision-making process of prioritization of seismic rehabilitation projects.

CHAPTER 6: RESULTS

Results Menu

The **RESULTS** menu has four submenus: **DAMAGES, BENEFIT-COST RESULTS, INJURIES & DEATHS,** and **SUMMARY**, as follows:



The contents of these four submenus are discussed below.

DAMAGES

The four tables in this section of RESULTS summarize four types of damages:

scenario damages,
expected annual damages,
expected avoided annual damages, and
expected residual annual damages.

These types of damages are defined as follows:

Scenario Damages

The estimated damages and losses per earthquake event of a given MMI (or range of effective peak ground acceleration, PGA) at the building;

Expected Annual Damages

The product of scenario damages and the expected annual probability of an earthquake of a given MMI or PGA;

Expected Annual Avoided Damages

The product of expected annual damages and the effectiveness of the rehabilitation measure in reducing expected damages. Expected annual avoided damages are the expected annual **benefits** of the rehabilitation project.

Expected Residual Annual Damages

The expected residual annual damages are damages expected to occur even after the rehabilitation is undertaken.

Each of these types of damages and losses are subdivided into five major categories: building damage, property (contents), relocation expenses, rental income losses, and the value of lost government services. In each case, the damages and losses are shown for each MMI/PGA bin. A section of the DAMAGES table is shown below:

SCENARIO DAMAGES ($ per earthquake event):							
MMI	VI	VII	VIII	IX	X	XI	XII
PGA (percent of g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Building Damages	152,500	376,250	499,700	689,000	1,713,000	2,296,500	3,367,500
Contents Damages	38,125	93,813	124,925	172,250	428,250	574,125	841,875
Relocation Expenses	0	0	0	0	290,133	445,733	731,333
Rental Income Losses	0	0	0	0	29,013	44,573	73,133
Value of Lost Services	10,153	24,982	33,266	45,870	114,044	152,890	199,726
Total Losses	200,778	494,045	657,893	907,120	2,574,440	3,513,822	5,213,568
EXPECTED ANNUAL DAMAGES ($):							
Building Damages	10,306	7,969	3,326	1,249	982	470	1,526
Contents Damages	2,576	1,980	831	312	245	118	381
Relocation Expenses	0	0	0	0	166	91	331
Rental Income Losses	0	0	0	0	17	9	33
Value of Lost Services	686	530	221	83	65	31	90
Total Losses	$13,569	$10,478	$4,379	$1,645	$1,475	$720	$2,362

Damages: Existing Building

Scenario damage estimates may be useful for some planning or policy purposes because they indicate the magnitude of losses per earthquake event (independent of the probability of such events). Thus, scenario losses indicate the extent of exposure to damage and losses **if and when** a corresponding earthquake does occur.

Expected annual damages (which include the annual probabilities of earthquakes) are central for benefit-cost analysis. These are the probabilistic (expected) annual damages and losses which are potentially avoidable (in full or in part). If the expected annual damages are low, then the benefits of avoiding all or part of these damages will also be low. Expected annual damages may be low, even if scenario damages are high, for areas with low seismic risk.

Scenario damage estimates and expected annual damage estimates thus contain complementary information which, in combination, present a complete picture of the damage estimates for the building under consideration. Both scenario damages and expected annual damages apply to the seismic performance of the **existing building**, and are thus independent of any rehabilitation alternative(s) being considered.

Damages: Rehabilitated Building

Avoided annual damages are the fraction of the expected annual damages which are avoided as a result of the specific rehabilitation project under evaluation. Avoided annual damage estimates apply only to the specific rehabilitation project under evaluation. Avoided annual damages are the differences between the expected annual damages for the existing building and the residual annual damages for the rehabilitated building. Avoided annual damages are the annual benefits of the specific project under consideration.

Avoided Annual Damages are the Annual Benefits of the Rehabilitation.

AVOIDED ANNUAL DAMAGES ($):							
Building Damages	10,306	6,463	2,218	557	570	187	519
Contents Damages	2,576	1,616	554	139	143	47	130
Relocation Expenses	0	0	0	0	97	36	113
Rental Income Losses	0	0	0	0	10	4	11
Value of Lost Services	686	430	148	37	38	12	31
Total Losses	13,569	8,509	2,920	733	857	286	804
RESIDUAL ANNUAL DAMAGES ($):							
Building Damages	0	1,495	1,108	692	412	284	1,006
Contents Damages	0	374	277	173	103	71	252
Relocation Expenses	0	0	0	0	70	55	219
Rental Income Losses	0	0	0	0	7	6	22
Value of Lost Services	0	100	74	46	27	19	60
Total Losses	$0	$1,969	$1,459	$911	$618	$434	$1,558

Residual annual damages are the probabilistic (expected) damages remaining **after** completion of the specific rehabilitation project under consideration. These damages indicate the level of exposure to damage and losses **after** completion of the rehabilitation project. In combination with the post-rehabilitation scenario damages, the residual annual damages provide a complete picture of the post-rehabilitation damage estimates.

BENEFIT-COST RESULTS

The tables on this page primarily present the benefit-cost results. However, there are five user-entered parameters in this section: discount rate and planning period, which affect all of the results, and the economic (statistical) values per minor injury, major injury and death, which affect only the benefit-cost results with the value of life. These important parameters substantially affect the magnitude of calculated benefits and thus the calculated benefit-cost ratios.

The total costs and benefits (including the expected number of avoided casualties) of each proposed rehabilitation project will vary. However, the societal cost assumed in the model per minor injury, per major injury and per death must be the same (even though the number of avoided casualties will vary from building to building and rehabilitation project to rehabilitation project). Similarly, the discount rate (which reflects the time value of money) must also be the same for all projects under evaluation.

To ensure consistency when evaluating alternative rehabilitation projects for a single building or rehabilitation projects for a number of buildings, the same values must be used for the discount rate and the economic (statistical) value per minor injury, major injury and death. Since these are significant policy-related parameters, their values should probably be decided at the agency level rather than on a case-by-case basis. Similarly, the same planning period (or useful lifetime of the rehabilitation projects) should be used for similar projects, with possible differences in planning periods reflecting only real differences in rehabilitation project lifetimes. In comparing projects, using differing values for these parameters would substantially distort the benefit-cost results and make comparisons meaningless.

A. Economic Parameters

Discount Rate

The discount rate is used to calculate the present value of benefits which occur in the future. Increasing the discount rate lowers the present value of future benefits and lowers benefit-cost ratios. Conversely, assuming a lower discount rate raises the present value of future benefits and increases benefit-cost ratios. Enter the discount rate as a percentage (i.e., enter 10 for 10%).

The choice of an appropriate discount rate is frequently one of the most difficult aspects of benefit-cost analysis. For Federally funded projects, a 10% discount rate was previously mandated by the Office of Management and Budget, OMB, (Executive Order 12291, 1981). Recently, however, this mandate has been lifted. On October 29, 1992, OMB issued Circular A-94, Revised (Transmittal Memo No. 64), Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. For "public investments" which are not "internal Federal government investments", the Circular recommends a discount rate of approximately 7 percent. For internal Federal government investments, the Circular recommends a discount rate of about 4 percent, which is the "real discount rate", estimated from the current interest rate on long term Treasury bonds less the current rate of inflation.

For internal Federal government investments a discount rate of about 4% is appropriate now; this rate is updated periodically.

The seismic rehabilitation of Federal government buildings meets OMB's criteria for internal Federal government investments; therefore, a discount rate of about 4% is appropriate. As per the OMB Circular, this rate should be revised periodically to reflect current discount rates. The OMB Circular will be updated annually. Current real discount rates can be obtained from the current 30 year Treasury bond rate less the current rate of inflation. For more details, see Chapter 3 of Volume 2 of this project.

Planning Period

The planning period (horizon) is the time period over which the economic benefits of rehabilitation programs are considered. Longer planning horizons capture more future benefits and thus increase benefit-cost ratios. Short planning horizons capture future benefits for fewer years and thus result in lower benefit-cost ratios.

Appropriate planning horizons may be as short as one year for one time public education efforts which have no impact beyond the first year. Planning horizons of 5 to 10 years for equipment purchases, and 30 to 50 years for building projects are typical. For major infrastructure projects such as levees, planning horizons as long as 50 to 100 years may be appropriate. To ensure consistency of assumptions and results from project to project, agencies should probably adopt uniform guidelines for planning horizons.

Present Value Coefficient

The discount rate and planning period account for the time value of money and the useful lifetime of the rehabilitation, respectively. In combination, they determine the present value coefficient which is a multiplier on expected annual benefits which determines the net present value of such expected annual benefits. None of the compilations of damages and losses discussed previously depend on these parameters. However, the benefit-cost results presented below do depend strongly on the discount rate and planning period.

B. Summary of Damages and Economic Losses (Without Value of Life)

This section summarizes three categories of expected damages and losses: annual expected, annual avoided, and annual residual. In each case breakdowns are given for the five damage categories: building damage, property (contents), relocation expenses, rental income, and value of lost government services.

The right hand column in this table is the present value of the avoided annual losses (for each of the five categories and a total). **These are the benefits of the rehabilitation project** without including the value of injuries and death.

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$381,964
TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT:	$419,000
TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS:	($37,036)
BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS:	0.91

The results compare the benefits (present value of total damages and losses avoided) and costs (total costs of the seismic rehabilitation project). Results are shown two ways:

1) as the total benefits minus the costs (present value criterion), and

2) as a benefit-cost ratio.

Rehabilitation projects in which benefits exceed costs (on a present value basis) have present value criteria greater than zero and benefit-cost ratios above one. These two benefit-cost results provide complementary information, depending on whether or not total capital requirements are significant in the decision making process.

C. Value of Injuries and Deaths Avoided (With the Value of Life)

This section considers benefit-cost results including the economic value of avoided casualties in addition to the other damages and losses considered previously. The expected numbers of casualties were presented earlier in the section labeled "Death Losses & Injuries." To convert these estimates into economic losses, dollar values must be assigned to deaths and injuries.

Value of Injuries

Economic values must be assigned to minor and major injuries. The default value for minor injuries (not requiring hospitalization) is \$1,000. The default value for major injuries (requiring hospitalization) is \$10,000. Other values may be entered, if desired.

Value of Avoiding a Minor Injury:	\$1,000
Value of Avoiding a Serious Injury:	\$10,000
Statistical Value of Life:	\$1,700,000

Value of a Statistical Life

The economic value of human life is an important and difficult issue. The benefit-cost model can be run either including or excluding the statistical value of human life. When the value of life is included, the value of avoided deaths is frequently one of the principal factors producing high benefit/cost ratios for prospective rehabilitation programs, particularly for high occupancy facilities.

A consensus value for a statistical human life is approximately \$1.74 million, based on several Federal Agency studies. A fuller discussion of the value of life issue is contained in Appendix 1 of Volume 2 of the recently published benefit-cost model.[1] This Value of Life paper is reprinted as Chapter 4 of Volume 2 of this report. The default value in the program is \$1.7 million. Other values may be entered, if desired. However, for consistency, agencies should probably make agency-level decisions about appropriate economic values for deaths, minor injuries and major injuries.

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED:	\$396,445
TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS:	(\$22,555)
BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS:	0.95

The right hand column in this table is the present value of the avoided annual losses (for each of the five categories and the totals, shown above). **These are the benefits of the rehabilitation project** including the value of injuries and death.

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[1] Federal Emergency Management Agency. "A Benefit-Cost Model for the Seismic Rehabilitation of Buildings". Volume 2: Supporting Documentation. Earthquake Hazards Reduction Series 62, FEMA 227. April, 1992.

DEATH LOSS & INJURIES

In a manner analogous to the damage tables discussed above, casualty estimates are summarized in five tables which include estimates of the expected numbers of minor injuries, major injuries and deaths as follows:

Before Rehabilitation

Scenario casualties (per earthquake event), and expected annual casualties (considering the probabilities of earthquakes).

After Rehabilitation

Scenario casualties (per earthquake event), expected annual casualties (considering the probabilities of earthquakes), and avoided (annual) injuries and deaths.

SCENARIO INJURIES & DEATHS WITHOUT REHABILITATION:							
Number of Minor Injuries	6.79E-02	1.62E-01	2.09E-01	4.60E-01	1.71E+00	4.35E+00	1.26E+01
Number of Serious Injuries	9.05E-03	2.16E-02	2.79E-02	6.13E-02	2.28E-01	5.79E-01	1.68E+00
Number of Deaths	2.26E-03	5.40E-03	6.96E-03	1.53E-02	5.71E-02	1.45E-01	4.21E-01
EXPECTED INJURIES & DEATHS WITHOUT REHABILITATION:							
Number of Minor Injuries	4.59E-03	3.43E-03	1.39E-03	8.33E-04	9.82E-04	8.90E-04	5.72E-03
Number of Serious Injuries	6.12E-04	4.58E-04	1.85E-04	1.11E-04	1.31E-04	1.19E-04	7.62E-04
Number of Deaths	1.53E-04	1.14E-04	4.64E-05	2.78E-05	3.27E-05	2.97E-05	1.91E-04
SCENARIO INJURIES & DEATHS WITH REHABILITATION:							
Number of Minor Injuries	6.79E-03	1.62E-02	2.09E-02	4.60E-02	1.71E-01	4.35E-01	1.26E+00
Number of Serious Injuries	9.05E-05	2.16E-04	2.79E-04	6.13E-04	2.28E-03	5.79E-03	1.68E-02
Number of Deaths	2.26E-06	5.40E-06	6.96E-06	1.53E-05	5.71E-05	1.45E-04	4.21E-04
EXPECTED INJURIES & DEATHS WITH REHABILITATION:							
Number of Minor Injuries	4.59E-04	3.43E-04	1.39E-04	8.33E-05	9.82E-05	8.90E-05	5.72E-04
Number of Serious Injuries	6.12E-06	4.58E-06	1.85E-06	1.11E-06	1.31E-06	1.19E-06	7.62E-06
Number of Deaths	1.53E-07	1.14E-07	4.64E-08	2.78E-08	3.27E-08	2.97E-08	1.91E-07
AVOIDED INJURIES & DEATHS DUE TO REHABILITATION:							
Number of Minor Injuries	4.13E-03	3.09E-03	1.25E-03	7.50E-04	8.83E-04	8.01E-04	5.14E-03
Number of Serious Injuries	6.06E-04	4.53E-04	1.84E-04	1.10E-04	1.30E-04	1.18E-04	7.55E-04
Number of Deaths	1.53E-04	1.14E-04	4.63E-05	2.78E-05	3.27E-05	2.96E-05	1.90E-04

As for the non-casualty damages and losses summarized previously, the scenario and expected casualty estimates may be useful for planning or policy purposes. The expected avoided annual casualties are central to the benefit-cost analysis (i.e., the present value of these avoided casualties is counted as a benefit when the value of life is included in the benefit-cost analysis).

SUMMARY

This section summarizes all of the input parameters used in the calculation and summarizes the benefit-cost results, both with and without the value of life being included.

Boxes at the top of the summary printout identify the building under consideration and the rehabilitation project being evaluated. A scenario run identification number may be entered (on the Building ID data entry page) to delineate multiple analyses of projects, with varying sets of assumptions. To avoid confusion, users are strongly urged to enter a run identification number whenever multiple analyses of the same project are conducted. The pink data entry box for run identification number also appears on the summary page.

All of the input data which affect the calculated benefit-cost results are summarized in two tables: a table of single-value items, and a table of items which are defined for each MMI/PGA bin.

SUMMARY		Scenario Run Identification:
Court House	1234 Apple Street	Anywhere, USA 12345
Rehab Project Descripti	0	
Facility Class:	Steel Frame with URM Infill	

Data used for this analysis:	
Building Replacement Value per square foot	$150.00
Total Floor Area (square feet):	520,000
Total Building Replacemnt Value ($1,000)	$78,000
Demolition Threshold	100%
Total Contents Value	$133,120
Cost of Providing Services per day	$417,699
Continuity Premium	$400,000
Value of lost services per day	$817,699
Total Private Monthly Rental Revenue	$500
Total Relocation Costs ($/sq.ft./month):	$1.50
Total Seismic Rehabilitation Costs ($1,000)	$12,254
Occupancy per 1000 sq.ft.	1.3
Soil Type	S2

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
EPA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	3	7	16	30	46	62	76
Modified MDF (%)	3	7	16	30	46	62	76
Minor Injury Rate/1000	1.7E-01	6.6E-01	2.3E+00	1.4E+01	3.8E+01	1.6E+02	2.7E+02
Major Injury Rate/1000	2.2E-02	8.8E-02	3.0E-01	1.8E+00	5.0E+00	2.1E+01	3.6E+01
Death Rate/1000	5.5E-03	2.2E-02	7.6E-02	4.6E-01	1.3E+00	5.4E+00	9.0E+00
Content MDF (%)	3	7	16	30	46	62	76
Functional Downtime (days)	3	7	16	30	30	30	30
Days of Relocation Necessary	0	0	75	191	316	365	365
Building Rehab Effectiveness (	100	77	64	47	33	27	13
Contents Rehab Effectiveness	100	77	64	47	33	27	13
Rehab Minor Injury Rate/1000	1.7E-02	6.6E-02	2.3E-01	1.4E+00	3.8E+00	1.6E+01	2.7E+01
Rehab Major Injury Rate/1000	2.2E-04	8.8E-04	3.0E-03	1.8E-02	5.0E-02	2.1E-01	3.6E-01
Rehab Death Rate/1000	5.5E-06	2.2E-05	7.6E-05	4.6E-04	1.3E-03	5.4E-03	9.0E-03
Annual Number of Earthquake	7.8E-02	2.7E-02	9.3E-03	2.8E-03	9.3E-04	3.5E-04	8.5E-04

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$11,954,765	$12,255,844
TOTAL BENEFITS MINUS TOTAL COSTS :	($298,786)	$12,234
Benefit cost ratio :	0.98	1.00

CHAPTER 7: BENEFIT-COST ANALYSIS OF EIGHT FEDERAL BUILDINGS

Seismic rehabilitation projects for eight Federal buildings were analyzed with the Benefit-Cost program. These example projects were selected to include as much diversity as possible in building type (structural system), location, function, and agency/owner, subject to data availability. These eight example buildings are listed below:

Building Name	**Location**	**Agency/ Owner**	**Building Type/ Structural System**
Veterans' Administration Medical Center	Memphis, TN	Veterans' Administration	C2 -concrete frame with concrete shear wall
US Federal Building/Courthouse	Butte, MT	General Services Administration	URM - Unreinforced masonry bearing wall
US Federal Building	Albuquerque, NM	General Services Administration	URM - Unreinforced masonry bearing wall
Jackson Federal Building	Seattle, WA	General Services Administration	S5 - steel frame with infill shear walls
TEAD Motor Pool Facility, Building 158	Tooele Army Depot, UT	US Army	W1 - Light wood frame
Nuclear Facility Storage Complex, Building 271	Mare Island Naval Shipyard, Vallejo, CA	US Navy	S2 - Steel braced frame
Special Weapons Training Center, Building 678	Naval Construction Battle Center, San Diego , CA	US Navy	PC1 - Precast concrete tilt-up with flex diaphragm
US Coast Guard Station, Building 8	Boston, MA	US Coast Guard	URM - Unreinforced masonry bearing wall

Narratives describing each of the eight example building analyses are given below. For the first example, the Veterans Administration Medical Center in Memphis, a complete print-out of the benefit-cost program results is given in Appendix II. For each example, the summary results pages are printed from the benefit-cost model.

Veterans Administration Medical Center
1030 Jefferson Avenue, Memphis, TN

Function

This 805,700 square foot building is a large, densely occupied hospital. Occupancy is approximately 3,000.

Structure

The building composed of a low rise (3 story) rectangular section (approximately 552,000 square feet) and a 15 story tower (approximately 253,000 square feet) rising from the middle of the low rise structure. An open court of about 60'x135' lies within the lower section. The low-rise building includes one ground floor basement, two full stories, and a partial third story composed of separate units connected to the tower by passageways.

The structure was completed in 1967; some enlargements and renovations were made to the ground floor and basement in 1982. Construction is primarily cast-in-place concrete. Floor and roof construction is generally either one-way pan joists supported on beams, or two-way pan (waffle-type) joists; however, some significant areas have one-way and two-way flat slabs with beams. Vertical loads are transferred to foundations by concrete columns and, in some cases, concrete walls. Lateral load resistance is provided by shear walls and frame action.

Foundations for the low rise portion of the building are either individual spread footings, bearing approximately two feet below the ground floor pipe basement, or drilled, bell-bottom caissons installed through areas where the ground story and ground floor pipe basement were not part of the original construction. Approximately 70 columns support the tower and immediately adjacent portions of the low rise. The columns are supported by a 152' by 170' concrete mat, 3" to 4" thick.

The building is clad in panels of precast concrete, either with a finish of embedded bricks or exposed concrete. These panels are attached to the concrete building frame with threaded inserts and slotted connectors so that the panels are not subjected to wind-generated shear loads.

Seismic Evaluation

In 1985, the Veterans' Administration contracted with Walk Jones & Francis Mah, Inc. and Allen & Hoshall, Inc. of Memphis TN to study the feasibility of seismic modification and ward renovations to the Medical Center. Rutherford & Chekene, consulting engineers, San Francisco, evaluated seismic strengthening renovations.

The original structural design apparently considered only wind and not seismic forces. Initial investigations revealed that existing floors and shear walls were inadequate to provide the required lateral resistance. Torsional problems due to the location of the existing shear walls were also detected. Expansion joints were inadequate, causing excessive drift.

Ted Winstead of Allen & Hoshall, concluded that the damage to the unimproved building would be intense at the upper MMI scale, with possible collapse. Since this outcome is not reflected by one of the existing damage functions for a moment resisting non-ductile concrete building, a specific damage function was devised by Winstead for both the existing and rehabilitated building.

Damage to the unimproved building will be intense at MMI VIII, with probable collapse at MMI IX or higher. The shear walls in the tower are grossly inadequate to provide lateral resistance. Torsional problems exist due to the location of the shear wall; there are inadequate expansion joints, and excessive drift.

Seismic Rehabilitation

Reinforcing the existing tower by a "Four Corners" scheme was proposed for the Medical Center. This scheme places new concrete shafts rising at each corner of the tower, connected to one another at the penthouse level by a concrete "hat girder" at the tower perimeter. The new towers will require the existing foundation to be modified and enlarged. Additional shear walls will also be installed in the low rise portion of the building, and the existing expansion joints will be enlarged.

The cost of seismic rehabilitation was estimated in 1985 at $21.1 million excluding any non-seismic construction or renovation work. Selected occupants would have to be relocated during the project. The cost of relocation (assuming an average of 12 months relocation and $2.00 per month per square foot for relocation costs) is approximately $19 million dollars. This relocation cost is included in the cost of the rehabilitation project because it is necessary and directly related to the seismic rehabilitation. On the other hand, the cost of non-seismic renovation is excluded from the benefit-cost analysis because the benefits are not considered in the seismic benefit-cost calculation. The total cost of the seismic rehabilitation is approximately $40 million. Thus, the seismic benefit-cost calculation counts fully both the costs and the benefits of the seismic portion of the overall rehabilitation/renovation of this hospital.

Building Mean Damage Functions

The seismic performance of the existing building and the building after rehabilitation are shown in the building's mean damage functions (expected damages as percentages of replacement value). The mean damage functions for the VA hospital are shown below:

BUILDING MEAN DAMAGE FUNCTIONS

	Effective PGA	4-8	8-16	16-32	32-55	55-80	80-100	>100
	MMI	VI	VII	VIII	IX	X	XI	XII
High rise	Original Building	0	25	78	100	100	100	100
	Rehabilitated	0	4	6	12	19	25	30
Low rise	Original Building	0	18	43	70	95	100	100
	Rehabilitated	0	5	6	13	20	30	40
Whole Building	Original Building	0	23	67	90.6	98.4	100	100
	Rehabilitated	0	4.3	6	12.3	19.3	26.57	33.1

Benefit-Cost Results

The analysis of this example is particularly interesting because the building is highly vulnerable to seismic damage (even collapse), but the building is located in a moderate, rather than high, seismicity area.

The total seismic rehabilitation costs are approximately $40.5 million. Without the value of life, the benefits of avoiding damages and losses total about $33.3 million, resulting in a benefit-cost ratio of 0.83. This ratio less than one results primarily from the moderate seismicity at this site, and from the relatively expensive rehabilitation project (about 40% of building replacement value). However, even without the value of life, benefits might exceed costs if higher values were assigned to relocation costs (due to seismic damage) avoided by the rehabilitation and to the value of the services provided by the hospital in the post-earthquake situation. In the present analysis, a post-earthquake continuity premium of approximately 5 times the normal daily cost of providing services was assumed.

When the value of casualties avoided is also considered, the total benefits of the rehabilitation rise to nearly $98 million, and the resulting benefit-cost ratio is 2.42. The high value of casualties avoided is due to the high occupancy of the building and to the fact that the existing building is expected to collapse in high MMI events.

BENEFIT COST RESULTS

Veterans' Administration Med 1030 Jefferson Ave. Memphis, TN 38104

Facility Class: Concrete Frame with Concrete Shear Wall

Project Description: Add shear walls and moment frame

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$804,298	$711,386	$92,912	$9,817,661
Contents Damages	$748,335	$657,168	$91,166	$9,069,414
Relocation Expenses	$253,267	$219,567	$33,700	$3,030,187
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$958,205	$830,995	$127,210	$11,468,355
Total Damages and Losses	$2,764,105	$2,419,117	$344,988	$33,385,616

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $33,385,616

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $40,457,800

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($7,072,184)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.83

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	1.57E+00	1.41E+00	1.57E-01	$19,491
Serious Injuries	4.02E+00	3.97E+00	4.02E-02	$548,560
Deaths	2.73E+00	2.73E+00	2.73E-03	$63,938,862
			Total Value	$64,506,913

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $97,892,529

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: $57,434,729

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 2.42

Analyst: Goettel & Horner Inc.

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SUMMARY

Run Identification:	Final	
Veterans' Administration Medical	1030 Jefferson Ave.	Memphis, TN 38104
Rehab Project Description:	Add shear walls and moment frame	
Facility Class:	Concrete Frame with Concrete Shear Wall	

Data used for this analysis:

Building Replacement Value per square foot	$115.00
Total Floor Area (square feet):	805,700
Total Building Replacement Value	$92,655,500
Demolition Threshold Damage Percentage:	50%
Total Contents Value	$96,000,000
Cost of Providing Services per day	$302,701
Continuity Premium	$1,500,000
Value of lost services per day	$1,802,701
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$2.50
Total Seismic Rehabilitation Costs	$40,457,800
Average Day Occupancy	3,000
Average Night Occupancy	2,900
Soil Type	S2

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	1	25	75	100	100	100	100
Modified MDF (%)	1	25	100	100	100	100	100
Minor Injury Rate/1000	3.000E-02	8.400E+00	1.000E+02	5.000E+01	5.000E+01	5.000E+01	5.000E+01
Major Injury Rate/1000	4.000E-03	1.120E+00	3.000E+02	2.500E+02	2.000E+02	1.500E+02	1.500E+02
Death Rate/1000	1.000E-03	2.800E-01	5.000E+01	5.000E+02	7.000E+02	8.000E+02	8.000E+02
Content MDF (%)	1	25	75	100	100	100	100
Functional Downtime (days)	1	25	30	30	30	30	30
Days of Relocation Necessary:	0	150	365	365	365	365	365
Building Rehab Effectiveness (%)	100	83	94	88	81	73	67
Contents Rehab Effectiveness (%)	100	83	94	88	81	73	67
Rehab Minor Injury Rate/1000	3.000E-03	8.400E-01	1.000E+01	5.000E+00	5.000E+00	5.000E+00	5.000E+00
Rehab Major Injury Rate/1000	4.000E-05	1.120E-02	3.000E+00	2.500E+00	2.000E+00	1.500E+00	1.500E+00
Rehab Death Rate/1000	1.000E-06	2.800E-04	5.000E-02	5.000E-01	7.000E-01	8.000E-01	8.000E-01
Annual Number of Earthquakes	5.108E-02	1.345E-02	3.541E-03	8.196E-04	2.293E-04	7.575E-05	1.412E-04

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$33,385,616	$97,892,529
TOTAL BENEFITS MINUS TOTAL COSTS :	($7,072,184)	$57,434,729
Benefit cost ratio :	0.83	2.42

Analysit: Goettel & Horner Inc.

United States Federal Building/Courthouse
400 North Main Street, Butte, MT

Function

This 62,000 square foot building contains the Federal courts and administrative functions for the region. Occupants include U.S. District Court, U.S. Marshals Service, F.B.I., U.S.D.A. Forest Service, and U.S. Bankruptcy Court. Occupancy is about 285 during business hours.

Structure

The first phase of this building was constructed in 1902 and the remainder in 1932. This four-story building is unreinforced masonry construction.

Seismic Evaluation

A seismic structural evaluation and analysis was completed on July 22, 1992 and listed the following structural deficiencies:

- The unreinforced masonry bearing walls are inadequate to resist the seismic forces for seismic zone 3.
- The masonry bearing walls lack the ductility required under the 1991 UBC for modern structures.
- A soft-story problem exists below the second level due to the discontinuity of the existing unreinforced masonry walls at the lightwell below this level. This discontinuity has the tendency to stiffen the building in the upper stories creating an abrupt change at this level which tends to cause more severe earthquake damage and increase the potential for collapse at the soft story level.
- Many of the unreinforced masonry walls consist of a series of piers between window openings which, because they are unreinforced, lack the boundary steel to develop their limited in-plane shear capacity and resist rocking.
- Unreinforced masonry parapets and balustrades at the roof are on all four sides of the building and at the outer unbraced walls at the lightwell. These pose a serious falling hazard to people on the sidewalks and in parking areas below.

- The unreinforced masonry bearing walls on the exterior of the building and in the lightwell are inadequately anchored to the structure. Since these walls support the floor and roof structure, total or partial collapse of the masonry bearing walls will create a falling hazard to occupants in the building, people on sidewalks, and in other areas adjacent to the building.

- The floor and roof diaphragms of the 1902 and the 1931 buildings were constructed at different times and do not appear to be adequately connected. Because of the insufficient capacity to transfer the lateral loads across this connection, the diaphragms in each building will move independently during an earthquake rather than as a single continuous unit. This will, in effect, produce a plan irregularity in each of the two separate U-shaped diaphragms causing the different wings of the building to vibrate independently and at different frequencies. This vibrational difference will concentrate damage at the inside corners of the building.

- The existing straight sheathing at the roof structures of the two portions of the building consists of 1x6 sheathing boards on the wood roof joists. This straight sheathing does not have sufficient shear capacity to resist the shear forces required by the UBC for seismic zone 3.

Since the first seismic design for buildings was required under the 1958 Uniform Building Code, this building is considered substandard. It is located in UBC earthquake Zone 3 on S1 soil.

Seismic Rehabilitation

Two rehabilitation options were considered for the building. The most economical option is a $2.2 million shear wall retrofit to increase the lateral strength of the building. A $4.5 million base isolation project was rejected as too expensive.

Building Mean Damage Functions

The mean damage functions for the Butte Federal Building, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines. The existing building was characterized as "standard," which means a building with typical seismic performance for this building class. The rehabilitated building under Option A (shear wall scheme) was characterized as "special," which means a building specifically designed for seismic performance. Option B (base isolation) was not analyzed, but is included for comparison to Option A.

BUILDING MEAN DAMAGE FUNCTIONS

Effective PGA		4-8	8-16	16-32	32-55	55-80	80-100	>100
MMI		VI	VII	VIII	IX	X	XI	XII
Original Building		9.0	22.6	39.5	64.7	77.1	89.4	100
Building Option A	shear wall retrofit	1.5	2.7	9.0	22.6	39.5	64.7	77.1
Building Option B	base isolation	0.5	1.0	3.0	7.0	10.0	15.0	20

Benefit-Cost Results

This example is a substantially vulnerable building (unreinforced masonry) in a moderate seismicity area. Several factors combine to produce very low benefit-cost ratios for this project. First, the rehabilitation project is very expensive - nearly 60% of the building's replacement value. Second, even though the building has major damage at higher MMI events, the damage at lower MMI events is only moderate. Thus, the potential benefits of avoiding these damage are somewhat limited. Third, the seismic risk at the site is modest, because of the location and further because of the S1 (rock) soil conditions at the site. The S1 conditions result in lower intensity ground motions than would be experienced if the building were located on a softer site.

The benefit-cost ratios for this rehabilitation project 0.13 and 0.14, without and with the value of life, respectively.

BENEFIT COST RESULTS

U.S. Federal Building 400 North Main Street Butte, MT

Facility Class: Unreinforced Masonry Bearing Wall

Project Description: Add shear walls

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$5,876	$4,870	$1,005	$67,213
Contents Damages	$3,777	$3,131	$646	$43,208
Relocation Expenses	$621	$514	$107	$7,089
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$14,869	$12,455	$2,414	$171,887
Total Damages and Losses	$25,143	$20,970	$4,173	$289,397

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $289,397

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $2,164,000

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($1,874,603)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.13

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	3.91E-03	3.52E-03	3.91E-04	$49
Serious Injuries	8.27E-04	8.19E-04	8.27E-06	$113
Deaths	2.95E-04	2.95E-04	2.95E-07	$6,914
			Total Value	$7,075

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $296,473

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: ($1,867,527)

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 0.14

Analyst: Goettel & Horner Inc.

SUMMARY	Run Identification:	Final
U.S. Federal Building	400 North Main Street	Butte, MT
Rehab Project Description:	Add shear walls	
Facility Class:	Unreinforced Masonry Bearing Wall	

Data used for this analysis:

Building Replacement Value per square foot	$70.00
Total Floor Area (square feet):	62,000
Total Building Replacement Value	$4,340,000
Demolition Threshold Damage Percentage:	100%
Total Contents Value	$2,790,000
Cost of Providing Services per day	$114,504
Continuity Premium	$0
Value of lost services per day	$114,504
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$1.00
Total Seismic Rehabilitation Costs	$2,164,000
Average Day Occupancy	285
Average Night Occupancy	10
Soil Type	S1

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	9	23	40	65	77	89	100
Modified MDF (%)	9	23	40	65	77	89	100
Minor Injury Rate/1000	1.020E+00	6.240E+00	2.460E+01	1.843E+02	2.769E+02	3.450E+02	4.000E+02
Major Injury Rate/1000	1.360E-01	8.320E-01	3.280E+00	2.457E+01	3.691E+01	2.020E+02	4.000E+02
Death Rate/1000	3.400E-02	2.080E-01	8.200E-01	6.143E+00	9.229E+00	9.550E+01	2.000E+02
Content MDF (%)	9	23	40	65	77	89	100
Functional Downtime (days)	9	23	30	30	30	30	30
Days of Relocation Necessary:	0	131	266	365	365	365	365
Building Rehab Effectiveness (%)	83	88	77	65	49	28	23
Contents Rehab Effectiveness (%)	83	88	77	65	49	28	23
Rehab Minor Injury Rate/1000	1.020E-01	6.240E-01	2.460E+00	1.843E+01	2.769E+01	3.450E+01	4.000E+01
Rehab Major Injury Rate/1000	1.360E-03	8.320E-03	3.280E-02	2.457E-01	3.691E-01	2.020E+00	4.000E+00
Rehab Death Rate/1000	3.400E-05	2.080E-04	8.200E-04	6.143E-03	9.229E-03	9.550E-02	2.000E-01
Annual Number of Earthquakes	9.415E-03	1.584E-03	2.445E-04	5.047E-05	1.278E-05	5.587E-06	7.211E-06

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$289,397	$296,473
TOTAL BENEFITS MINUS TOTAL COSTS :	($1,874,603)	($1,867,527)
Benefit cost ratio :	0.13	0.14

Analysit: Goettel & Horner Inc.

United States Federal Building
123 Fourth Street S.W., Albuquerque, NM

Function

This 56,400 square foot building is primarily courtroom and related space. Occupancy is approximately 225 during business hours.

Structural

The Court House was constructed before any seismic codes were adopted, and is located in UBC earthquake zone 2B on soil type S2. The building was constructed in two portions, with other minor alterations and small additions completed at various times during the life of the building. The original portion (the present east section) was constructed from drawings dated 1908. An addition was constructed to the west of the original building from drawings dated 1930. The present total plan dimensions of the building are approximately 165'x116'.

The concrete floor slabs, approximately 8" thick, as well as the structural steel beams and girders in the floors are supported by the unreinforced masonry bearing walls at the exterior of the building with structural concrete and steel columns, and spread footing foundations. The longitudinal and transverse lateral systems are shear walls. The roof diaphragm is wood, while the floor diaphragms are cast-in-place concrete. The roof is composed of wood joists/gluelams; the floor framing is steel beams and flat slabs.

When combined, the original 1908 building and the 1930 addition have a U-shaped floor plan at level 3, and the roof. The L-shaped floor and roof of the addition were placed against the original building for the present U-shaped floor configuration, with an opening for the lightwell in the center of the U at the northern end of the upper levels of the building. There does not appear to be any shear connection between the two separate diaphragms which would cause the two floor diaphragms to move independently during an earthquake rather than a single continuous diaphragm. The plan irregularity in the two diaphragms will generate torsional effects in the building when subjected to an earthquake. Different wings of the building can vibrate independently and at different frequencies, leading to a concentration of damage at the re-entrant corners of the lightwell walls. Floor diaphragms and unreinforced masonry walls are especially prone to damage in these areas. Because the two separate diaphragms meet at one of the re-entrant corners of the U-shaped diaphragm, and the diaphragms are not connected together, damage will be even more severe at this area.

At the lower levels of the building the two diaphragms combine in essentially a rectangular shape, but because they lack a positive connection between the two separate diaphragms, the diaphragms can vibrate independently during an earthquake. Significant damage will most likely be experienced where the two diaphragms meet.

In general, the original 1908 building structure consists of reinforced concrete structural floor slabs supported by structural steel floor beams and girders. The concrete floor slab was cast around the structural steel beams and girders to provide support for the floor slab and fire resistance for the steel beams and girders. Drawings of the original building were quite limited, and existing finishes prevented viewing most of the existing structure without demolition, so some portions of the existing structure remain unknown. In two or three locations a small area of the concrete cover had been removed and the steel beams were visible.

Field investigation where pipes penetrate the concrete floor slabs indicate the floor slabs are reinforced with expanded metal in the bottom of the slabs. The individual thicknesses of the structural slab and topping slab were not possible to measure and are not known.

The concrete floor slabs as well as the structural steel beams and girders in the floors are supported by the unreinforced masonry bearing walls at the exterior of the building and structural steel.

There is a soft story below level 2 due to the light well and discontinuous walls.

Seismic Evaluation

A seismic structural evaluation and analysis was completed on May 24, 1993 and listed the following structural deficiencies:

- The unreinforced masonry bearing walls are inadequate to resist the seismic forces for seismic Zone 2B which are mandated by the 1991 UBC.
- Due to the non-existent reinforcement, the masonry bearing walls in this building lack the ductility required under the 1991 UBC for modern structures.
- A soft-story problem exists below level 2 due to the discontinuity of the existing unreinforced masonry walls at

the north lightwell below this level. The discontinuity has the tendency to stiffen the building in the upper stories creating an abrupt change at this level. This tends to cause more severe earthquake damage and increase the potential for collapse at the soft story level.

- Many of the unreinforced masonry walls consist of a series of piers between window openings which, because they are unreinforced, lack the boundary steel to develop their limited in plane shear capacity and resist rocking.

- The unreinforced masonry bearing walls on the exterior of the building are inadequately anchored to the structure. Since these walls support the floor and roof structure total or partial collapse of the masonry bearing walls will create a falling hazard to occupants in the building and people on the sidewalks, in the alley, and other areas adjacent to the building.

- The floor and roof diaphragms of the 1908 building and the 1930 addition building were constructed at different times and do not appear to be adequately connected. Because of the insufficient capacity to transfer the lateral loads across this connection, the diaphragms in each building will move independently during an earthquake rather than as a single continuous unit. This will in effect, produce a plan irregularity in each of the two separate diaphragms causing the different wings of the building to vibrate independently and at different frequencies which will lead to concentrated damage at the inside corners of the building.

- The existing straight sheathing at the roof structures of the two portions of the building consists of 1x6 sheathing boards on the wood roof joists. This straight sheathing does not have sufficient shear capacity to resist the shear forces required by the UBC for seismic Zone 2B.

The building is located in UBC seismic Zone 2B. Structural seismic assessment of the building based on the 1991 UBC indicated a poor seismic rating. The structure has a fairly high probability of partial or total collapse if an earthquake producing ground motions consistent with seismic Zone 2B occurs near Albuquerque. The building has significantly less than 80 percent of the base shear capacity required for new construction. During a large seismic disturbance, this structure would perform poorly due to the overstress created in the unreinforced masonry shear walls and the lack of ductility in the walls. There could be extensive structural and nonstructural damage, potential structural collapse, and/or falling hazards. Smaller earthquakes centered near the site could have the same effects as a very large, more distant earthquake.

The building structure does not meet the current code requirements for wall reinforcement and has limited strength to resist the minimum code earthquake forces for seismic Zone 2B. Experience has shown that for a small (Richter Magnitude 5.0 or less) earthquake centered some distance from the site, the limited shear wall capacity in the unreinforced masonry bearing walls should be adequate. Earthquakes as low as approximately Richter magnitude 5.5 that are centered close to the site could cause significant damage to the building.

This building is especially vulnerable to the effects of earthquakes and the resultant falling hazards: there is concern for the ability of the building systems to provide safe egress to occupants.

Following a major earthquake, it is expected that there would be considerable damage, but if the suggested remedial measures outlined are taken, the potential number of injuries and deaths associated with non-structural items will have been greatly reduced.

Seismic Rehabilitation

Two rehabilitation schemes were considered for this building, considered substandard in its original condition: the addition of new concrete shear walls for the full height of the building, costing $1.3 million (option A); and base isolation costing $4.5 million (option B) in 1993. The cost to mitigate non-structural hazards was estimated at approximately $146,000. The base isolation scheme was deemed too expensive. Therefore, we evaluate the shear wall scheme with a total construction cost of about $1.46 million. Including relocation costs of about $225,000, the total cost of this rehabilitation is approximately $1.7 million.

Option A (shear walls) would require addition of reinforced concrete shear walls to the inside of the exterior masonry walls at selected locations, connecting the two segments of the building at the interface, placing new footings at the shear walls, anchor exterior walls, and add seismic chords.

Building Mean Damage Functions

The mean damage functions for the Albuquerque Federal Building, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines. The existing building was characterized as "standard," which means a building with typical seismic performance for this building class. The rehabilitated building under Option A (shear wall scheme) was characterized as "special," which means a building specifically designed for seismic performance.

Option B (base isolation) was not analyzed, but is included for comparison to Option A.

BUILDING MEAN DAMAGE FUNCTION

	Effective PGA	4-8	8-16	16-32	32-55	55-80	80-100	>100
	MMI	VI	VII	VIII	IX	X	XI	XII
Existing Building		9.0	22.6	39.5	64.7	77.1	89.4	100
Building Option A	Shear wall rehab	1.5	2.7	9.0	22.6	34.5	64.7	77.1
Building Option B	Base Isolation	0.5	1.0	3.0	7.0	10.0	15.0	20.0

Benefit-Cost Results

This example is a substantially vulnerable building (unreinforced masonry) in a moderate seismicity area. Several factors combine to produce moderately low Benefit-Cost ratios for this project. First, the project is moderately expensive, approximately 40% of the building's replacement value. Second, seismic risk at this site is relatively low. Third, the damage percentages at lower MMIs, where earthquake probabilities are comparatively high, are only moderate.

Thus, the Benefit-Cost ratios for this project are 0.43 and 0.43 without and with the value of life, respectively. The value of casualties avoided is too small to significantly change the Benefit-Cost ratio.

The Benefit-Cost ratios for this Albuquerque project are significantly higher than those for the Butte project because of the higher seismic risk, the S2 soil type compared to S1 at Butte, and because the rehabilitation costs are a lower percentage of replacement value.

BENEFIT COST RESULTS

U.S. Federal Building 123 Fourth Street, SW Albuquerque, NM

Facility Class: Unreinforced Masonry Bearing Wall

Project Description: Add shear walls

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$14,810	$12,337	$2,473	$170,262
Contents Damages	$8,886	$7,402	$1,484	$102,157
Relocation Expenses	$1,481	$1,236	$245	$17,060
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$37,261	$31,263	$5,999	$431,448
Total Damages and Losses	$62,439	$52,238	$10,201	$720,926

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $720,926

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $1,685,600

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($964,674)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.43

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	7.29E-03	6.56E-03	7.29E-04	$91
Serious Injuries	1.25E-03	1.23E-03	1.25E-05	$170
Deaths	3.91E-04	3.90E-04	3.91E-07	$9,153
			Total Value	$9,414

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $730,341

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: ($955,259)

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 0.43

Analyst: Goettel & Horner Inc.

SUMMARY

Run Identification: Final

U.S. Federal Building	123 Fourth Street, SW	Albuquerque, NM
Rehab Project Description:	Add shear walls	
Facility Class:	Unreinforced Masonry Bearing Wall	

Data used for this analysis:

Building Replacement Value per square foot	$75.00
Total Floor Area (square feet):	56,400
Total Building Replacement Value	$4,230,000
Demolition Threshold Damage Percentage:	100%
Total Contents Value	$2,538,000
Cost of Providing Services per day	$110,400
Continuity Premium	$0
Value of lost services per day	$110,400
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$1.00
Total Seismic Rehabilitation Costs	$1,685,600
Average Day Occupancy	225
Average Night Occupancy	10
Soil Type	S2

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	9	23	40	65	77	89	100
Modified MDF (%)	9	23	40	65	77	89	100
Minor Injury Rate/1000	1.020E+00	6.240E+00	2.460E+01	1.843E+02	2.769E+02	3.450E+02	4.000E+02
Major Injury Rate/1000	1.360E-01	8.320E-01	3.280E+00	2.457E+01	3.691E+01	2.020E+02	4.000E+02
Death Rate/1000	3.400E-02	2.080E-01	8.200E-01	6.143E+00	9.229E+00	9.550E+01	2.000E+02
Content MDF (%)	9	23	40	65	77	89	100
Functional Downtime (days)	9	23	30	30	30	30	30
Days of Relocation Necessary:	0	131	266	365	365	365	365
Building Rehab Effectiveness (%)	83	88	77	65	49	28	23
Contents Rehab Effectiveness (%)	83	88	77	65	49	28	23
Rehab Minor Injury Rate/1000	1.020E-01	6.240E-01	2.460E+00	1.843E+01	2.769E+01	3.450E+01	4.000E+01
Rehab Major Injury Rate/1000	1.360E-03	8.320E-03	3.280E-02	2.457E-01	3.691E-01	2.020E+00	4.000E+00
Rehab Death Rate/1000	3.400E-05	2.080E-04	8.200E-04	6.143E-03	9.229E-03	9.550E-02	2.000E-01
Annual Number of Earthquakes	2.429E-02	4.157E-03	7.117E-04	1.100E-04	2.276E-05	6.179E-06	8.076E-06

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$720,926	$730,341
TOTAL BENEFITS MINUS TOTAL COSTS :	($964,674)	($955,259)
Benefit cost ratio :	0.43	0.43

Analyst: Goettel & Horner Inc.

Jackson Federal Building
915 Second Avenue, Seattle, WA 98174

Function

This 315,000 square foot building contains offices for approximately 25 Federal agencies. Occupancy is approximately 3200 during business hours.

Structural

The Jackson Federal building is a nine story office building constructed in the early 1930s. The first three floors, sub-basement, basement, and the first floor are full floors covering the site, floors two through five are U-shaped, and floors six through nine form a tower. Replacement value is estimated at approximately $35 million.

The original building contained timber pilings in the foundation system with poured-in-place concrete floor joists. Concrete slabs were poured on clay tiles, perimeter steel beams encased in concrete, and brick encased vertical steel columns were located at the perimeter. The exterior system of the building consists of brick, CMU, aluminum spandrel panels with brick backing, and terra cotta. The roof consists of concrete joists with steel girders. Diaphragms are cast-in-place concrete. The longitudinal and transverse lateral systems are shear walls.

Seismic Evaluation

A seismic structural evaluation and analysis was completed on November 23, 1987 and listed the following structural deficiencies:

- The exterior masonry walls were overstressed and would be expected to resist the seismic forces before the steel frame.
- The corners of the building need to be tied together to transfer diaphragm forces into the shear walls.
- Parapets range from 4 to 11 feet in height and are constructed of unreinforced masonry and terra cotta ornamentation.
- The exterior of the building is faced with brick and terra cotta ornaments that are not adequately anchored to prevent a falling hazard.

The building is located in UBC seismic Zone 3, located on S-3 soil type. The potential exists for a large amount of structural and non-structural damage from a large scale earthquake. The parapets and building facing represent serious falling hazards.

This building has experienced two moderate earthquakes in 1949 and 1965 with relatively little damage and no visible structural damage.

Seismic Rehabilitation

Complete rehabilitation was undertaken, consisting of the following: complete renovation of interior spaces with main hallways staying historical full height. Concrete shear walls were added. The historical exterior had only risk reduction, with anchors and straps added to reduce falling hazards. Entirely new mechanical, electrical, and plumbing systems were installed. The building was brought into general compliance with the 1988 UBC for Zone 3. Structural costs for the project were estimated at about $2.1 million in 1990, with total construction costs, including complete interior renovation, at $17 million.

Approximately 50% of the total construction costs are attributable to seismic rehabilitation. The other 50% is for interior renovation, including upgrades to the mechanical and electrical systems, and asbestos abatement. Therefore, for the benefit-cost analysis a construction cost of $8.5 million was assumed. Relocation costs add another $3.8 million, so the total cost of the seismic rehabilitation is estimated at $12.3 million.

Building Mean Damage Functions

The mean damage functions for the Jackson Federal Building, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines. The existing building was characterized as "standard," which means a building with typical seismic performance. The rehabilitated building was characterized as "special," which means a building specifically designed for seismic performance.

BUILDING MEAN DAMAGE FUNCTIONS

	Effective PGA	4-8	8-16	16-32	32-55	55-80	80-100	>100
	MMI	VI	VII	VIII	IX	X	XI	XII
Original Building		1.5	5.7	16.1	30.8	44.9	66.1	90.0
Rehabilitated Building	Shear wall rehab	1.0	1.5	5.7	16.1	30.8	44.9	66.1

Benefit-Cost Results

The Benefit-Cost ratios for this rehabilitation project are 0.31 and 0.32 without and with the value of life, respectively. These relatively low values arise from the moderate seismicity of the Seattle area, the fact that this steel framed building is only moderately vulnerable to seismic damage, and because the rehabilitation costs are relatively high (approximately 35% of the replacement value of the building).

BENEFIT COST RESULTS

U.S. Federal Building 915 Second Ave Seattle, WA 98174

Facility Class: Steel Frame with URM Infill

Project Description: Shear wall retrofit

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$141,678	$100,731	$40,947	$1,390,162
Contents Damages	$90,159	$64,102	$26,057	$884,649
Relocation Expenses	$18,081	$8,654	$9,428	$119,426
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$140,678	$103,101	$37,577	$1,422,865
Total Damages and Losses	$390,596	$276,587	$114,009	$3,817,101

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $3,817,101

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $12,280,000

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($8,462,899)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.31

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	1.21E-01	1.09E-01	1.21E-02	$1,503
Serious Injuries	1.61E-02	1.60E-02	1.61E-04	$2,205
Deaths	4.03E-03	4.03E-03	4.03E-06	$94,554
			Total Value	$98,262

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $3,915,363

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: ($8,364,637)

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 0.32

Analyst: Goettel & Horner Inc.

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SUMMARY	Run Identification:	Final

U.S. Federal Building	915 Second Ave	Seattle, WA 98174
Rehab Project Description:	Shear wall retrofit	
Facility Class:	Steel Frame with URM Infill	

Data used for this analysis:

Building Replacement Value per square foot	$110.00
Total Floor Area (square feet):	315,000
Total Building Replacement Value	$34,650,000
Demolition Threshold Damage Percentage:	100%
Total Contents Value	$22,050,000
Cost of Providing Services per day	$359,628
Continuity Premium	$0
Value of lost services per day	$359,628
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$2.00
Total Seismic Rehabilitation Costs	$12,280,000
Average Day Occupancy	3,200
Average Night Occupancy	50
Soil Type	S3

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	2	6	16	21	45	66	78
Modified MDF (%)	2	6	16	21	45	66	78
Minor Injury Rate/1000	9.750E-02	4.800E-01	2.280E+00	4.080E+00	3.000E+01	1.920E+02	2.846E+02
Major Injury Rate/1000	1.300E-02	6.400E-02	3.040E-01	5.440E-01	4.000E+00	2.560E+01	3.794E+01
Death Rate/1000	3.250E-03	1.600E-02	7.600E-02	1.360E-01	1.000E+00	6.400E+00	9.486E+00
Content MDF (%)	2	6	16	21	45	66	78
Functional Downtime (days)	2	6	16	21	30	30	30
Days of Relocation Necessary:	0	0	79	116	309	365	365
Building Rehab Effectiveness (%)	100	73	65	23	31	32	15
Contents Rehab Effectiveness (%)	100	73	65	23	31	32	15
Rehab Minor Injury Rate/1000	9.750E-03	4.800E-02	2.280E-01	4.080E-01	3.000E+00	1.920E+01	2.846E+01
Rehab Major Injury Rate/1000	1.300E-04	6.400E-04	3.040E-03	5.440E-03	4.000E-02	2.560E-01	3.794E-01
Rehab Death Rate/1000	3.250E-06	1.600E-05	7.600E-05	1.360E-04	1.000E-03	6.400E-03	9.486E-03
Annual Number of Earthquakes	7.790E-02	2.161E-02	6.335E-03	1.356E-03	3.014E-04	1.019E-04	1.994E-04

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$3,817,101	$3,915,363
TOTAL BENEFITS MINUS TOTAL COSTS :	($8,462,899)	($8,364,637)
Benefit cost ratio :	0.31	0.32

Analysit: Goettel & Horner Inc.

TEAD Motor Pool Facility Bldg. No. 158
Tooele Army Depot, Utah 84074

Function

This 6936 square foot wood frame building, built in 1942 as a barracks and later converted to provide office space plus temporary housing, was vacant as of December 1991.

Structure

This building, classified as type W-1 (light wood frame), is a two-story structure measuring 104'x29.5'. The building contains many closely spaced partition walls with gypsum board sheathing in both the crosswise and lengthwise directions of the building. These walls provide significant strength and rigidity to the structure even though many of them do not extend to the building foundations.

The first floor is constructed over a crawl space, approximately 2-4 feet above the existing grade. The first floor is constructed of 2x8 wood joists spaced at 24", bearing on beams composed of 3 - 2x12s spiked together, supported by concrete piers bearing on spread type footings. On top of the joists is 1x8 nominal diagonal wood sheathing which provides a nominal horizontal diaphragm.

The second floor is constructed of 2x8 wood joists spaced at 24", which bear on 2x4 wood stud walls. The wood stud walls bear directly on the 2x8 wood joists of the first level floor and do not align with the 3 - 2x12 beams below. This floor also has a 1x8 nominal diagonal nominal wood sheathing diaphragm.

The roof is 2x6 wood rafters spaced at 24" which bear on the exterior walls at the exterior walls and on 2x4 cripple walls parallel to the center corridor. The cripple walls bear directly on 2x6 ceiling joists spaced at 24" and are offset from the corridor walls below. The roof rafters are covered with 1x8 straight sheathed wood planks which form a nominal diaphragm.

The exterior walls are constructed of 2x4 studs spaced at 24" with a 1x8 nominal horizontal wood sheathing. The building has many non-bearing interior walls constructed of 2x4 wood stud walls with gypsum board sheathing. These walls contribute greatly to the lateral rigidity of the structure even though most of them do not connect to the building foundations.

Concrete foundation walls are located at each end of the building. These walls are continuous for the full width of the building and return approximately 5' around the corner at each end. Concrete walls also exist around the mechanical room and the stair towers. The remainder of the perimeter and interior of the building is supported on concrete piers with limited lateral force resisting strength.

Seismic Evaluation

The following existing structural deficiencies affecting the capacity of the lateral system of the building were found:

- Connections between the wood beams and the concrete foundation walls are incapable of transferring the tension and compression "drag strut" forces to the concrete foundation walls.
- The building superstructure is not adequately attached to the foundation walls to transfer the shear forces between the wood stud walls and the concrete foundation walls.
- The existing roof and floor diaphragms exceed the maximum allowable width to length ratios. Interior shear walls must be used to reduce the length to width ratios.
- The existing shear walls do not have the required shear capacity to safely resist the current design forces according to the 1982 TM 5-809-0 "Seismic Design for Buildings".
- The roof diaphragm does not have the required shear capacity to safely resist the 1982 design forces.
- The ends of the shear walls are not adequately attached to the foundation walls for hold down forces to keep the walls from overturning.

To attain near-code compliance level of performance, the roof and shear walls will require installation of plywood to develop the required shear transfer forces. Additional hold-down anchors will be required to anchor the shear walls to the concrete foundations and to provide tension capacity of the walls between the first and second levels.

Seismic Rehabilitation

Although a number of deficiencies have been found in this building, wood structures of this type have generally performed well during earthquakes. ATC-14 states "Wood framed buildings generally do not pose a significant life safety threat during seismic events except in rare cases. But, building contents may be badly shaken. " The recommended measures would not bring the building completely up to current code requirements, but rather would increase the performance of the building and maintain a "life safety" level of performance.

The addition of small corrective measures to structures can increase the lateral resistance greatly, whereas additional expenditures beyond the initial measure achieve diminished effects.

To attain a minimum "life safety" level of performance, additional concrete footings and foundation walls, and additional bolts between the existing superstructure and the existing foundation walls should be installed. In 1991, rehabilitation costs to achieve a life safety level of performance were estimated at $41,000.

To attain near-code compliance level of performance, the roof and shear walls will require installation of plywood to develop the required shear transfer forces. Additional hold-down anchors will be required to anchor the shear walls to the concrete foundations and to provide tension capacity of the walls between the first and second levels. In 1991, rehabilitation costs to achieve a near-code compliance level of performance were estimated at $109,000.

Building Mean Damage Functions

The mean damage functions for the TEAD Motor Pool Building, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines. The existing building was characterized as "non-standard," which means a building with substantially poorer than typical seismic performance. For the life-safety rehabilitation, the rehabilitated building was characterized as "standard" which means a building with typical seismic performance for this type of building. For the near code rehabilitation, the rehabilitated building was characterized as "special" which means a building with seismic performance similar to a building specifically designed for seismic performance.

The benefit-cost analysis was performed for Option A, life-safety, information on Option B, near-code performance, is included for reference.

BUILDING MEAN DAMAGE FUNCTIONS

	Effective PGA	4-8	8-16	16-32	32-55	55-80	80-100	>100
	MMI	VI	VII	VIII	IX	X	XI	XII
Original Building		4.7	9.2	19.8	24.4	37.3	60	90
Option A	Life Safety	.8	1.5	4.7	9.2	19.8	24.4	37.3
Option B	Near-Code	0	0	.8	1.5	4.7	9.2	19.8

Benefit-Cost Results

The Benefit-Cost ratio for this rehabilitation project is quite low, 0.20 with and without the value of life. Because the building is vacant, there is no value in avoided casualties. The Benefit-Cost ratio is low because of the relatively low seismicity at the site and because this wood frame structure is not nearly as seismically vulnerable as some other building classes would be.

However, the rehabilitation of this building is relatively inexpensive (only about 12% of the building replacement value) and quite effective in reducing seismic damages. If the building were occupied, and especially if the building function had a high post-earthquake continuity premium, the Benefit-Cost ratio for this rehabilitation could be much higher.

BENEFIT COST RESULTS

TEAD Motor Pool Facility Tooele Army Depot Tooele, UT 84074

Facility Class: Wood (commercial or industrial)

Project Description: Shear walls and hold-down anchors

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$632	$518	$113	$7,154
Contents Damages	$63	$52	$11	$714
Relocation Expenses	$0	$0	$0	$0
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$12	$10	$2	$137
Total Damages and Losses	$707	$580	$127	$8,004

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $8,004

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $40,960

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($32,956)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.20

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	0.00E+00	0.00E+00	0.00E+00	$0
Serious Injuries	0.00E+00	0.00E+00	0.00E+00	$0
Deaths	0.00E+00	0.00E+00	0.00E+00	$0
			Total Value	$0

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $8,004

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: ($32,956)

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 0.20

Analyst: Goettel & Horner Inc.

SUMMARY	Run Identification:	Final
TEAD Motor Pool Facility	Tooele Army Depot	Tooele, UT 84074
Rehab Project Description:	Shear walls and hold-down anchors	
Facility Class:	Wood (commercial or industrial)	

Data used for this analysis:

Building Replacement Value per square foot	$50.00
Total Floor Area (square feet):	6,936
Total Building Replacement Value	$346,800
Demolition Threshold Damage Percentage:	50%
Total Contents Value	$34,680
Cost of Providing Services per day	$67
Continuity Premium	$0
Value of lost services per day	$67
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$0.00
Total Seismic Rehabilitation Costs	$40,960
Average Day Occupancy	0
Average Night Occupancy	0
Soil Type	S2

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	5	9	20	24	37	42	55
Modified MDF (%)	5	9	20	24	37	42	100
Minor Injury Rate/1000	3.000E-02	1.020E-01	3.000E-01	7.320E-01	2.136E+00	2.676E+00	1.071E+01
Major Injury Rate/1000	4.000E-03	1.360E-02	4.000E-02	9.760E-02	2.848E-01	3.568E-01	1.429E+00
Death Rate/1000	1.000E-03	3.400E-03	1.000E-02	2.440E-02	7.120E-02	8.920E-02	3.571E-01
Content MDF (%)	5	9	20	24	37	42	55
Functional Downtime (days)	5	9	20	24	30	30	30
Days of Relocation Necessary:	0	0	0	0	0	0	0
Building Rehab Effectiveness (%)	83	83	76	62	47	42	63
Contents Rehab Effectiveness (%)	83	83	76	62	47	42	63
Rehab Minor Injury Rate/1000	3.000E-03	1.020E-02	3.000E-02	7.320E-02	2.136E-01	2.676E-01	1.071E+00
Rehab Major Injury Rate/1000	4.000E-05	1.360E-04	4.000E-04	9.760E-04	2.848E-03	3.568E-03	1.429E-02
Rehab Death Rate/1000	1.000E-06	3.400E-06	1.000E-05	2.440E-05	7.120E-05	8.920E-05	3.571E-04
Annual Number of Earthquakes	2.546E-02	4.474E-03	7.864E-04	1.246E-04	2.626E-05	7.217E-06	9.620E-06

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$8,004	$8,004
TOTAL BENEFITS MINUS TOTAL COSTS :	($32,956)	($32,956)
Benefit cost ratio :	0.20	0.20

Analysit: Goettel & Horner Inc.

Building 271
Mare Island Navy Shipyard, Vallejo, CA 94592

Function

The primary use of this building, part of the Nuclear Facility Storage Complex, is to process and maintain refueling equipment, storage, and process waste. Occupancy during business hours is approximately 40.

Structure

This 53,720 sq. ft. building, approximately 340'x106, was constructed in 1917 with two mezzanine levels (26'x340') and a crane bay. In some places the structure reaches 84' in height. This steel-braced frame (S2) structure was valued at $9.6 million in 1983.

This steel-braced frame building is built on a spread footing foundation, with cast-in-place concrete diaphragms. The exterior non-load bearing cladding is industrial glass and metal. The longitudinal lateral system is braced frames; the transverse lateral system is truss and columns. Special features include 7 roof monitors in 13 bays. The concrete roof slab is supported on roof trusses 10' deep; there is one-way frame action and vertical X-bracing.

The original structure was designed to have five bays, each 25 ft. long, but was extended to thirteen bays, each 25 ft. long plus a 15 ft. end. The second mezzanine was added below the first, and newer bridge cranes installed.

Seven of the 13 bays are 10 ft. higher than the others, forming roof monitors. The distance to the top of the monitor along the south and north walls are approximately 84 and 78 feet six inches above ground level, respectively.

Supporting the concrete slab roof are 10-ft.-deep steel trusses spanning 80 and 26 ft. The top chord of the steel trusses supports the roof of the monitor, the bottom chord of the steel trusses support the roof valley between the monitors.

Each of the typical 14 transverse bents is made up of three lines of columns and provides support for the roof truss system and the mezzanines. The two southerly rows of columns also support the crane girders for the 80-ton bridge crane. All three columns in each bent are fixed at the foundation level.

The main lateral load-resisting system in the building's transverse direction is the frame made up of fixed based columns and roof truss. In the longitudinal direction, the main lateral load-resisting system is the vertical cross-bracing. system.

Seismic Evaluation

This structure is located in UBC Zone 4, on an unknown soil type. Given the location of the building, the structure is probably on fill and, therefore, S4 soil type was assumed. The building's lateral bracing system was judged inadequate to resist Zone 4 force levels.

Seismic Rehabilitation

The rehabilitation consists of strengthening four of the six sets of existing bracing; welding additional steel onto existing bracing members; and improving connections. The rehabilitation objective was damage control. The total cost of the seismic structural modifications was estimated at $271,000 in 1983. Relocation costs for this project are estimated at $215,000, bringing the total project costs to $486,000.

Building Mean Damage Functions

The mean damage functions for Mare Island Building 271, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines. The existing building was characterized as "non-standard," which means a building with substantially poorer than typical seismic performance. The rehabilitated building was characterized as "standard" which means a building with typical seismic performance for this type of building. It should be noted that this type of building, braced steel frame, has much better seismic performance than other types such as unreinforced masonry. Thus, the percentages of expected damages shown below are relatively low for low-to-moderate intensities of ground shaking.

BUILDING MEAN DAMAGE FUNCTIONS

	Effective PGA	4-8	8-16	16-32	32-55	55-80	80-100	>100
	MMI	VI	VII	VIII	IX	X	XI	XII
Original Building		0.8	5.1	10.1	15.8	27.0	38.8	60.0
Rehabilitated Building	Strengthen Bracing	.6	1.8	5.1	10.0	15.8	27.0	38.8

Benefit-Cost Results

The Benefit-Cost ratio for this project is very high, 4.16 with and without the value of life, even though this steel frame building is not exceptionally vulnerable to seismic damage. The high ratio arises in part because of the high seismicity and S4 soil type. In addition, however, the project cost is low (only 5% of the building replacement value). Benefits are also high because the value of contents in this building is exceptionally high.

BENEFIT COST RESULTS

Building 271 Mare Island Navy Shipyard Vallejo, CA

Facility Class: Steel Braced Frame

Project Description: Modify existing frames

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$57,679	$34,189	$23,490	$471,834
Contents Damages	$150,299	$89,036	$61,263	$1,228,759
Relocation Expenses	$5,208	$2,369	$2,839	$32,700
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$34,994	$20,741	$14,253	$286,241
Total Damages and Losses	$248,180	$146,335	$101,845	$2,019,535

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $2,019,535

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $485,880

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: $1,533,655

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 4.16

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	8.36E-04	7.52E-04	8.36E-05	$10
Serious Injuries	1.11E-04	1.10E-04	1.11E-06	$15
Deaths	2.79E-05	2.78E-05	2.79E-08	$653
			Total Value	$679

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $2,020,214

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: $1,534,334

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 4.16

Analyst: Goettel & Horner Inc.

SUMMARY

SUMMARY	**Run Identification:**	**Final**
Building 271	Mare Island Navy Shipyard	Vallejo, CA
Rehab Project Description:	Modify existing frames	
Facility Class:	Steel Braced Frame	

Data used for this analysis:

Building Replacement Value per square foot	$179.00
Total Floor Area (square feet):	53,720
Total Building Replacement Value	$9,615,880
Demolition Threshold Damage Percentage:	50%
Total Contents Value	$25,517,000
Cost of Providing Services per day	$9,967
Continuity Premium	$50,000
Value of lost services per day	$59,967
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$4.00
Total Seismic Rehabilitation Costs	$485,880
Average Day Occupancy	40
Average Night Occupancy	1
Soil Type	S4

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	2	5	10	16	27	39	51
Modified MDF (%)	2	5	10	16	27	39	100
Minor Injury Rate/1000	9.750E-02	3.000E-01	1.200E+00	2.280E+00	1.056E+01	2.352E+01	7.629E+01
Major Injury Rate/1000	1.300E-02	4.000E-02	1.600E-01	3.040E-01	1.408E+00	3.136E+00	1.017E+01
Death Rate/1000	3.250E-03	1.000E-02	4.000E-02	7.600E-02	3.520E-01	7.840E-01	2.543E+00
Content MDF (%)	2	5	10	16	27	39	51
Functional Downtime (days)	2	5	10	16	27	30	30
Days of Relocation Necessary:	0	0	30	77	166	260	365
Building Rehab Effectiveness (%)	66	64	49	36	41	30	61
Contents Rehab Effectiveness (%)	66	64	49	36	41	30	61
Rehab Minor Injury Rate/1000	9.750E-03	3.000E-02	1.200E-01	2.280E-01	1.056E+00	2.352E+00	7.629E+00
Rehab Major Injury Rate/1000	1.300E-04	4.000E-04	1.600E-03	3.040E-03	1.408E-02	3.136E-02	1.017E-01
Rehab Death Rate/1000	3.250E-06	1.000E-05	4.000E-05	7.600E-05	3.520E-04	7.840E-04	2.543E-03
Annual Number of Earthquakes	1.229E-01	3.558E-02	1.125E-02	2.333E-03	5.876E-04	1.075E-04	2.192E-04

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$2,019,535	$2,020,214
TOTAL BENEFITS MINUS TOTAL COSTS :	$1,533,655	$1,534,334
Benefit cost ratio :	4.16	4.16

Analysit: Goettel & Horner Inc.

Building 678, Special Weapons Training Facility U.S. Navy, North Island, San Diego, CA

Function

This approximately 64,500 square foot building is part of the Special Weapons Training Center at North Island, in San Diego, California. Occupancy during business hours is approximately 130.

Structure

This 2-story structure, originally constructed in 1958, consists of three structures in an "H" shape. The three parts of the building are separated by 4 1/2 inch expansion joints.

The building was constructed of precast concrete tilt-up walls (building type PC1), with steel roof beams and flat slab floors. Diaphragms are cast-in-place concrete; columns are steel, with precast concrete bearing walls on spread footing foundations. The longitudinal and transverse lateral systems are shear walls. Overall, the condition of the building appeared good without signs of extreme weathering, damage, or cracking.

Seismic Evaluation

The three structures were analyzed separately using the equivalent lateral force procedure (Chapter 4 of ATC-3). The detailed seismic analysis of each structure indicated that the basic shear strength and interconnection of the exterior panels for in-plane loads were adequate. However, the following seismic deficiencies were noted:

- The connections of the tilt-up walls to the floor and roof diaphragms at the ground, second, and roof levels were inadequate. The problem occurred at a variety of locations for both in-plane shear loads delivered from the diaphragm and out-of-plane tension loads due to perpendicular forces.
- The connections between the precast walls and second floor diaphragms were inadequate to resist the out-of-plane bending due to diaphragm deflections.
- The interior masonry walls were not anchored to the floor or structure above and therefore subject to sliding. Additionally, the bending strength in the walls was insufficient for perpendicular loads if the bases and tops were anchored.

Seismic Rehabilitation

The proposed rehabilitation scheme consists of strengthened foundations and wall ties anchored at the floor and roof, while interior partitions would be strengthened and braced, with additional shear walls. The anticipated structural cost in 1981 was about $2.6 million. The objective of the rehabilitation is damage control.

Because the tilt-up concrete panels have sufficient vertical and lateral load strength, it appeared that the best way to correct the connection deficiency was to add new connections. The walls should be reconnected to the roof diaphragm with through-bolts welded to flat plates which are connected to the metal decking. At the ground level, continuous 6x6 angles should be bolted to the tilt-up panels and the continuous foundations.

To correct the diaphragm inadequacies and limit the overall diaphragm deflection, additional interior shear walls should be installed, two walls in the east and west units, and an additional wall at the approximate center of the building in the center unit.

Building Mean Damage Functions

The mean damage functions for Building 678, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines, in conjunction with engineering analysis performed by Degenkolb Structural Engineers. The existing building was characterized as "standard" which means a building with typical seismic performance for this building type. For the rehabilitated building, a building-specific estimate of the mean damage function was made, based on available engineering information.

BUILDING MEAN DAMAGE FUNCTIONS

Effective PGA		4-8	8-16	16-32	32-55	55-80	80-100	>100
MMI		VI	VII	VIII	IX	X	XI	XII
Original Building		1.4	4.8	10.5	18.6	0.5	46.8	64.5
Rehabilitated Building	shear wall scheme	.4	1.0	2.4	5.3	9.6	15.2	23.4

Benefit-Cost Results

The structure is located on unknown soil type. For the purposes of benefit-cost analysis, the soil was assumed to be S2.

The Benefit-Cost ratio for this project is 0.18 with and without the value of life. This low ratio arises, despite the high seismicity of this location, for two main reasons. First, the mean damage function for the existing building shows only moderate seismic vulnerability, especially at low-to-moderate MMIs. Second, the cost of the rehabilitation is very high (approximately 60% of the building replacement value).

BENEFIT COST RESULTS

Building 678 | US Navy | San Diego, CA

Facility Class: Precast Concrete Tilt-up w/ Flexible Diaphragm

Project Description: Shear wall retrofit

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$33,842	$25,512	$8,330	$352,087
Contents Damages	$8,156	$6,145	$2,011	$84,803
Relocation Expenses	$4,335	$3,199	$1,135	$44,150
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$18,169	$13,691	$4,477	$188,951
Total Damages and Losses	$64,501	$48,547	$15,954	$669,990

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $669,990

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $3,796,000

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($3,126,010)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.18

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	6.12E-03	5.51E-03	6.12E-04	$76
Serious Injuries	8.16E-04	8.08E-04	8.16E-06	$112
Deaths	2.04E-04	2.04E-04	2.04E-07	$4,783
			Total Value	$4,971

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $674,961

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: ($3,121,039)

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 0.18

Analyst: Goettel & Horner Inc.

SUMMARY

SUMMARY	Run Identification:	Final
Building 678	US Navy	San Diego, CA
Rehab Project Description:	Shear wall retrofit	
Facility Class:	Precast Concrete Tilt-up w/ Flexible Diaphragm	

Data used for this analysis:

Building Replacement Value per square foot	$100.00
Total Floor Area (square feet):	64,500
Total Building Replacement Value	$6,450,000
Demolition Threshold Damage Percentage:	50%
Total Contents Value	$1,612,500
Cost of Providing Services per day	$12,579
Continuity Premium	$25,000
Value of lost services per day	$37,579
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$2.00
Total Seismic Rehabilitation Costs	$3,796,000
Average Day Occupancy	130
Average Night Occupancy	5
Soil Type	S3

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	1	5	11	19	30	47	64
Modified MDF (%)	1	5	11	19	30	47	100
Minor Injury Rate/1000	3.000E-02	3.000E-01	1.380E+00	2.820E+00	1.380E+01	4.543E+01	1.766E+02
Major Injury Rate/1000	4.000E-03	4.000E-02	1.840E-01	3.760E-01	1.840E+00	6.057E+00	2.354E+01
Death Rate/1000	1.000E-03	1.000E-02	4.600E-02	9.400E-02	4.600E-01	1.514E+00	5.886E+00
Content MDF (%)	1	5	11	19	30	47	64
Functional Downtime (days)	1	5	11	19	30	30	30
Days of Relocation Necessary:	0	0	34	99	190	324	365
Building Rehab Effectiveness (%)	72	79	77	72	68	68	77
Contents Rehab Effectiveness (%)	72	79	77	72	68	68	77
Rehab Minor Injury Rate/1000	3.000E-03	3.000E-02	1.380E-01	2.820E-01	1.380E+00	4.543E+00	1.766E+01
Rehab Major Injury Rate/1000	4.000E-05	4.000E-04	1.840E-03	3.760E-03	1.840E-02	6.057E-02	2.354E-01
Rehab Death Rate/1000	1.000E-06	1.000E-05	4.600E-05	9.400E-05	4.600E-04	1.514E-03	5.886E-03
Annual Number of Earthquakes	9.453E-02	3.039E-02	1.039E-02	2.600E-03	6.490E-04	2.345E-04	5.319E-04

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$669,990	$674,961
TOTAL BENEFITS MINUS TOTAL COSTS :	($3,126,010)	($3,121,039)
Benefit cost ratio :	0.18	0.18

Analysit: Goettel & Horner Inc.

Building 8, U.S. Coast Guard Support Station, 427 Commercial Street, Boston, MA

Function

This 196,000 square foot building is used primarily as storage/warehouse space, but also provides detention facilities, medical/dental offices, the CGES retail exchange, Group Boston and First Coast Guard District armories. On average, 50 persons are employed and/or reside in the building.

Structure

This building was constructed in approximately 1910, with 7 stories above grade, 1 story below. The building dimensions are 187'x131, and story height varies from 11' to 13'. Total height is 93'.

Diaphragms are cast-in-place concrete. There is a masonry exterior, unreinforced masonry bearing walls and pile foundations. The longitudinal and transverse lateral systems are shear walls.

Seismic Evaluation

This building was considered seismically vulnerable because of inadequate wall-diaphragm ties, numerous wall openings, and unbraced parapets. This building is constructed on S3 soil.

Seismic Rehabilitation

The rehabilitation project infilled wall openings, strengthened diaphragms by tying to walls, installed new roof diaphragms, and braced parapets. Rehabilitation is expected to provide great improvement at the lower magnitude intensities.

In 1983, the structural cost of rehabilitation was estimated at $325,000; total renovation costs, including complete interior renovation, were estimated at $2.25 million. For the purposes of benefit-cost analysis, $1.25 million was attributed to seismic work. In addition, relocation costs of $3.5 million brought the total cost to approximately $4.8 million.

Building Mean Damage Functions

The mean damage functions for Building 8, before and after rehabilitation, are shown below. The damage functions were estimated by Larry Reaveley, using ATC-36 data as guidelines. The existing building was characterized as "standard" which means a building with typical seismic performance for this building type. For the rehabilitated building, the building was characterized as "special", which means a building specifically designed to resist seismic forces.

BUILDING MEAN DAMAGE FUNCTIONS

Effective PGA		4-8	8-16	16-32	32-55	55-80	80-100	>100
MMI		VI	VII	VIII	IX	X	XI	XII
Original Building		2.7	9.0	22.6	39.5	64.7	77.1	89.4
With Rehabilitation		1.8	2.7	9.0	22.6	39.5	64.7	77.1

Benefit-Cost Results

The Benefit-Cost ratios for this project are 0.57 without and with the value of life. The number of avoided casualties is so small that it does not significantly affect the Benefit-Cost results.

Given the moderate seismicity of this location, it is somewhat surprising that the Benefit-Cost ratio is as high as 0.57. The reasons for this include the vulnerability of the existing building, and the fact that the rehabilitation project is moderate in cost (33% of the building replacement value).

BENEFIT COST RESULTS

Building 8	US Coast Guard	Boston, MA

Facility Class: Unreinforced Masonry Bearing Wall

Project Description: infill openings, tie diaphragms to walls, brace parapets, new roof dia

A. ECONOMIC PARAMETERS :

Discount Rate:	7	percent
Planning Period:	50	years
Present Value Coefficient:	13.80	

B. SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Annual Expected	Annual Avoided	Annual Residual	Present Value of Damages Avoided
Building Damages	$129,696	$102,883	$26,813	$1,419,862
Contents Damages	$90,164	$71,889	$18,276	$992,121
Relocation Expenses	$30,456	$16,660	$13,796	$229,917
Rental Income Losses	$0	$0	$0	$0
Value of Lost Services	$6,481	$5,288	$1,193	$72,980
Total Damages and Losses	$256,798	$196,720	$60,078	$2,714,880

PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED: $2,714,880

TOTAL COSTS OF THE SEISMIC REHABILITATION PROJECT: $4,778,000

TOTAL BENEFITS MINUS TOTAL COSTS WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: ($2,063,120)

BENEFIT COST RATIO WITHOUT THE VALUE OF AVOIDED INJURIES & DEATHS: 0.57

C. VALUE OF INJURIES AND DEATHS:

Value of Avoiding a Minor Injury:	$1,000
Value of Avoiding a Serious Injury:	$10,000
Statistical Value of Life:	$1,700,000

	Annual Expected Number	Annual Avoided Number	Annual Residual Number	Present Value of Damages Avoided
Minor Injuries	1.96E-02	1.77E-02	1.96E-03	$244
Serious Injuries	3.58E-03	3.55E-03	3.58E-05	$490
Deaths	1.18E-03	1.17E-03	1.18E-06	$27,561
			Total Value	$28,294

PRESENT VALUE OF TOTAL DAMAGES, ECONOMIC LOSSES, DEATHS AND INJURIES AVOIDED: $2,743,174

TOTAL BENEFITS MINUS TOTAL COSTS WITH THE VALUE OF AVOIDED INJURIES & DEATHS: ($2,034,826)

BENEFIT COST RATIO WITH THE VALUE OF AVOIDED INJURIES & DEATHS: 0.57

Analyst: Goettel & Horner Inc.

SUMMARY	Run Identification:	Final
Building 8	US Coast Guard	Boston, MA
Rehab Project Description:	infill openings, tie diaphragms to walls, brace parapets, new roof diaphragm	
Facility Class:	Unreinforced Masonry Bearing Wall	

Data used for this analysis:

Building Replacement Value per square foot	$75.00
Total Floor Area (square feet):	196,000
Total Building Replacement Value	$14,700,000
Demolition Threshold Damage Percentage:	50%
Total Contents Value	$10,407,600
Cost of Providing Services per day	$7,888
Continuity Premium	$0
Value of lost services per day	$7,888
Total Private Monthly Rental Revenue	$0
Total Relocation Costs ($/sq.ft./month):	$2.00
Total Seismic Rehabilitation Costs	$4,778,000
Average Day Occupancy	200
Average Night Occupancy	10
Soil Type	S3

Data used in this analysis that varies by MMI:

MMI	VI	VII	VIII	IX	X	XI	XII
PGA (%g)	4-8	8-16	16-32	32-55	55-80	80-100	>100
Mean Damage Function (%)	9	23	40	65	77	89	100
Modified MDF (%)	9	23	40	100	100	100	100
Minor Injury Rate/1000	1.020E+00	6.240E+00	2.460E+01	1.843E+02	2.769E+02	3.450E+02	4.000E+02
Major Injury Rate/1000	1.360E-01	8.320E-01	3.280E+00	2.457E+01	3.691E+01	2.020E+02	4.000E+02
Death Rate/1000	3.400E-02	2.080E-01	8.200E-01	6.143E+00	9.229E+00	9.550E+01	2.000E+02
Content MDF (%)	9	23	40	65	77	89	100
Functional Downtime (days)	9	23	30	30	30	30	30
Days of Relocation Necessary:	0	131	266	365	365	365	365
Building Rehab Effectiveness (%)	100	60	43	60	35	23	11
Contents Rehab Effectiveness (%)	100	60	43	60	35	23	11
Rehab Minor Injury Rate/1000	1.020E-01	6.240E-01	2.460E+00	1.843E+01	2.769E+01	3.450E+01	4.000E+01
Rehab Major Injury Rate/1000	1.360E-03	8.320E-03	3.280E-02	2.457E-01	3.691E-01	2.020E+00	4.000E+00
Rehab Death Rate/1000	3.400E-05	2.080E-04	8.200E-04	6.143E-03	9.229E-03	9.550E-02	2.000E-01
Annual Number of Earthquakes	5.315E-02	1.125E-02	2.495E-03	4.000E-04	7.180E-05	2.148E-05	3.313E-05

SUMMARY OF DAMAGES AND ECONOMIC LOSSES:

	Without Value of Life	With Value of Life
PRESENT VALUE OF TOTAL DAMAGES AND ECONOMIC LOSSES AVOIDED:	$2,714,880	$2,743,174
TOTAL BENEFITS MINUS TOTAL COSTS :	($2,063,120)	($2,034,826)
Benefit cost ratio :	0.57	0.57

Analysit: Goettel & Horner Inc.

CHAPTER 8: GLOSSARY

Avoided Future Damages and Losses
The avoided future damages and losses are the net present value of the reduced losses due to the rehabilitation project. Avoided future damages and losses reflect the extent to which the rehabilitation project is effective in reducing expected future damages and losses, and counted in the benefit-cost analysis.

Building Damages
Building damages are the expected damages to the structure as a percentage of the building's replacement value for earthquakes of each MMI or PGA range. Structural damages include both structural and non-structural elements, including mechanical, electrical, and plumbing systems but excluding the building's contents.

Contents Damages
Contents damages are the expected damages to the building's contents as a percentage of the total contents' replacement value for earthquakes of each MMI or PGA range. Contents damages include furniture, office equipment, light fixtures, flooring, and other items specific to individual tenants' usages, but exclude mechanical, electrical, and plumbing systems.

Continuity Premium
Some government services, such as emergency response or emergency medical care, may be more valuable than normal in the post-earthquake time period. A post-earthquake continuity premium is the dollar amount agencies would be willing to pay to maintain agency functions after the earthquake.

Deaths Avoided
The annual value of avoided earthquake death losses is determined by the building size, average occupancy, the change in the expected death rate between unrehabilitated and rehabilitated buildings, and the dollar value assigned to a statistical human life, approximately $1.74 million, based on several Federal Agency studies.

Default Values
Default or reference values are the estimated "typical" values "built-in" to the model which, if used, will facilitate a rough benefit-cost analysis. However, since few, if any, specific buildings are "typical" in all areas relevant to seismic rehabilitation benefit-cost analysis, applying the results of a "typical" building analysis to a specific building may yield inaccurate results.

Demolition Threshold Damage Percentage	The demolition threshold damage percentage is the level of damage (expressed as a percentage of the building's replacement value) at which the building will be demolished rather than repaired. This percentage usually varies by the type, style, and/or age of the structure.
Discount Rate	The discount rate, entered as a percentage, calculates the present value of benefits and costs which occur in the future. Increasing the discount rate lowers the present value of future benefits and lowers benefit-cost ratios. Conversely, assuming a lower discount rate raises the present value of future benefits and increases benefit-cost ratios.
Exceedance Probability	The exceedance probability is the probability of exceeding a particular value in a stated time period. For example, in a particular location there may be a 10% probability of exceeding a given PGA in 50 years.
Expected Annual Damages	The expected annual damages are the statistical average amount of damages expected from earthquakes for an "average" year at the building's site before any proposed rehabilitation project.
Expected Annual Avoided Damages	The expected annual avoided damages are the annual number of expected earthquakes multiplied by the expected effectiveness of the proposed rehabilitation project in reducing damages. Expected annual avoided damages are the expected annual **benefits** of the benefit-cost analysis.
Expected Annual Residual Damages	The expected annual residual damages are the difference between the expected annual damages and the expected annual avoided damages after rehabilitation.
Functional Downtime	Functional downtime is the time that an agency is unable to provide its services due to earthquake damage. If an agency's building is badly damaged in an earthquake, an agency would likely re-establish its function in temporary, alternate quarters, thus minimizing the loss of its function, or functional downtime.
Government Services Lost	The value of government services lost when the building becomes unusable during an earthquake are valued by estimating what an agency spends each month to provide services from a given building. This includes salaries and benefits, utilities and other non-wage operating costs, and either rent or a rent-proxy (if the building is agency-owned). This method is known as Quasi-Willingness-to-Pay (**QWTP**).

Major Injuries	Major injuries are defined as those which require hospitalization. The default average value for major injuries included in the benefit-cost model is $10,000.
Mean Damage Function (MDF)	The mean damage function is the expected amount of damage which a particular building will sustain over the range of possible ground motions. The expected damage is listed separately by MMI and PGA bins as a percentage of building replacement value.
Minor Injuries	Minor injures are defined as those which do not require hospitalization. The default average value for minor injuries in the benefit-cost model is $1,000.
MMI bin	Modified Mercalli Intensity scale ratings, arranged in bins from I-XII. As the MMI number increases, so does the expected intensity of the shaking from an earthquake. The MMI bins, or intensity rankings, parallel the Percent of G (PGA) intervals.
Modified Mean Damage Function (MMDF)	The modified mean damage function is the expected damage to a structure (as a percentage of the building's replacement value) after including the demolition threshold damage percentage (DTDP). If the default or user-entered values are greater than the DTDP, then the benefit-cost model assumes that all values equal to or greater than the DTDP are 100%, i.e., the building will be demolished.
Net Present Value	The net present value of benefits and costs accounts for the time value of money. Dollars received in the future are worth less than dollars received immediately due to risk and uncertainty. Benefits are expected to accrue in the future. Thus, the expected net present value of a seismic rehabilitation project is the sum of the present value of net benefits expected to accrue each year over the life of the project, minus the net costs of the rehabilitation project.
PGA	Effective peak ground acceleration, or PGA, is a quantitative measure of the level of ground shaking, expressed as a percentage of g, the acceleration of gravity.
Planning Horizon	The planning horizon, or useful lifetime, of the rehabilitation project varies depending on the type of project, with 30 to 50 years being common for building projects.
Quasi-Willingness to Pay (QWTP)	For public sector buildings, the value of government services lost when the building becomes unusable during an earthquake must be included. Government services are valued using the Quasi-Willingness to Pay (**QWTP**) model. **QWTP** assumes that government services are worth what is paid to provide the services.

Rental Income Losses	Rental income losses are lost payments paid by private tenants for all or a portion of the building. Inter- or intra-agency rents within the Federal Government are **not** counted because such payments are generally transfers and their loss does not represent a true economic loss. Other private sector economic losses (such as lost wages) are not considered because they are assumed to be generally negligible for Federal Government buildings.
Relocation Expenses	Relocation expenses occur when a structure is damaged badly enough in an earthquake to require repairs before it is usable. Relocation expenses are defined as the product of relocation costs per month and the expected period for which the building will be unusable due to seismic damage.
Scenario Damages	Scenario damages are the total damages per earthquake of a given MMI (or range of effective peak ground acceleration, PGA) to the building and contents, the relocation costs, rental income losses, and the value of lost governmental services.
Soil Types	S0 - Hard rock S1 - Rock S2 - Very dense soil S3 - Stiff soil S4 - Soft soil
Spectral Acceleration	A quantitative measure of ground motion, including the frequency of motion, used in NEHRP maps.
Value of Life	The value of life is the value placed on a statistical life. A consensus value for a statistical human life is approximately $1.74 million, based on several Federal Agency studies.

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