APPENDIX 1: ECONOMIC ASSUMPTIONS AND EQUATIONS

The economic assumptions and equations which define the benefit-cost analysis of seismic rehabilitation projects are summarized in this chapter.

Benefit-Cost Model Without the Value of Life

The benefits of a hazard rehabilitation project are the avoided future damages and losses (i.e., the extent to which the rehabilitation project is effective in reducing expected future damages and losses). The net present value of benefits accounts for the time value of money, because benefits are expected to accrue in the future and dollars received in the future have a present value which is less than dollars received immediately. 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 initial cost of the rehabilitation project. The expected net present value, NPV, is defined as:

$$NPV = \frac{B_1}{1+i} + \frac{B_2}{(1+i)^2} + \ldots + \frac{B_t}{(1+i)^t} + \ldots + \frac{B_T}{(1+i)^T} - INV$$

where:

- B_t is the expected annual net benefit of the rehabilitation project for year t;
- i is the annual discount rate;
- T is the length of the planning horizon (useful life of the rehabilitation project); and
- INV is the initial investment (the cost of the project).

Each year's expected net benefit is discounted to its present value and then added together to yield the total expected net present value. 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. The discount rate corrects benefits expected in the future to their net present value.

If expected net benefits are constant each year over the life of the project, the expected net present value equation is simplified to the constant annual benefits and one discount term representing the present value for the entire planning horizon. With this simplification, the expected net present value equation is reduced to:

$$NPV = B_t \left[\frac{1-(1+i)^{-T}}{i} \right] - INV$$

This is the underlying equation which is used for the benefit cost-model in this report.

For completeness, we mention two other factors which could be included in the expected net present value calculation: the salvage value of the rehabilitation investment at the end of the planning horizon and the annual costs to maintain the effectiveness of the rehabilitation project. However, the present value of the salvage value of seismic rehabilitation projects is generally quite small, because of the long planning horizons appropriate for building projects. Similarly, the annual maintenance costs of typical seismic projects are generally negligible. Thus, in the present benefit-cost model, neither the salvage value nor the annual maintenance costs are included.

Benefit-Cost Model With the Value of Life

The benefit-cost model discussed above does not include the value of life. However, reducing the expected number of deaths and injuries is often the principal motivation for seismic hazard rehabilitation projects. The model can be modified to include the value of expected deaths avoided by retrofitting.

Benefit-cost results are always presented both with and without the value of life.

The expected net present value including the value of life is the expected net present value without the value of life, plus the present value of expected annual deaths and injuries avoided by seismic rehabilitation. The expected net present value including the value of life is thus defined as:

$$NPV^{vol} = NPV + (VDA + VIA)\left[\frac{1-(1+i)^{-T}}{i}\right]$$

where:

NPV^{vol}	is the expected net present value including the value of life;
NPV	is the expected net present value excluding the value of life;
VDA	is the annual value of expected deaths avoided;
VIA	is the annual value of expected injuries avoided;
i	is the annual discount rate; and
T	is the planning horizon.

Economic Assumptions for Modeling Benefits

Underlying Assumptions

The benefits of a seismic hazard rehabilitation project are the reduction in damages that would otherwise be expected. Expected annual benefits are defined as the sum of expected avoided damages and losses. There are three different types of damages which are considered: scenario damages, expected annual damages, and expected annual avoided damages. Definitions of these terms are:

Scenario Damages:

the expected damages 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, and

Expected Annual Avoided Damages:

the product of expected annual damages and the effectiveness of the rehabilitation measure in reducing expected damages.

A schematic example illustrating these damage terms is given below:

Table 1

Earthquake (MMI)	Scenario Damages	Annual Earthquake Probability	Expected Annual Damages	Effectiveness of Rehabilitation Measure	Expected Avoided Damages
VI	$20,000	10%	$2,000.	100%	$2,000.
VII	$25,000	5%	$1,250.	80%	$1,000.
VIII	$35,000	2%	$700.	50%	$350.
IX	$50,000	1%	$500.	25%	$125.
		Total: $4,450.		Total: $3,475.	

In this example, the scenario damages indicate the expected damages each time an earthquake of the given Modified Mercalli Intensity (MMI) occurs at the site of the building. Scenario damages may also be characterized in ranges of effective peak ground acceleration instead of or in addition to characterization by MMI. Scenario damages do **not** depend on how frequently such earthquakes are expected to occur. The annual earthquake probabilities indicate the degree of seismic risk at the specific site under consideration. The expected annual damages are the product of scenario damages and annual earthquake probability. Expected annual damages ($4,450 in this example) are the best estimate of the **average** damages per year expected at this site; such estimates do not indicate that these damages will occur every year. Expected annual damages are those **without** undertaking the rehabilitation measure. The effectiveness of the rehabilitation measure is an estimate of how much expected damages will be reduced by the rehabilitation measure under consideration. The expected avoided damages (i.e., the benefits) are the product of expected annual damages and the effectiveness of the rehabilitation measure. The expected **avoided** damages ($3,475 in this example) are thus the expected benefits of undertaking the rehabilitation measure.

Detailed Economic Assumptions and Equations Without the Value of Life

Scenario Damages

Scenario damages (SCD^{EQ}) are the sum of building damages (**BD**), contents damages (**CD**), relocation costs (**REL**), rental income losses (**RENT**), and the value of lost services (**VLS**) for earthquakes of each MMI or PGA range:

$$SCD^{EQ} = BD^{EQ} + CD^{EQ} + REL^{EQ} + RENT^{EQ} + VLS^{EQ}$$

where:

BD^{EQ}	are scenario building damages;
CD^{EQ}	are scenario contents damages;
REL^{EQ}	are scenario relocation costs;
$RENT^{EQ}$	are scenario rental income losses; and
VLS^{EQ}	is the scenario value of lost government services.

Building Damages

Building damages (BD^{EQ}) are estimated as the product of floor area of the buildings (**FA**), replacement value of the building per square foot (**RV**), and expected damage as a percentage of replacement value for earthquakes of each MMI or PGA range:

$$BD^{EQ} = FA\ RV\ ED^{EQ}$$

where:

FA	is the floor area of the building (in square feet);
RV	is the replacement value of the building (per square foot); and
ED^{EQ}	is expected damage percentage for earthquakes of each MMI or PGA range.

Contents Damages

Contents damages (CD^{EQ}) are estimated as the product of floor area of the buildings (**FA**), replacement value of the building contents per square foot (**RVC**), and expected contents damage percentage (ECD^{EQ}) for earthquakes of each MMI or PGA range:

$$CD^{EQ} = FA\ RVC\ ECD^{EQ}$$

where:

FA	is the floor area of the building (in square feet);
RVC	is the replacement value of the building contents (per square foot); and
ECD^{EQ}	is expected damage percentage for contents for earthquakes of each MMI or PGA range.

Relocation Expenses

Relocation expenses (REL^{EQ}) are defined as the product of relocation costs per month (**REL**) and the expected period for which the residence will be unusable (LOF^{EQ}).

$$REL^{EQ} = REL\ LOF^{EQ}$$

where:

REL	is the relocation cost per month; and
LOF^{EQ}	is the estimated number of months of loss of function for earthquakes of each MMI or PGA range.

Rental Income Losses

Rental income losses ($RENT^{EQ}$) are included if all or a portion of the building are rented to private tenants. Inter- or intra-agency rents within the Federal Government are **not** counted because such payments are generally transfers and loss of such payments 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. Rental income losses are the product of rental rate per month per square foot of gross leasable area (**RR**), gross leasable floor area (**GLA**), and the expected number of months that the rental income will be lost (LOF^{EQ}).

$$RENT^{EQ} = RR\ GLA\ LOF^{EQ}$$

where:

RR	is the rental rate per month per square foot;
GLA	is gross leasable floor area in square feet; and
LOF^{EQ}	is the estimated number of months of loss of function for earthquakes of each MMI or PGA range.

Government Services Lost

For public sector buildings, the value of government services lost ($\mathbf{VLS}^{EQ}$) when the building becomes unusable during an earthquake must be included. Government services are valued using the Quasi-Willingness to Pay (**QWTP**) model. **QWTP** is a simple methodology that assumes that government services are worth what we pay to provide the services. A detailed review of the assumptions in the **QWTP** model is given as Chapter 2 of Volume 2.

$\mathbf{VLS}^{EQ}$ is the sum of agency wages (**WAGE**) plus benefits (**BENE**) and support budget (**SUPP**) per day, multiplied by the number of days of loss of agency function ($\mathbf{LOAF}^{EQ}$). The period of lost services depends on the agency's ability to find alternative quarters and to establish normal functions. This period may vary depending on the structure, size and function of the agency and the availability of suitable quarters after the earthquake. Note that the period of loss of agency function may be much shorter than the period of relocation necessary due to seismic damage, because agencies will resume their functions in temporary quarters, where:

$$VLS^{EQ} = (WAGE + BEN + SUPP)\ LOAF^{EQ}$$

where:

VLS^{EQ}	is the value of lost agency services for an earthquake of a given MMI or PGA range;
WAGE	is the total wages paid to the resident work force per day;
BENE	is the total benefits paid to the resident work force per day;
SUPP	is the support expenditures per day; and
$LOAF^{EQ}$	is the period of loss of agency function for an earthquake of a given MMI or PGA range.

Expected Annual Damages

Expected annual damages ($\mathbf{AD}^{EQ}$) are the product of scenario damages ($\mathbf{SCD}^{EQ}$) and the expected annual probability of an earthquake of a given MMI or range of PGA ($\mathbf{EAE}^{EQ}$):

$$AD^{EQ} = SCD^{EQ}\ EAE^{EQ}$$

where:

- SCD^{EQ} are scenario damages (as defined previously); and
- EAE^{EQ} is the expected annual number of earthquakes of a given MMI or PGA range.

Expected Avoided Damages

Expected avoided damages ($\mathbf{AVD}^{EQ}$) are the product of scenario damages ($\mathbf{SCD}^{EQ}$), the expected annual probability of an earthquake ($\mathbf{EAE}^{EQ}$), and the effectiveness of the rehabilitation measure ($\mathbf{EFF}^{EQ}$):

$$AVD^{EQ} = SCD^{EQ}\ EAE^{EQ}\ EFF^{EQ}$$

where:

- SCD^{EQ} are scenario damages for each damaging earthquake of a given MMI or PGA range;
- EAE^{EQ} is the expected annual probability of an earthquake of a given MMI or PGA range; and
- EFF^{EQ} is the effectiveness of the rehabilitation measure in reducing expected damages for earthquakes of a given MMI or PGA range.

Expected Annual Benefits

The expected annual benefits (**AB**) of a seismic hazard rehabilitation project are the sum of expected avoided damages (**AVD**) summed over the full range of damaging earthquakes considered (e.g., MMI VI to MMI XII or ranges of effective peak ground accelerations, PGA).

$$AB = \sum_{EQ=\min}^{\max} AVD^{EQ}$$

where:

- EQ is the damaging earthquake considered (MMI or PGA);

min	is the minimum damaging earthquake considered;
max	is the maximum earthquake considered; and
AVD^{EQ}	are the expected annual avoided damages from earthquakes of each MMI or PGA bin being considered.

Detailed Economic Assumptions and Equations: With the Value of Life

The benefit-cost model discussed above does not include the value of life. However, reducing the expected number of deaths and injuries is often the principal motivation for seismic hazard rehabilitation projects. The model can be modified to include the value of expected deaths avoided by retrofitting to life-safety standards.

Value of Deaths Avoided

The annual value of avoided earthquake death loss is assumed to be the product of the area of the building in square feet, times the average occupancy per square foot, times the difference in expected death rates between unrehabilitated and rehabilitated buildings, times the dollar value of one human life. The annual value of reducing the earthquake death loss due to rehabilitation is thus defined as:

$$VDA = \sum_{EQ=\min}^{\max} EAE^{EQ} \, (FA \; OCP \; (DR^{EQ} - DRR^{EQ})) \; VOL$$

where:

VDA	is the annual value of expected deaths avoided by rehabilitating buildings to life-safety standards;
EAE^{EQ}	is the expected annual probability of an earthquake of given MMI or PGA range;
FA	is the floor area of the building in square feet;
OCP	is the average occupancy rate per square foot;
DR^{EQ}	is the expected death rate;

DRR^{EQ} is the expected death rate after rehabilitation; and

VOL is the dollar value of one statistical human life.

Value of Injuries Avoided

Similarly, the value of injuries avoided, ***VIA***, is estimated:

$$VIA = \sum_{EQ=\min}^{\max} EAE^{EQ} \; (FA \; OCP \; (IR^{EQ} - IRR^{EQ})) \; VOI$$

where:

IR^{EQ} is the expected injury rate in the existing building;

IRR^{EQ} is the expected injury rate after rehabilitation; and

VOI is the dollar value of one statistical injury.

In the benefit-cost model, injuries are considered in two categories: minor injures, which do not require hospitalization and major injuries, which do require hospitalization.

Benefit-cost results are always presented both with and without including the value of life so that the benefits of avoiding physical damages and the benefits of avoiding deaths and injuries can be analyzed separately.

Definitions of Economic Terms

Benefit-Cost Analysis

Benefit-cost analysis provides estimates of the "benefits" and "costs" of a proposed project or change. The term "benefit-cost analysis" is used to denote economic analyses that apply either the maximum present value criterion or the benefit-cost ratio criterion to evaluate prospective actions. Both costs and benefits are discounted to their net present value. The maximum present value criterion subtracts costs from benefits to determine if benefits exceed costs. Benefit/cost ratios provide an alternative evaluation: prospective actions in which benefits exceed costs have benefit-cost ratios above one. The logic of benefit-cost analysis requires that benefit-cost ratios, and/or the present value criterion, be compared across competing alternatives.

Cost-Benefit Analysis

Cost-benefit analysis has identical economic assumptions to benefit-cost analysis and differs only in the nomenclature used to describe the analysis. Subtle differences in meaning between benefit-cost and cost-benefit analysis have been discussed by Hurter et al. (1982). These authors prefer the term benefit-cost for three reasons:

1) determining benefits is often the most difficult aspect of the analysis; if costs are placed first, the emphasis is wrong;
2) when ratios are used to compare projects, the ratio used is benefit-cost, not cost/benefit; and
3) placing the word "costs" first seems to suggest a negative attitude toward projects. It should be noted, however, that economic concepts, particularly as reflected in benefit-cost analysis, are completely neutral with respect to the undertaking of projects.

Cost-Effectiveness Analysis

Cost-effectiveness analysis identifies the least-cost way to achieve a stated objective; it is strictly a comparison among means to a given end (Andrews, 1982). Thus, cost effectiveness is the ability to achieve a given benefit at a minimum cost. In cost effectiveness analysis, the merits of the objective itself are not evaluated in economic terms. This approach is typically used to select methods of achieving specific environmental standards.

The Stafford Act uses cost-effectiveness when it means that benefits exceed costs in §404, Hazard Mitigation, and §406, Public Assistance.

Economic Efficiency

Economic efficiency is attained when the economy is functioning in a way that maximizes the value of society's consumption over time (Ward and Deren, 1991). Economic efficiency may also be viewed as the contribution to overall social welfare (Leman, 1989). It is generally accepted that a benefit-cost ratio above one indicates an improvement in economic efficiency. Benefit-cost analysis however does not indicate whether the project is the "most efficient" allocation of scarce resources for two reasons. First, benefit-cost analysis is an average rather than a marginal concept. The ratio indicates the relationship between benefits and costs for a given project size. Economic efficiency, however, requires that a project be sized where marginal benefits equal marginal costs, which maximizes the total net benefits. Second, the typical project benefit-cost analysis does not survey the complete array of spending alternatives for all public projects/programs unrelated to the project under analysis. Economic efficiency under a budget constraint would require that the marginal benefits for all public spending alternatives be equal.

Economic Impact Assessment

Economic impact assessment is both simpler and broader than either benefit-cost analysis or cost-effectiveness analysis in that it does not necessarily require aggregation or even categorization of effects as costs or benefits. It requires only the projection of economic effects of proposed actions and the listing of these for consideration. Impact assessment is broader than benefit-cost or cost-effectiveness analysis because it includes identification of all economic impacts: the changes in total (direct, indirect and induced) regional employment and income created by the proposed project. The inclusion of indirect and induced regional economic benefits and costs in the formal benefit-cost analysis is not generally accepted by the economics profession. Many economists maintain that such indirect and induced economic impacts represent a change in the distribution of economic activity and should not be confused with true gains in economic efficiency.

Informal Benefit-Cost Analysis

Informal benefit-cost analysis embraces an indefinite range of procedures for the general identification and balancing of desirable and undesirable effects of proposed actions on society. Thus, informal benefit-cost analysis simply approximates pure common sense, and it should not be compared with formal economic analyses of prospective projects.

Risk-Benefit Analysis

Risk benefit analysis compares the economic benefits of a proposed project with the environmental and/or health-safety risks that are also created by the project. Ideally, the environmental and/or health-safety risks should be quantified in economic terms which in many cases is almost, if not impossible.

APPENDIX 2: BENEFIT-COST MODEL EXAMPLE

This appendix consists of a full print-out of an example benefit-cost analysis for the Veterans' Administration Medical Center, Memphis, Tn.

Benefit-Cost Analysis of the

Seismic Rehabilitation of Federal Buildings

Version 1.0
August 4, 1994

Building Name:	**Veterans' Administration Medical Center**
Address:	**1030 Jefferson Ave.**
City, State, Zip:	**Memphis, TN 38104**
Analyst:	**Goettel & Horner Inc.**
Rehabilitation Project:	**Add shear walls and moment frame**
Run Identification:	**Final**

Prime Contractor:
VSP Associates, Inc.
455 University Avenue, Suite 340
Sacramento, CA 95825
Telephone: (916) 648-9112

Technical Assistance:
Goettel & Horner Inc.
2725 Donner Way
Sacramento, CA 95818
Telephone: (916) 451-4160

BUILDING ID

Building Name:	Veterans' Administration Medical Center
Address:	1030 Jefferson Ave.
City, State, Zip:	Memphis, TN 38104
Analyst:	Goettel & Horner Inc.
Run ID:	Final
Managing Agency:	Veterans' Administration
Contact Person:	Ted Spence
Address:	1030 Jefferson Ave.
City, State, Zip:	Memphis, TN 38104
Telephone:	901/523-8990 ext. 5017

HELP ON DATA ENTRY

BUILDING TYPE

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

I	Concrete Frame with Concrete Shear Wall

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)

BUILDING DESCRIPTION

Total Floor Area (square feet):	805,700		Calculated
Building Replacement Value per square foot	$115		$115
Total Building Replacement Value	$92,655,500		$92,655,500
Number of Stories Above Grade:	14		
Date of Construction	1967		
Historic Building Controls?	No		

MEAN DAMAGE FUNCTION (% OF BUILDING REPLACEMENT VALUE)

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

Facility Class: Concrete Frame with Concrete Shear Wall

Building Replacement Value: $115.00 /sq.ft. $92,656 x 1,000 Total

Demolition Threshold Damage Percentage: 50

Describe the building's seismic deficiencies:

Existing floors and shear walls are inadequate to provide necessary lateral resistance. Building is vulnerable to collapse in higher MMI events.

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							
B Typical	0.5	2.8	6.6	13.0	23.6	35.5	47.6
C Seismic Design	0.0	0.5	2.8	6.6	13.0	23.6	35.5
D Typical California	1.1	4.6	6.9	15.5	24.3	38.0	47.6

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

A Poor	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User Entered Estimate:	1.0	25.0	75.0	100.0	100.0	100.0	100.0
Modified MDF:	1.0	25.0	100.0	100.0	100.0	100.0	100.0

BUILDING CONTENTS (Damage as a % of replacement value)

DESCRIPTION & VALUE OF BUILDING CONTENTS:	$/sq. ft.	Total ($1,000)
All contents	$119.15	$96,000

MEAN DAMAGE FUNCTION FOR CONTENTS:

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
Default (% damage)	1.0	25.0	75.0	100.0	100.0	100.0	100.0
User Entered (% damage)							

RELOCATION TIME (due to seismic damage)

Expected Days of Relocation:

Default Estimate (days)	0	150	365	365	365	365	365
User Entered (days)							

Relocation costs ($/sf/mo)	Rental Cost ($/sf/mo)	Total Relocation Costs ($/sq.ft./mo)
$1.00	$1.50	$2.50

DEATH & INJURY RATES (per 1,000 occupants) EXISTING BUILDING

Default Minor Injury Rate	3.00E-02	8.40E+00	2.61E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
User Entered Estimate:			1.00E+02	5.00E+01	5.00E+01	5.00E+01	5.00E+01
Default Major Injury Rate	4.00E-03	1.12E+00	3.49E+01	4.00E+02	4.00E+02	4.00E+02	4.00E+02
User Entered Estimate:			3.00E+02	2.50E+02	2.00E+02	1.50E+02	1.50E+02
Default Death Rate	1.00E-03	2.80E-01	8.71E+00	2.00E+02	2.00E+02	2.00E+02	2.00E+02
User Entered Estimate:			5.00E+01	5.00E+02	7.00E+02	8.00E+02	8.00E+02

Analyst: Goettel & Horner Inc.

OCCUPANCY DATA

Veterans' Administratio 1030 Jefferson Ave. Memphis, TN 38104

OCCUPANCY:	Day	Night	
Average Number of Occupants:	3000	2900	
Days per Week:	7	7	
Hours per Day	12	12	
Average Occupancy (24 hours, 7 days per week):			2,950.00

VALUE OF GOVERNMENT SERVICES LOST

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.)	$104,000,000
1b. Does this include rent? (1=yes, 2=no)	2
2a. Number of full-time-equivalent persons working in the building:	
2b. Average annual salary-plus-benefits paid to the above:	
2c. Average annual utilities, and other non-wage operating expenses :	

Rental Values For Support of Agency Functions

3a. Amount of floor space occupied by government tenants (sq. ft.):	805,700
3b. Proxy annual rent estimate (if 1a. does not include rent):	$6,485,885
Daily cost of providing services from this building:	$302,701

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:	$1,500,000
TOTAL VALUE OF LOST SERVICES PER DAY:	$1,802,701

FUNCTIONAL DOWNTIME

Functional downtime is the number of days to restore government service after an earthquake, either in the existing building or in temporary quarters. Functional downtime is different from relocation time and may be much shorter

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 Damage (%)	1	25	100	100	100	100	100
Default Downtime (Days)	1	25	30	30	30	30	30
User Entered (days)							

BUILDING RENTAL INCOME

Space Rented to Private Entities	Average Rental Rate	Total Private Rent
0 Sq.Ft.	$0.00 $/sq.ft.	$0 $/mo.

Analyst: Goettel & Horner Inc.

REHABILITATION PROJECT DESCRIPTION

Veterans' Administration Med 1030 Jefferson Ave.	Memphis, TN 38104
Building Type:	Concrete Frame with Concrete Shear Wall
Project Description:	Add shear walls and moment frame
Objective of Rehabilitation:	Life Safety

REHABILITATION PROJECT COSTS

Direct Construction Costs		$21,121,000
	Base Year of Costs	1985
Indirect Construction Costs:		
	A&E Fees, Testing, Permits	
	Project Management	
	Other Costs	
Relocation Costs:		
	Duration of Occupant Relocation (months)	12.0
	Cost of Occupant Relocation per sq. ft. per month	$2.00
	Cost of Relocation of Occupants	$19,336,800
Total Seismic Rehabilitation Costs		$40,457,800

EFFECTIVENESS OF THE REHABILITATION

BUILDING MEAN DAMAGE FUNCTIONS:

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
EXSITING BUILDING:	1.0	25.0	100.0	100.0	100.0	100.0	100.0

REHABILITATED BUILDING:

A	Poor							
B	Typical	0.5	2.8	6.6	13.0	23.6	35.5	47.6
C	Seismic Design	0.0	0.5	2.8	6.6	13.0	23.6	35.5
D	Typical California	1.1	4.6	6.9	15.5	24.3	38.0	47.6

Select Mean Damage Function (A,B,C,D) from the Table Above OR Enter Your Own Estimates:

C	Seismic Design	0.0	0.5	2.8	6.6	13.0	23.6	35.5
	User Entered Estimate:	0.0	4.3	6.0	12.3	19.3	26.6	33.1

REHABILITATION EFFECTIVENESS: (percentage of damage avoided)

BUILDING	100	83	94	88	81	73	67
CONTENTS Default:	100	83	94	88	81	73	67
User Entered Estimate:							

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

MINOR INJURIES							
Estimated Before Rehab	3.00E-02	8.40E+00	1.00E+02	5.00E+01	5.00E+01	5.00E+01	5.00E+01
Estimated After Rehab	3.00E-03	8.40E-01	1.00E+01	5.00E+00	5.00E+00	5.00E+00	5.00E+00
User Entered Estimate:							
MAJOR INJURIES							
Estimated Before Rehab	4.00E-03	1.12E+00	3.00E+02	2.50E+02	2.00E+02	1.50E+02	1.50E+02
Estimated After Rehab	4.00E-05	1.12E-02	3.00E+00	2.50E+00	2.00E+00	1.50E+00	1.50E+00
User Entered Estimate:							
DEATHS							
Estimated Before Rehab	1.00E-03	2.80E-01	5.00E+01	5.00E+02	7.00E+02	8.00E+02	8.00E+02
Estimated After Rehab	1.00E-06	2.80E-04	5.00E-02	5.00E-01	7.00E-01	8.00E-01	8.00E-01
User Entered Estimate:							

Analyst: Goettel & Horner Inc.

SEISMIC RISK

Veterans' Administration Medical Center 1030 Jefferson Ave. Memphis, TN 38104

To estimate the expected annual number of earthquakes at the site under consideration:

a) specify the soil type (S0, S1, S2, S3, or S4) in the green box below

S2

b) choose ONE of the seismic risk assessment methods below:

SEISMIC RISK ASSESSEMENT METHODS:

1) DEFAULT METHOD: Enter two 0.3 second spectral acceleration values in the green boxes below. These vlaues may be obtained from the Seismic Risk Table for about 300 cities which is in the User's Quide, or may be reqad from the 1991 NEHRP maps.

Spectral Acceleration Contours	
Period (seconds)	0.3
Time Period	% of g
50 Year	58
250 Year	155

Effective Peak Acceleration	
Adjustment Factor	2.5
Time Period	% of g
50 Year	23
250 Year	62

Click button if seismic data changed

UPDATE SEISMIC

2) SITE-SPECIFIC GEOTECHNICAL METHOD: Enter numbers from a site-specific geotechnical seismic risk assessment, if available, in the blue line below

SEISMIC RISK TABLE

HELP

Expected Annual Number of Earthquakes

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
Default Estimate	5.11E-02	1.34E-02	3.54E-03	8.20E-04	2.29E-04	7.58E-05	1.41E-04
Geotechnical Estimate:							

Analyst: Goettel & Horner Inc.

DAMAGES

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

Facility Class: Concrete Frame with Concrete Shear Wall

Project Descriptio Add shear walls and moment frame

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	926,555	23,163,875	92,655,500	92,655,500	92,655,500	92,655,500	92,655,500
Contents Damages	960,000	24,000,000	72,000,000	96,000,000	96,000,000	96,000,000	96,000,000
Relocation Expenses	0	10,071,250	24,506,708	24,506,708	24,506,708	24,506,708	24,506,708
Rental Income Losses	0	0	0	0	0	0	0
Value of Lost Services	1,802,701	45,067,526	54,081,032	54,081,032	54,081,032	54,081,032	54,081,032
Total Losses	3,689,256	102,302,651	243,243,240	267,243,240	267,243,240	267,243,240	267,243,240

EXPECTED ANNUAL DAMAGES ($):

Building Damages	47,327	311,545	328,139	75,941	21,248	7,019	13,080
Contents Damages	49,035	322,791	254,987	78,683	22,015	7,272	13,552
Relocation Expenses	0	135,455	86,790	20,086	5,620	1,856	3,459
Rental Income Losses	0	0	0	0	0	0	0
Value of Lost Services	92,078	606,141	191,528	44,325	12,402	4,097	7,634
Total Losses	$188,440	$1,375,932	$861,444	$219,035	$61,284	$20,244	$37,725

AVOIDED ANNUAL DAMAGES ($):

Building Damages	47,327	257,960	308,450	66,601	17,147	5,152	8,750
Contents Damages	49,035	267,271	239,688	69,005	17,766	5,338	9,066
Relocation Expenses	0	112,156	81,583	17,615	4,535	1,363	2,314
Rental Income Losses	0	0	0	0	0	0	0
Value of Lost Services	92,078	501,885	180,036	38,873	10,008	3,007	5,107
Total Losses	188,440	1,139,272	809,757	192,094	49,456	14,859	25,238

RESIDUAL ANNUAL DAMAGES ($):

Building Damages	0	53,586	19,688	9,341	4,101	1,867	4,329
Contents Damages	0	55,520	15,299	9,678	4,249	1,934	4,486
Relocation Expenses	0	23,298	5,207	2,471	1,085	494	1,145
Rental Income Losses	0	0	0	0	0	0	0
Value of Lost Services	0	104,256	11,492	5,452	2,394	1,090	2,527
Total Losses	$0	$236,660	$51,687	$26,941	$11,828	$5,385	$12,487

Analyst: Goettel & Horner Inc.

DEATH LOSS & INJURIES

Veterans' Administration Medical Cente 1030 Jefferson Ave. Memphis, TN 38104

Facility Class: Concrete Frame with Concrete Shear Wall

Project Description: Add shear walls and moment frame

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
Mean Damage Function	1	25	75	100	100	100	100
SCENARIO INJURIES & DEATHS WITHOUT REHABILITATION:							
Number of Minor Injuries	8.85E-02	2.48E+01	2.95E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02
Number of Serious Injuries	1.18E-02	3.30E+00	8.85E+02	7.38E+02	5.90E+02	4.43E+02	4.43E+02
Number of Deaths	2.95E-03	8.26E-01	1.48E+02	1.48E+03	2.07E+03	2.36E+03	2.36E+03
EXPECTED INJURIES & DEATHS WITHOUT REHABILITATION:							
Number of Minor Injuries	4.52E-03	3.33E-01	1.04E+00	1.21E-01	3.38E-02	1.12E-02	2.08E-02
Number of Serious Injuries	6.03E-04	4.44E-02	3.13E+00	6.04E-01	1.35E-01	3.35E-02	6.25E-02
Number of Deaths	1.51E-04	1.11E-02	5.22E-01	1.21E+00	4.74E-01	1.79E-01	3.33E-01
SCENARIO INJURIES & DEATHS WITH REHABILITATION:							
Number of Minor Injuries	8.85E-03	2.48E+00	2.95E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01
Number of Serious Injuries	1.18E-04	3.30E-02	8.85E+00	7.38E+00	5.90E+00	4.43E+00	4.43E+00
Number of Deaths	2.95E-06	8.26E-04	1.48E-01	1.48E+00	2.07E+00	2.36E+00	2.36E+00
EXPECTED INJURIES & DEATHS WITH REHABILITATION:							
Number of Minor Injuries	4.52E-04	3.33E-02	1.04E-01	1.21E-02	3.38E-03	1.12E-03	2.08E-03
Number of Serious Injuries	6.03E-06	4.44E-04	3.13E-02	6.04E-03	1.35E-03	3.35E-04	6.25E-04
Number of Deaths	1.51E-07	1.11E-05	5.22E-04	1.21E-03	4.74E-04	1.79E-04	3.33E-04
AVOIDED INJURIES & DEATHS DUE TO REHABILITATION:							
Number of Minor Injuries	4.07E-03	3.00E-01	9.40E-01	1.09E-01	3.04E-02	1.01E-02	1.87E-02
Number of Serious Injuries	5.97E-04	4.40E-02	3.10E+00	5.98E-01	1.34E-01	3.32E-02	6.18E-02
Number of Deaths	1.51E-04	1.11E-02	5.22E-01	1.21E+00	4.73E-01	1.79E-01	3.33E-01

Analyst: Goettel & Horner Inc.

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.

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

Analyst: Goettel & Horner Inc.