Economic Analysis of Residential Building Using Cost Benefit Ratio

Gaurav Chandrakant Vispute[1], Pranay Raju Khare[2]

Department of Civil Engineering, Dr. D.Y. Patil School of Engineering & Technology,
Dr. D.Y. Patil Knowledge City, Charoli (BK), Lohegaon, Pune-412105
Maharashtra, India

Abstract-This paper examines the benefits and cost of improving residential structures in middle-income developing countries such that they are less vulnerable to hazards during their lifetime. Since the challenges for cost benefit analysis are to express avoided losses in probabilistic terms, evaluate and assess risk, direct and indirect benefits, land use and climate. In detail, we examineearthquake risk. The purpose in undertaking these analyses is to shed light another benefits and costs over time, recognizing the bounds of the analysis, and to demonstrate a systematic probabilistic approach for evaluating alternative risk reducing measures.

***Keywords: cost benefit ratio, direct indirect benefits, EP Curve,disaster risk reduction*.**

I. INTRODUCTION

Economic analysis show large benefits from disaster risk reduction (DRR) in many developed and developing country contexts. Examining investments in 4,000 disaster risk reduction programs, including retrofitting buildings against seismic risk and structural flood defence measures, in developing countries, a review of 21 studies on investments as diverse as planting mango forests to protect against tsunamis and relocating schools out of high-hazard areas demonstrated, with few exceptions, equally high benefit-cost ratioMechler(2005). In spite of potentially high returns, there is limited investment in loss reduction measures by those residing in hazard-prone areas. In the Japan, several studies shows that only about 10 percent of earthquake and flood-prone households have undertaken costeffective disaster risk reduction measures. Attribute this inaction to a myopic focus on short-time horizons.The upfront costs of the investment in DRR loom large relative to the perceived expected benefits from the measures. Policy makers are also reluctant to commit significant funds to riskreduction, which may also be explained by short time horizons, and additionally by the absence of concrete information on net economic and social benefits and limited budgetary resources.

In this paper we apply probabilistic cost-benefit analysis (CBA) to evaluate selected DRR measures that reduce losses to structuresin hazard-prone areas in low- and middleincome developing countries. There is a substantial literature on the use of CBA and other appraisal methods to pro-actively evaluate risk-reduction investments, but there are few applications in developing countries Benson and Twigg (2004)Since it is misleading to assess the benefits of prevention using deterministic models, the challenges for cost-benefit analyses are to express avoided losses in probabilistic terms, evaluate and assess risk, monetize direct and indirect benefits and include dynamic drivers such as changing population, land use and climate. We examine the benefits and costs of improving or retrofitting residential structures in highly exposed developing countries such that they are less vulnerable to hazards during their lifetime.

The paper is organized as follows: Following a brief discussion of our methodology in section 2, we show the results of the benefit-cost calculations for selected DRR measures across the four cases in section 3. Section 4 presents more details of the challenges and limitations of utilizing CBA analysis. Section 5 summarizes the main results and suggests a future research agenda.

II. METHODOLOGY

As described below, the case studies follow a format with respect to evaluating the costs and benefits of structural DRR measures.

Exceedance Probability Curve

The basic probabilistic measure for assessing the catastrophe exposure of a house or portfolio of assets is the Exceedance Probability (EP) curve. An EP curve indicates the probability that at least X is lost in a given year. An EP curve is one output of a catastrophe model, involving four mainmodules depicted in Figure 1.

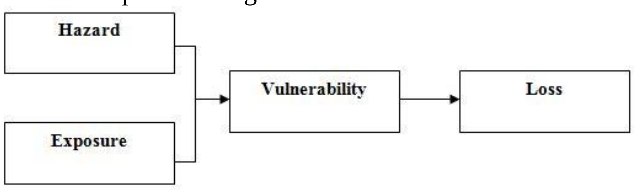

Figure1. EP estimation Methodology

- A **hazard** module characterizes the hazard in a probabilistic manner. Often, the full suite of events which can impact the exposure at risk is described by magnitude and associated annual probability, among other characteristics.
- An **exposure** module describes a single structure orcollection of structures that may be damaged.A

vulnerabilitymodule estimates the damage to the exposure at risk given the magnitude of the hazard.

- **Vulnerability** is typically characterized as a mean estimate of damage (e.g. percentage ofhouse destroyed) and associated uncertainty given a hazard level.
- A financial **loss**module estimates losses to the various stakeholders that must manage the risk (e.g., homeowner, insurer).

Cost-Benefit Analysis (CBA)

We select measures for reducing losses from the disaster in residential building. We then construct EP curves for a representative house or houses with and without theDRR measure in place. Cost estimates of each DRR measure are derived from various sources. Combining these estimates, we compute a benefit-cost ratio (B/C ratio). The most attractive DRR measure from an economic standpoint is the one withthe highest B/C ratio assuming there are no budget constraints with respect tothe cost of the investment. Using the B/C ratio as the metric captures the concept of the complex interactions of three main components that affect the final decision: vulnerability of the building, the hazard level of the area, and the cost of the measure discussed.

III. LIMITATIONS

It is important to note that the assumptions underlying this analysis are conservative in a number of ways. Firstly, taking account of lost life and climate change would likelyincrease the benefits of the selected mitigation measures. Secondly, not considered in this paper are the costs of household assets, loss of livelihoods and broader indirect losses from disasters; taking into account these effects would tend to increase the benefits of risk reduction.

The cost-benefit analyses in this paper are expected value analysis. This means that they assume zero risk; if the householder were more risk averse then this too would increase the economic benefit of risk reduction investment.

EP curve:

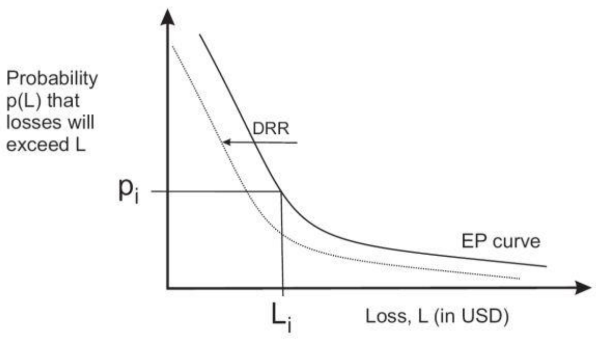

Figure2. Example of EP Curve and DRR Effect

We assume that there are 4 study buildings characterized by a ground floor with a soft story, possessing short columns or both. Soft story means that the ground floor space a window, garage door. Soft story structures, possessing large ground floor openings, are collapse hazards in strong ground shaking. A short column is a column in reinforced concrete buildings where the partial height infill walls are used to provide natural lighting and ventilation and thus, creating a column shorter than the other columns within the structure. Short column failure occurs when the column is subject to high shear stresses and unable to resist these stresses. Moreover, the flexibility of the frame can be increased by adding partial or full shear walls (here referred to as structural upgrade) as described in Smyth (2004).

In the absence of shear walls, risks to soft story buildings can be reducedthrough the use of a steel moment frame in the open floor. We assume that the addition of shear walls will automatically retrofit the effect of soft story and therefore there is no additional cost for soft story DRR. The short column effect canbe mitigated either through adding masonry inserts at both sides of the column, Guevara and García(2005) or separation of the infill wall from the surrounding frame.

Three DRR measures for reducing seismic risk to a representative five-story reinforced concrete building are thus analysed:

- Measure 1: Retrofit short column (SC), and/or soft story (SS) but no shear walls added.
- Measure 2: Partial shear walls (PSW) are added. Short columns are mitigated if applicable.
- Measure 3: Full shear walls (FSW) are added. Short columns (SC) are mitigated if Applicable.

Cost-benefit calculations:

Cost-benefit Analysis of projects/investments that save atrisk lives generally use of a value of statistical Life (VSL) to estimate the benefits or costs. If a disaster risk DRR project reduces the probability that an individual dies, conditional on the disaster event occurring, the project will save a number of statistical lives equal to the sum of reductions in the riskof death over the exposed population. Applying a VSL to CBA, however, can be controversial since it is ethically difficult to put a price tag on a life. For this reason we do not make use ofa point value, but undertake a sensitivity analysis using a range of statistical life value estimates. As an upper bound of the VSL, we take the highest practical estimate in the United States, USD 6 million, which is commonly used by the US Environmental Protection Agency (Cropper and Sahin 2008). As a lower range, we make use of a method suggested by Cropper and Sahin (2008), which scales the VSL according to the country per capita income relative to the US. This method yields a Turkish VSL approximately equal to USD 750,000. We use these figures as the lower and upper range of the VSL.

Table 1: Earthquake Risk: Summary of Selected B/C Ratios

DRR Measure	Time Horizon (years)	Type1				Type2				Type3			
		Camlibahce Min Hazard		Atakoy Max Hazard		Camlibahce Min Hazard		Atakoy Max Hazard		Camlibahce Min Hazard		Atakoy Max Hazard	
		Discount Rate		Discount Rate		Discount Rate		Discount Rate		Discount Rate		Discount Rate	
		5%	12%	5%	12%	5%	12%	5%	12%	5%	12%	5%	12%
Mitigating SC/ Mitigating SS	10	0.12	0.09	0.01	0.01	0.05	0.04	0.00	0.00	0.08	0.06	0.01	0.00
	25	0.22	0.12	0.02	0.01	0.09	0.05	0.01	0.00	0.14	0.08	0.01	0.01
Mitigating SC/ Adding PSW	10	0.12	0.09	0.01	0.01	0.05	0.04	0.00	0.00	0.07	0.05	0.00	0.00
	25	0.22	0.12	0.01	0.01	0.09	0.05	0.01	0.00	0.12	0.07	0.01	0.00
Mitigating SC/ Adding FSW	10	0.06	0.05	0.00	0.00	0.03	0.02	0.00	0.00	0.06	0.04	0.00	0.00
	25	0.11	0.06	0.01	0.00	0.06	0.03	0.00	0.00	0.11	0.06	0.01	0.00

- **SS=Soft Story; FSW=Full Shear Wall**
- **SC=Short Column; PSW=Partial Shear Wall**

In Table 2 we show how the B/C estimates change if we include the value of reducing mortality risk. We take as an example the case of seismicretrofit using steel metal frames for a Type 1 constructed house in a low-riskarea. As can be seen, the B/C ratios when VSL is not incorporated in the analysis (ranging from 0.09 to 0.21 depending on the discount rate and time horizon of the building) increase significantly if the value of reducing mortality risk is included. Even for the lowest VSL (USD 750,000) the DRR measure is attractive assuming a discount rate of 5% and a time horizon of 25 years. With the maximum VSL (USD 6 million) the B/C ratios ranges from 3.5 to 8.1) as a function of the discount rates and time horizons that we consider in our analyses.

Table 2: Earthquake Risk: B/C Ratios Taking into Account the Value of Life for Baseline Type 1 and Measure 1 (Numbers above 1 in Bold)Multi-year micro-insurance:

Analysis	Time Horizon (Years)	Camlibahce Min Hazard	
		Discount Rate	
		5%	12%
Value of statistical life **not** included	10	0.12	0.09
	25	0.22	0.12
VSL= USD 750,000	10	0.7	0.5
	25	**1.3**	0.7
VSL= USD 6 million	10	**4.5**	**3.5**
	25	**8.1**	**4.9**

Consider the following simple example where insurance premiums reflect the risks of future disasters. A middle-income family in India could invest $150 to strengthen the roof of its house so as to reduce the damage by $3,000 from a future cyclone with an annual probability of 1 in 100. An insurer would be willing to reduce the annual charge by $30 (1/100 x $3,000) to reflect the lower expected losses that would occur if a cyclone hit the area in which the family is residing. If the house was expected to last for ten or more years, the net present value of the expected benefit of investing in this measure would exceed the up-front cost at an annual discount rate as high as 15 percent.

Principle 1: *Even in low- and middle income countries, (micro)-insurance can be a useful policy tool for encouraging adoption of DRR measures, especially for the wealthier middle class, if premiums reflect risk.*

Under current annual insurance contracts, many property owners would be reluctant to incur the $150 expenditure, because they would get only $30 back next year and are likely to consider only the benefits over the next two or three years when making their decisions. If they underweight the future, the expected discounted benefits would likelybe less than the $150 up-front costs.

In addition, budget constraints could discourage them from investing in the DRR measure. Suppose a twenty-year required (micro)-insurance policy were tied to the property rather than to the individual. If the family were able to secure a $150 loan for 20 years at an annual interest rate of 10 percent, its annual payments would be $14.50. If the insurance premium was reduced by $30, the savings to the family each year would be $15.50.

Principle 2: *Financial arrangements should tie cost-effective DRR measures to the property or land (or group of properties and pieces of land) rather than to the individuals.*

These DRR loans would constitute a new financial product. A financial institution such as the Grameen bank, would have a financial incentive to provide this type of loan, the insurer knows that its potential loss from a major disaster is reduced. Moreover, the general public will now be less likely to have large amounts of their tax dollars going for disaster relief—a win-win-win situation for all(see Kunreuther and Michel-Kerjan 2010; Jaffee et al. in press).

Principle 3: *Explicit linkages should be made to ex ante and ex post impacts of DRR measures.*

IV. RESULTS AND CHALLENGES

This research has focused exclusively onDRR measures that can be adopted by households and did not include measures that can be implemented only or most effectively at the community or national levels, such as early warning systems or school safety programs. The focus on a single structure or household is not appropriate for DRR measures that have a public good character and protect assets and lives at the community or national scales. Nor is the single household perspective convincing for governments or donors considering support for these one-household-based structuralmeasures across a wide area.

To be relevant for donors and other investors, it would be instructive to expand the scale and scope of the CBA undertaken in this study to provide a more realistic and complete assessment of the potential value of DRR for specific regions and covering both private and public-good investments.

These results are robust in the sense that the underlying frame and assumptions of the analysis were conservative. The results also showed that many selected DRR measures were not cost effective, which might change.

CONCLUSIONS

1. We have examined the benefits and costs of improving or retrofitting residential structures.
2. The structures and risks chosen for this study are typical for low-, middle- and high-income persons.
3. The cases demonstrate many challenges in providing fully integrated benefit-cost estimates: valuing mortality/morbidity risk, taking account of climate change, risk aversion, multiple hazards and indirect losses, and giving a full account of the uncertainties in the analysis.
4. A CBA analysis that considers benefits accrued may be sensitive to changes in the baseline risk level over time.
5. Risk-averse individuals are willing to pay more than their expected losses to avoid the risk of incurring very large losses at one time.
6. If a mud house is demolished and built on a raised plinth, it could at the same time be reinforced with bamboo to strengthen it against earthquakes. This would be a relatively minor additional cost and might significantly increase the marginal benefits if both hazards were included synergistically in the analysis.

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