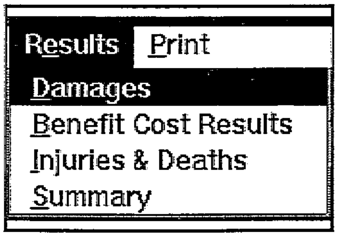
CHAPTER 6: RESULTS

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	33,265	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	7,959	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.

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.	1.8
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 :	($298,785)	$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.

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.

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

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

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.