Benefit-Cost Study for 369 Apartment Buildings in Istanbul

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ABSTRACT:

A specially designed benefit-cost study was made of retrofitting of residential buildings as part of a feasibility study for the Government of Turkey funded by a World Bank loan. The study was part of the Marmara Earthquake Emergency Reconstruction project aimed at mitigating seismic risks in Istanbul and reducing the social, economic and financial impacts of earthquakes. The 369 mainly reinforced concrete buildings examined were built between 1963 and 1992, typically 6 storeys high, and contained over 4000 apartments.

Detailed analyses of the costs and benefits of two retrofitting solutions for each building were made. Costs assessed included construction costs, alternative accommodation, and loss of rental during construction. Benefits assessed included reductions in damage, injury, loss of life and post-earthquake housing. The study examined the net benefits of taking action through retrofitting or replacing each building, for a range of times occurrence of the M7.2 scenario earthquake. The information from the study will be valuable to owners, the Bakirkoy Municipality and to other municipalities in developing approaches to retrofitting of residential buildings.

Other aspects of the study included seismology, geotechnical investigations, as-built condition surveys, structural analyses, earthquake performance assessment, development of retrofitting solutions and social impact surveys.

1 INTRODUCTION

Istanbul has a 60% probability of experiencing a major earthquake in the next 30 years. In 2002 the Bakırköy Municipality, the closest part of Istanbul to the Marmara Sea section of the North Anatolian Fault, undertook preliminary surveys of its residential building stock, including soil condition and rapid structural performance assessments of each building individually (İstanbul University/ İstanbul Technical University, 2003). The survey enabled the authorities to identify approximately 3500 buildings, or one third of its total stock, as being "high" or "very high" earthquake risk, categorized on the basis of structural and soil conditions. Owners of all 3500 buildings were invited to participate in the project. The invitation required that a majority of owners of each building accepted, in writing, to be part of a more detailed assessment. As a result of this process, 369 of these high and very high risk buildings were the subject of the study.

The overall aim of this study was to develop technically sound, innovative, economically feasible and socially acceptable retrofit methodologies that could be applied to the seismically vulnerable residential building stock in İstanbul, and possibly in other similar regions of Turkey. The approach was to look in detail at each building and at the attitudes and circumstances of the owners/occupants before devising suitable retrofit solutions. The technical feasibility and social/economic acceptability of retrofit solutions were thus closely linked so that the study provided a valuable information resource for the Bakırköy Municipality and other municipalities in planning retrofitting schemes and approaches to earthquake risk reduction.

The benefit-cost studies were the final step in a comprehensive review all aspects affecting the earthquake risk. This included a review of regional and local seismology, new geotechnical investigations, extensive condition surveys, preparation of as-built drawings, sophisticated structural analyses, evaluation of earthquake performance, development of retrofitting solutions taking account of social impacts and constraints.

Material for this paper has been taken from project reports prepared by the consultants, Beca Prota Joint Venture in association with the Middle East Technical University (Beca Prota Joint Venture, 2005a & 2005b).

2 METHODOLOGY

The methodology for the benefit-cost analysis was developed specifically to meet the needs of the project and provided estimates of benefits and costs for the retrofit options and for replacement of the building with a new one of the same size. These benefits and costs were then compared with the costs of doing nothing. The basis of the analysis was to assume that the scenario earthquake could occur at some time in the future and to compare its effect on the existing and retrofitted/replaced buildings for a range of times between retrofitting/replacement and occurrence of earthquake. Because the scenario earthquake dominates the overall hazard in Istanbul, this was seen to be a valid approach and has the advantage of that the results can be readily understood by owners and administrators.

For each selected time to occurrence of the scenario earthquake, the benefits and costs were computed for four options: Do Nothing, Demolish and Rebuild, and two Retrofit options (one using internal elements and the other using external elements) The "demolish and rebuild" option is not strictly "retrofit" but it is a viable seismic risk mitigation alternative and a useful bench mark against which to measure the costs and benefits of investment in retrofitting.

The analysis model was split into four main sections.

- Initial Benefits and Costs, including costs of retrofitting and relocation of occupants during retrofitting, and benefits of increased property values.
- Time Dependent Benefits and Costs, comprising maintenance, depreciation, insurance and assessed rental differentials.
- Earthquake Dependent Benefits and Costs, including building damage, loss of contents, injuries and fatalities, and an allowance for overall business interruption and social disruption.
- Summary of Benefits and Costs, presenting both the comparative situation to Do Nothing, and the absolute situation for all options including that of doing nothing.

When applicable, values were discounted to net present values (NPV). For each of the 369 buildings values of benefits, costs and benefit/cost ratios were computed for times to scenario earthquake of 0, 5, 10, 20, 30 and 50 years.

Table 1 shows an outline of the computer model input and calculation form. This shows the various sections and range of input variables. In addition to those shown there were global variables that were common to each analysis, but were capable of adjustment between analyses. A list of these is given in Table 2.

Table 1 – Example Benefit Cost Analysis

Caption	Do Nothing	Demolish and Rebuild	Retrofit 1	Retrofit 2
- **Group : 0Summary of Benefit Cost Information for Selected Building**				
Time To Earthquake (years)	1			
Benefit Cost Ratio	0	2.7	9.06	5.6
Benefits less Costs	0	2148600	2935400	2710300
Net Benefit with respect to Do Nothing	0	3409800	3299700	3299600
Net Cost with respect to Do Nothing	0	1261200	364300	589300
Individual B/C ratio	-4.03	0.06	0.02	0.02
Total Earthquake Losses (NPV)	3451300	318800	290200	290200
Total Benefit (NPV)	173100	450400	311800	311700
Total Costs (NPV)	813900	2075100	1178200	1403200
Earthquake-dependent Disbenefits	3451300	318800	290200	290200
Time-dependent Benefits	173100	225400	199300	199200
Time-dependent Costs	63900	39800	55600	55600
Initial Benefits	0	225000	112500	112500
Initial Costs	750000	2035400	1122700	1347700
- **Group : 1Building Information**				
Age of Building (years)	30	30	30	30
Property Category	A	A	A	A
Land Area (m2)	1800	1800	1800	1800
Building Area (m2)	1500	1500	1500	1500
Total Floors	7	7	7	7
Number of Basements	2	2	2	2
Number of Flats	12	12	12	12
Flats to Move Out	0	12	6	6
Time Moved Out (month)	0	15	4	4
Demolition Cost (YTL/m2)	0	50	0	0
Retrofit/Reconstruction Cost (YTL/m2)	0	825000	225000	450000
Retrofit Cost / Flat (YTL/m2)	0	68750	18750	37500
Retrofit Cost / m2 (YTL)	0	0	0	0
Number of occupants/building (at time of EQ)	14	14	14	14
Capacity Existing	30	0	0	0
Capacity Retrofit	0	100	100	100
Pre EQ Reconstruction Time (Before EQ)	0	15	4	4
Post EQ Reconstruction Time (After EQ)	15	7.23	7.23	7.23
Discount Rate (% per year)	4	4	4	4
Remaining Life (years)	39	78	42.9	42.9
Damage Ratio (%)	100	24.1	24.1	24.1

Table 1 – Example Benefit Cost Analysis - continued

- Group : 2Initial Benefits and Costs				
BENEFITS				
Building Value (a1)	750000	975000	862500	862500
Land Value (a2)	0	0	0	0
Property Value	750000	975000	862500	862500
Total Net Initial Benefits (wrt Do Nothing)	0	225000	112500	112500
COSTS				
Property Value	750000	975000	862500	862500
Total Ret/Reb. Cost	0	825000	225000	450000
Total Property Cost	750000	1800000	1087500	1312500
Cost of Retrofit/Rebuild relocation				
moving out and back in (c1)	0	10400	5200	5200
temporary accomodation (c2)	0	225000	30000	30000
Total Retrofit/Rebuild Relocation Cost	0	235400	35200	35200
Total Initial Costs	750000	2035400	1122700	1347700
- Group : 3Time Dependent Benefits and Costs				
BENEFITS				
Rentals (k) (per annum)	180000	234000	207000	207000
Insurance premium (per annum)	1254	877.8	1003.2	1128.6
Insurance premium reduction (per annum)	0	376.2	250.8	125.4
Total Time Dependent Benefits (NPV)	173100	225400	199300	199200
COSTS				
Maintenance Cost (L) (NPV)	45400	27800	36200	36200
Depreciation Cost (M) (NPV)	18491.124260355	12019.2307692308	19331.629908553	19331.629908553
Total Time Dependent Costs (NPV)	63900	39800	55600	55600
- Group : 4Earthquake-dependent Benefits and Costs				
DISBENEFITS				
Earthquake Cost: cost due to injuries (d)				
	24200	15300	15300	15300
Earthquake Cost: Cost due to loss of lives (e)				
	2450000	16500	16500	16500
Earthquake Cost: cost of damage to building (f1)				
	750000	180800	180800	180800
Earthquake Cost: cost of damage to contents (f2)				
	247500	59600	59600	59600
Total Damage Cost	997500	240400	240400	240400
Temporary resettlement - moving costs (g1)	5200	5200	2600	2600
Temporary resettlement - accommodation costs (g2)	112500	54200	27100	27100
Total Resettlement Costs	117700	59400	29700	29700
Total				
Business Interruption/Social disruption (h)	0	0	0	0
Total Earthquake Costs	3589300	331500	301800	301800
Total Earthquake Costs (NPV)	3451300	318800	290200	290200

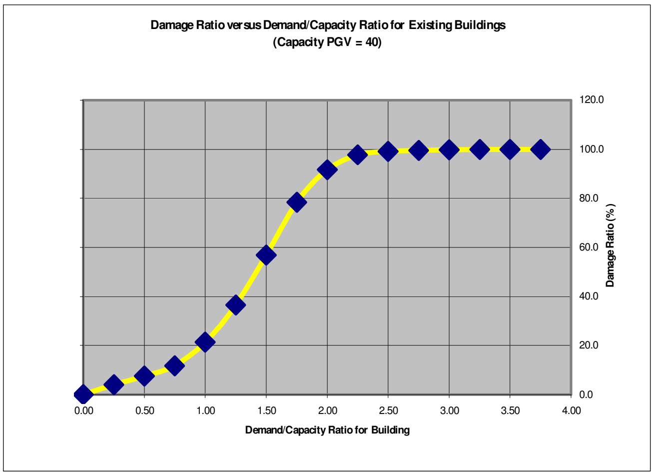
Table 2 List of Global Variables

Discount rate; Relocation (for retrofit) Cost Rate; Resettlement (post-earthquake) Cost Rate; Relocation (for retrofit) Accommodation Rate; Resettlement (post-earthquake) Accommodation Rate: Building Rate by Category; Injury and Fatality Cost Rates (10,000 YTL (US$8000) per serious injury and 250,000 YTL (US$200,000) per life.); *Contents Damage Coefficient; Business Interruption / Social Disruption Coefficient; Occupancy Factor; Rent Rate by Category; Market Adjustment (due to retrofit); Rent Adjustment; (due to retrofit); Insurance Premium Rate; Insurance Premium Adjustment Factor (due to retrofit); Remaining Life of Retrofitted Building by Category; Remaining Life Adjustment Factor.*

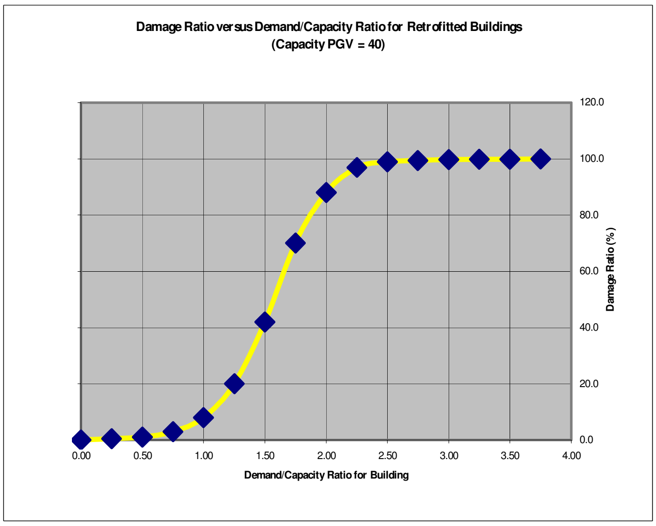
A computer model was developed to determine the initial, time-dependent and earthquake-dependent benefits and costs. The model was set up to look at benefits and costs from the perspective of a purchaser of a whole property (building and land) who would then rent all the apartments in the building for an indefinite period. Benefits and costs were calculated for each building using relevant variables, some of which were specific to each building, such as total area of building, age of building, and cost of retrofitting, and some of which were common to all buildings, such as rate of discount, cost of injuries or fatalities, relationship of damage ratio to structural capacity for retrofitted buildings, and occupant intensity.

The heart of the benefit cost analysis was the difference in damage ratio before and after retrofitting, values for which were derived to be compatible with data from past earthquakes in Turkey. Relationships were derived between damage ratio and casualty rates, again made compatible with Turkish earthquake data from the 1999 earthquakes.

The relationships assumed between damage ratio and the assessed structural capacities, expressed as demand-to-capacity ratios, are shown in Figure 1.



(a) Existing Buildings



(b) Retrofitted Buildings

Figure 1 Relationships between Damage Ratio and Assessed Demand/Capacity Ratio

Key output parameters were the (net present values of) overall costs, overall benefits and the ratio of costs to benefits at any given time to earthquake. These were computed in two ways: one relative to the Do Nothing option, and the other on an absolute basis.

The benefit-cost results were used to assess the merits of retrofitting for each option for each building and their relative merits. This approach allowed account to be taken of the overall condition of the building and the concrete strength. Buildings with low concrete strength and/or in poor condition would require significant column jacketing and/or corrosion treatment, considerably increasing costs. Replacement rather than retrofitting should show as the best option for such buildings.

3 RESULTS

Figure 2 is a sample Individual Building Retrofit and Benefit Cost Report produced to summarise the situation for each building prepared for managers of each building.

TURKISH REPUBLIC PRIME MINISTRY PROJECT IMPLEMENTATION UNIT
FEASIBILITY STUDIES FOR RETROFITTING of SELECTED BUILDINGS in ISTANBUL

Beca PROTA
JOINT VENTURE / ORTAK GİRİŞİMİ

Individual Building Retrofit and Benefit Cost Report

Building Data				K10
Building Reference Number:	MEER-34-B-K-10			
Building Address :	Kartaltepe Mahallesi Parkönü Caddesi Hak Apartmanı No: 10			
Construction Date:	1975	Exchange Rate (YTL / USD)		1.300
Storey Information:	2 Basement + Ground + 4 Regular Floors		Discount Rate Used	4%

Retrofit Option	Est. Property Value (Million YTL)	Bldg Area (m2)	Initial Bldg or Retrofit Cost (YTL)	Initial Bldg or Retrofit Cost (YTL/m2)	No. of Flats	No. Out	Time Out (Months)
New Building	0.75	1500	825000	550.00	12	12	15
Retrofit 1	0.75	1500	225000	150.00	12	6	4
Retrofit 2	0.75	1500	450000	300.00	12	6	4
Do Nothing	0.75	1500	0	0	12	0	0

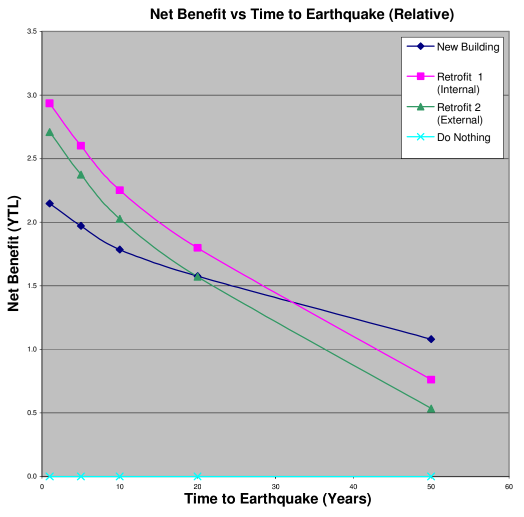
Benefit - Cost Data

Relative to Do Nothing Option

Retrofit Option	Item	Time to Earthquake (Years) 1	5	10	20	50
New Building	B/C ratio NB	2.70	2.68	2.65	2.80	2.40
	NPV Benefits (YTL)	3.41	3.14	2.87	2.45	1.85
	NPV Costs (YTL)	1.26	1.17	1.08	0.87	0.77
	NPV B-C	**2.1**	**2.0**	**1.8**	**1.6**	**1.1**
	IRR	**170%**	**22%**	**10%**	**5%**	**2%**
Retrofit 1 (Internal)	B/C ratio R1	9.06	8.79	8.45	10.73	2.91
	NPV Benefits (YTL)	3.30	2.94	2.55	1.98	1.16
	NPV Costs (YTL)	0.36	0.33	0.30	0.18	0.40
	NPV B-C	**2.9**	**2.6**	**2.3**	**1.8**	**0.8**
	IRR	**806%**	**54%**	**24%**	**13%**	**2%**
Retrofit 2 (External)	B/C ratio R2	5.60	5.25	4.84	4.83	1.86
	NPV Benefits (YTL)	3.30	2.94	2.55	1.98	1.16
	NPV Costs (YTL)	0.59	0.56	0.53	0.41	0.62
	NPV B-C	**2.7**	**2.4**	**2.0**	**1.6**	**0.5**
	IRR	**460%**	**39%**	**17%**	**8%**	**1%**
Do Nothing	B/C ratio	0.0	0.0	0.0	0.0	0.0
	NPV Benefits (YTL)	0.0	0.0	0.0	0.0	0.0
	NPV Costs (YTL)	0.0	0.0	0.0	0.0	0.0
	NPV B-C	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
	IRR	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Absolute Values

Retrofit Option	Item	Time to Earthquake (Years) 1	5	10	20	50
New Building	B/C Ratio NB	0.19	0.51	0.81	1.21	1.64
	Total Benefit (NPV) (YTL)	0.45	1.27	2.13	3.41	5.26
	Total Costs (NPV) (YTL)	2.08	2.23	2.39	2.67	3.15
	Total Earthquake Losses (NPV) (YTL)	0.32	0.27	0.22	0.15	0.05
	Net Benefit (NPV)	**-1.19**	**-0.48**	**0.26**	**1.34**	**2.81**
Retrofit 1 (Internal)	B/C Ratio R1	0.21	0.63	0.99	1.38	1.62
	Total Benefit (NPV) (YTL)	0.31	1.04	1.79	2.93	4.56
	Total Costs (NPV) (YTL)	1.18	1.39	1.61	1.98	2.78
	Total Earthquake Losses (NPV) (YTL)	0.29	0.25	0.20	0.14	0.04
	Net Benefit (NPV)	**-0.41**	**0.15**	**0.73**	**1.56**	**2.49**
Retrofit 2 (External)	B/C Ratio NB R2	0.18	0.56	0.88	1.25	1.50
	Total Benefit (NPV) (YTL)	0.31	1.03	1.79	2.93	4.56
	Total Costs (NPV) (YTL)	1.40	1.61	1.84	2.20	3.01
	Total Earthquake Losses (NPV) (YTL)	0.29	0.25	0.20	0.14	0.04
	Net Benefit (NPV)	**-0.63**	**-0.07**	**0.50**	**1.34**	**2.26**
Do Nothing	B/C Ratio DN	0.04	0.20	0.39	0.71	1.34
	Total Benefit (NPV) (YTL)	0.17	0.80	1.46	2.45	3.87
	Total Costs (NPV) (YTL)	0.81	1.05	1.31	1.79	2.38
	Total Earthquake Losses (NPV) (YTL)	3.45	2.95	2.42	1.64	0.51
	Net Benefit (NPV)	**-3.34**	**-2.45**	**-1.53**	**-0.24**	**1.73**



Notes:

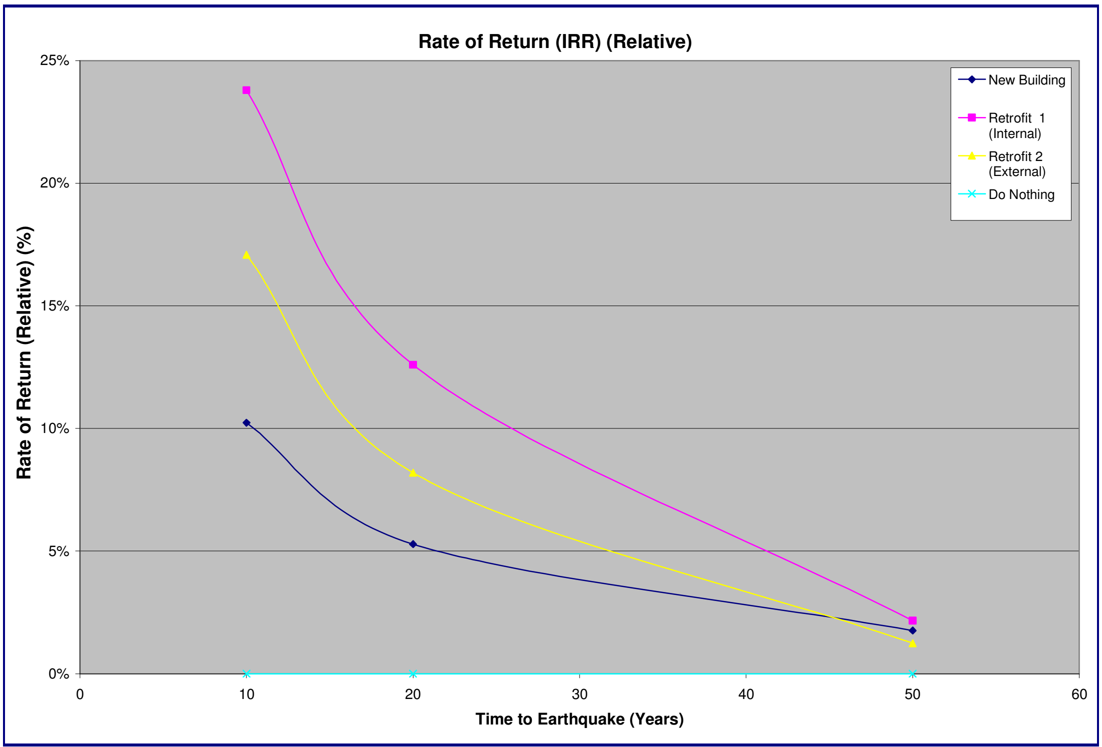
1. Est. Property Value is that used in the B/C analysis and is not a valuation
2. Building area is the total occupied area on all floors
3. Initial Building/Retrofit Costs are based on retrofit options on attached drawings
4. No of Flats assumes fl

Indicated Preferred Option (based on Preliminary Design) **:** **Retrofit 1**

Figure 2 Individual Building Retrofit and Benefit Cost Report – Page 1

Individual Building Retrofit and Benefit Cost Report

Building Data		K10
Building Reference Number:	MEER-34-B-K-10	



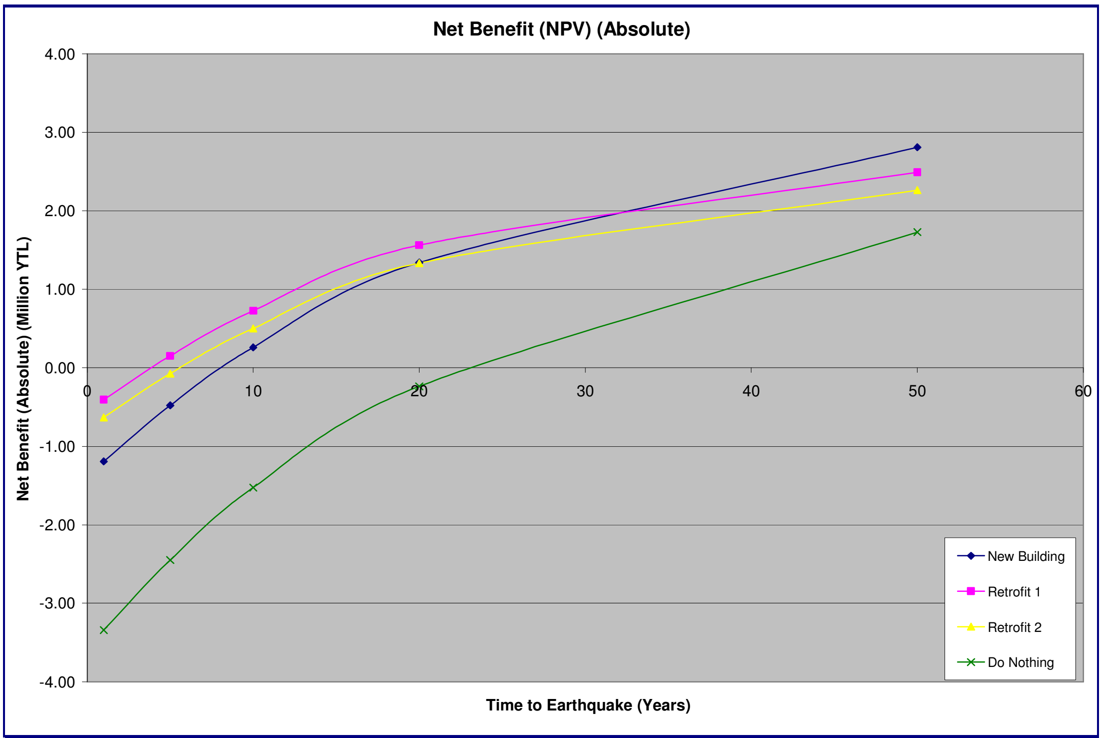


Figure 3 Individual Building Retrofit and Benefit Cost Report – Page 2

The Individual Building Report shows results in two ways. The first (relative) shows the costs and benefits compared with the Do Nothing option. The second (absolute) shows the costs and benefits as computed for each option including the Do Nothing option. (The Do Nothing option has no initial costs but has time-related costs and benefits, as well as earthquake losses.) All figures given are net present value (NPV). In the relative report, earthquake losses are included in benefits. For the absolute case the earthquake losses are shown separately.

For the relative case, a benefit-cost ratio is determined and an annual rate of return based on the net cost and the net benefit over the time to earthquake. For the absolute case, earthquake losses have been shown separately from costs, and a net benefit calculated as the difference between benefits (including the market value) and costs (including earthquake losses).

In order to help decision making, the results are given in graphical form to show more clearly the relative merits of the options considered. The form concludes with an indication of what appears to be the preferred option for the building (Do Nothing, Rebuild or Retrofit), based on the preliminary design information and the assumptions made in the benefit-cost analysis.

The penalties of the Do Nothing option are highlighted, though they become less as the time-to-earthquake increases. The benefits of retrofitting are clear and are very high when the time-to-earthquake is short. Nevertheless, for this example, they remain high even for time-to-earthquake of 50 years. This is principally because rents and capital value were assumed to increase as a result of the retrofitting or replacement.

The results for all 369 buildings showed wide variation with retrofit cost varying from 20% of replacement to over 100% (for buildings requiring extensive column jacketing). With this variation the shape and relative position of the graphs changed and the preferred option was usually quite evident from a brief inspection.

4 OVERALL BENEFITS TO BAKIRKOY

Figures for each building were aggregated to obtain an indication of overall benefits and costs for Bakirkoy if these buildings were to be retrofitted using the indicated preferred option. The benefit-cost analysis showed that retrofitting is feasible and an economic means of reducing earthquake risk in Bakirkoy. Results are shown in Table 3 for the relative case.

Table 3 Benefits and Costs for All Project Buildings

Time to Earthquake (years) ➔	1	5	10	20	30
Benefit to Cost (B/C) Ratio	4.7	4.4	4.1	3.6	3.2
NPV Benefits (US$ Million)	350	325	300	263	241
NPV Costs (US$ Million)	73	73	73	73	73
Net Benefits of Retrofitting/rebuilding (US$ M)	277	252	227	190	168
Indicative Rate of Return (% per annum)	395%	40%	19%	10%	8%

(Based on recommended options using relative figures)

Net benefits of retrofitting are significant and maintain their net present value even as the time to earthquake increases. Although significant costs are involved, the return on this investment gives benefit-to-cost ratios of between 4.7 and 3.2 depending on the time to earthquake.

In present terms, costs of US$73M show benefits of over US$241M for any time to earthquake up to 30 years. This investment in retrofitting the project buildings was estimated to save about 700 lives. When totaled over the 369 buildings, the difference between retrofitting and doing nothing was shown to be as much as US$277M When the analysis was extrapolated to cover the whole of Bakirkoy this figure became over US$2billion, excluding benefits to the community such as reduced business interruption, social disruption and emergency relief, which can easily double the overall benefit. For all of Bakirkoy, it was estimated that over 5000 lives would be saved.

The main message from the analysis is the sooner retrofit or replacement is carried out the sooner owners obtain peace of mind and protect their investment and their lives.

5 CONCLUSIONS

This study based on specially designed solutions for each of 369 buildings in the Istanbul municipality of Istanbul has provided valuable insights into benefits and costs and relative merits of retrofitting. This applies both to individual buildings used for the study and to the many similar buildings in other parts of Istanbul. As such it should provide a valuable resource for owners, municipalities and the Turkish government in making decisions on retrofitting to reduce earthquake risk.

The simple approach of using a scenario earthquake at different times in the future gives easy-to-understand results. The specially developed tabulations and graphs in the Individual Building Retrofit and Benefit Cost Reports provide a ready means of deciding on the best option.

The analyses successfully identified buildings for which replacement with a new building was the best option and gave some supporting data for this conclusion. More importantly, perhaps, the analysis and presentation of results highlighted the critical need to retrofit or replace rather than do nothing.

Even though challenges remain in order for retrofitting to be implemented by the private owners, including availability of funds and legal/planning constraints, the benefit-cost analysis showed that retrofitting was a good investment for most buildings.

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