

Why Do People Die in Earthquakes?

The Costs, Benefits and Institutions of Disaster Risk Reduction in Developing Countries

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Abstract

Every year, around 60,000 people die worldwide in natural disasters. The majority of the deaths are caused by building collapse in earthquakes, and the great majority occurs in the developing world. This is despite the fact that engineering solutions exist that can almost completely eliminate the risk of such deaths. Why is this? The engineering solutions are both expensive and technically demanding, so that the benefit-cost ratio of such solutions is often unfavorable compared with other interventions designed to save lives in developing countries. Nonetheless, a range of public disaster risk-reduction interventions (including construction activities)

are highly cost effective. The fact that such interventions often remain unimplemented or ineffectively executed points to a role for issues of political economy. Building regulations in developing countries appear to have limited impact in many cases, perhaps because of limited capacity and the impact of corruption. Public construction is often of low quality—perhaps for similar reasons. This suggests approaches that emphasize simple and limited disaster risk regulation covering only the most at-risk structures and that (preferably) can be monitored by non-experts. It also suggests a range of transparency and oversight mechanisms for public construction projects.

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WHY DO PEOPLE DIE IN EARTHQUAKES?
THE COSTS, BENEFITS AND INSTITUTIONS OF DISASTER RISK
REDUCTION IN DEVELOPING COUNTRIES

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Introduction

Natural disasters have killed thousands of people in the space of a few minutes. Their after-effects can kill thousands more over subsequent weeks and years. They can have a huge cost in terms of damaged buildings and infrastructure. And yet, many of the deaths and much of the damage is preventable. This paper focuses on where the great majority of the human cost of disasters is concentrated – the developing world. It examines the reasons behind continued, wide-scale death and destruction from disasters, and what these reasons suggest about effective responses in the context of developing countries.

Earthquakes kill thousands every year. The 8.0 magnitude Sichuan Earthquake in 2008 killed over 70,000 people. The 6.8 earthquake in Algeria in 2003 killed 2,700, the 1999 Marmara earthquake in Turkey killed 17,000 (Escaleras, Anbarci and Register, 2007, Anbarci, Escaleras and Register, 2005). Earthquakes account for the majority of deaths from a range of natural disasters which amounts to about 60,000 people a year worldwide – around 90 percent of which occur in developing countries (OECD, 2008).

Most earthquake deaths are related to building collapse or damage. In the 2008 Sichuan earthquake, for example, hundreds of thousands of buildings – including numerous public buildings such as schools and hospitals – collapsed. Beyond the human toll, the cost of this physical destruction can be considerable. The Marmara earthquake was estimated to have had a direct economic impact of over \$5 billion (World Bank, 2005).²

It is worth noting that while the majority of the human toll of disasters is borne by developing countries, most property damage occurs in wealthy countries (Box 1). The high human toll in developing countries is because despite the fact that it is well known how to design buildings to survive an earthquake well enough to avoid collapse, buildings in poor countries are usually not constructed according to such designs (Box 2). Correct construction of large, reinforced concrete structures in particular takes skills, expertise, time and money. All too often the capacities or the incentives required to ensure robust construction has been missing.

Fragile construction, alongside higher-risk land use practices, account for much higher death rates in similar-sized earthquakes close to population centers in the developing as opposed to the developed world. The 1988 earthquake in Armenia had half the energy release of the 1989 earthquake in Loma Prieta near San Francisco, California, and yet caused 25,000 deaths compared to 100 in San Francisco.³ The 2003 Paso Robles quake in California had the same power as the Bam quake in Iran, the death toll was two in California and 41,000 in Bam. According to later engineering analysis, a major

² To provide some indication of the human toll of an earthquake in a developing country setting as measured in economic terms, using a value of statistical life set at \$250,000, the loss of life alone in the Marmara earthquake ‘cost’ \$4.25 billion. This estimate comes with all of the considerable caveats about putting a financial value on human life.

³ The nature of construction in the two countries –with a much greater use of wood in San Francisco—may also have played a considerable role. Having said that, wooden buildings in the Kobe earthquake were some of the most likely to collapse (Ghosh, 1995)

difference was strict adherence to tough zoning and building codes in California compared to Iran and Armenia (see Box 3).

Box 1: Lives versus property: the differential toll of disasters in countries rich and poor

There is *absolutely no overlap* between the top twenty most costly insured disasters worldwide 1970-2005 and the top twenty worst catastrophes in terms of lives lost. All of the most costly events in terms of property damage hit wealthy countries (where the density of economic activity is higher), all of the most deadly hit developing countries. In addition, eighteen out of twenty of the most costly were hurricanes, typhoons and storms, eleven out of twenty of the most deadly were earthquakes (from OECD, 2008). Why is this? Earthquake deaths in particular can be prevented by engineering approaches that are widely applied in wealthy countries but rare in the developing world. It is more difficult to comprehensively prevent flood and wind damage using similar approaches.

Box 2: Poorly constructed buildings collapse in earthquakes

In the 2008 Sichuan earthquake, early evidence suggests that non-ductile and un-reinforced concrete buildings were particularly prone to collapse. This has been a ubiquitous problem in the developing World. Jain (2005) suggests that in 1999-2000 over 6,000 school buildings were constructed in Gujarat, India using seismically weak pre-cast construction technology. Three quarters of these schools were seriously damaged or collapsed during the 2001 Bhuj earthquake. Deaths from the 1999 Marmara earthquake in Turkey were blamed on collapse due to poorly-constructed reinforced concrete frames, construction using concrete diluted with too much sand, and construction near fault-lines (Escaleras, Anbarci and Register, 2007, Anbarci, Escaleras and Register, 2005). The Turkey experience illustrates that, while well-constructed reinforced concrete buildings are less likely to collapse in earthquakes than un-reinforced masonry, construction is technically complex and requires skilled workers motivated to meet high standards. And when such building do collapse because they are poorly built, they are more likely to kill occupants.

It is not that the world lacks the knowledge to considerably reduce the number of fatalities from natural disasters, then. A combination of better land use, better construction practices and improved preparedness would dramatically reduce risk across the full range of disasters. Why, then, are these mitigation measures not adopted in the developing world?

Disaster protection may be a luxury good in economic terms – demand for protection rises more than proportionally as incomes increase. In poor countries such protection may provide lower or more uncertain returns than a number of other investments in wellbeing – the vast majority of people do not die in disasters, and it may be easier and cheaper to prevent other causes of death. Construction of disaster-resistant buildings might be technically complex, taxing limited design and construction capacities in developing countries. The knowledge and understanding of citizens regarding the risks and mitigation measures around disasters may be limited, reducing demand for safe construction and/or the ability to ensure such construction is being carried out. The design and enforcement of regulations to ensure good construction may also be complex

and prone to failures of governance including corruption. We will see that all of these factors may play a role in the outcome of greater natural disaster fatalities in developing countries. In turn, this suggests a number of recommendations for countries regarding construction practices, public mitigation measures and regulation.

Box 3: Less damage is done by disasters in rich countries because of code enforcement

It is a repeated finding in the literature that fatalities resulting from an earthquake are inversely proportional to the level of per capita income (Anbarci, Escaleras and Register, 2005). This is in large part because of the widespread adoption of proactive measures to reduce disaster mortality introduced in developed countries since the Second World War. As codes improved in the developed world building collapse during earthquakes became less frequent. In Kobe, buildings constructed after a 1981 revision of Japan's building codes were far less likely to collapse in the 1995 earthquake than older buildings. And all of the reinforced concrete buildings which saw story collapse (particularly likely to kill occupants) were built prior to a 1971 code change regarding beam and column ductility (Ghosh, 1995). Similarly, Wharton (2008) notes that within the US, houses in one county hit by hurricane Charley in 2004 saw insurance claim frequencies that varied dramatically depending on if they had been built before or after 1996, when new wind-resistant standards were introduced. Homes built after 1996 had a 60 percent lower claim frequency than those built before 1996.

Individuals, Unprompted, Do Little to Prepare for or Insure Against Natural Disasters

Worldwide, absent legal requirements, individuals are unlikely to take even fairly simple measures to reduce disaster risk. In South Florida, where hurricanes are frequent, it appears that many residents fail to take short-term preparatory measures such as securing bottled water and filling their cars up with gas when storms threaten. Only 17 percent of people surveyed living along the Atlantic and Gulf coasts in the US suggested that they had taken steps to storm-proof their home in 2006 (Wharton, 2008). In 1974, a survey of California homeowners in earthquake-prone areas found that only 12 percent of respondents had adopted protective measures against earthquakes, and the figure was, if anything, lower by 1989. Similarly, even after the Marmara earthquake, willingness of householders to pay for earthquake-proof retrofitting in Turkey, even using subsidized credit, was low (World Bank, 2005).⁴

The market value attached to risk-reduction measures also appears to be limited. While it appears that housing rents in Tokyo are lower in areas of high risk of earthquake damage, and that rents for buildings in high-risk areas constructed prior to strengthened earthquake codes are lower still, the evidence suggests that retrofitting would still only make financial sense for building owners because of a considerable government subsidy (Nakagawa, Saito and Yamaga, 2007). (Furthermore, given that high risk areas are on historically swampy ground traditionally home to the poor, and older buildings are likely

⁴ Even those who do respond to calls for preparedness unsurprisingly favor preparations that are easier to make (moving furniture) over more time-consuming and expensive measures such as structural alteration (Mileti et. al., 1992).

to be less desirable, it is not clear how much even the observed relationships are due to economic response to earthquake risk as compared to path dependency and unobserved quality).⁵ This is all despite high earthquake risk-awareness in the city, the widespread publicity given to the city government's earthquake risk map, the comparative ease of using a building's age to determine earthquake-resistance codes applied to it, and renter confidence in the regulatory system that de jure codes were in fact enforced.

Again, absent legal requirements, few people in risk-prone areas buy insurance.⁶ In the 1996 floods in China, only 2.1 percent of the damage was covered by insurance. During the 1998 floods in that country, only 3.3 percent of damage costs were insured (OECD, 2008).⁷ It is worth noting that in Kobe, Japan, only 2.7 percent of the damage done by the Kobe earthquake was covered by insurance – this is not just a problem of poverty or lack of availability. Nonetheless, in the richest countries as a whole, insurance covered about 30 percent of the cost of natural disasters in 1980-2004 on average, compared to 1 percent in developing countries (Linnerooth-Bayer and Mechler, 2007). This reflects an overall pattern of lower insurance rates for all risks in developing countries.⁸

With regard to business, many firms worldwide voluntarily implement a range of mitigation strategies designed to ensure continuity (or at least reduce the length of interruption). At the same time, available survey evidence appears to suggest that the average business even in high risk areas in rich countries does comparatively little to prepare for disasters – and those preparations that they do accomplish appear to have little impact on their performance post-disaster (Box 4).

At the community level, public expenditure on disaster-prevention is sometimes deeply politically unpopular. While California voters often pass bonds for seismic safety upgrades, in New Orleans, for example, prior to Katrina, the Parish Levee board lobbied for flood protection to the level of a 100-year rather than 200-year hurricane and opposed hurricane protection floodgates at the mouths of the city's drainage canals because the local share of the total cost was considered too high (Burby, 2006). Healy (2008) suggests that government spending on disaster prevention is not rewarded by voters in the US, in contrast to spending on disaster relief, which carries significant electoral benefits. Federal spending on disaster relief in a county can increase the incumbent presidential party's vote percentage by 5 percent in that country compared to no response at all to prevention spending.

⁵ Thanks to Charles Scawthorn for this observation.

⁶ Insurance is of course an inadequate response for loss of life in any case. It also requires very large (advanced) markets --because so much of the damage done by natural disasters is due to big, extremely rare events, it requires considerable aggregation of the insured to produce a diversified portfolio not subject to considerable volatility in payments –evidence regarding the US National Flood Insurance Program suggests even an insurance market as large as the US may not be large enough.

⁷ Wharton (2008) suggests that in the US, insurance rates are lower (although sometimes are legally required to be lower) on buildings and areas where codes incorporate mitigation of losses from natural disasters. Benson and Clay (2004) suggest that this is not the case in a number of developing countries.

⁸ Thanks to Charles Scawthorn for this observation.

Box 4: Business response to disaster risk and impact

In wealthy countries, and in particular with regard to floods and hurricanes, property damage and business interruption form the great part the economic damage of disasters. Surveys of businesses including those in Santa Cruz and Northridge California (after earthquakes) and South Dade County, Florida (after a hurricane) suggest that many businesses were forced to close for at least some period after the disaster due to property damage, loss of lifeline service or employee absenteeism. Longer-term impacts included declining customer traffic due to community damage. Nonetheless, it should be noted that available evidence suggests that, at least in the US context, the vast majority of businesses do recover despite very low levels of disaster insurance and even lower levels of insurance claims.

What determines the extent and speed of business recovery from disasters appears to be primarily the nature of the business (sector, customer base, size), and the damage done to the community in which it operates (including interruption of lifeline services). These factors matter more than direct physical damage to business plant and buildings themselves, and considerably more than disaster preparedness measures taken at the company level.

Alongside the strong influence of disaster impacts beyond company control, the small impact of mitigation measures on outcomes may in part reflect the comparatively limited set of measures taken before (or, indeed, after) the disasters. For the great majority of companies, measures were limited to generic actions like first aid supplies and training rather than complex and disaster-specific measures like structural assessments and business relocation plans. And most measures taken focused on avoiding loss of life rather than business continuity. Perhaps unsurprisingly, larger companies in more regulated industries took more mitigation measures than did others (sources: Webb, Tierney and Dahlhamer, 1999, 2003, Tierney and Dahlhamer, 1997, Chang and Falit-Baiamonte, 2003).

That people in rich and poor countries frequently appear to place a low value on disaster mitigation suggests interpretations of protection as a ‘luxury good’ might be over simple. Similarly, given that rich countries also tend to have relatively well educated citizens with greater access to information, that there is still an unwillingness to pursue mitigation or even insurance in those countries suggests a limited role for ‘lack of knowledge’ in driving apathy towards disaster risk reduction (Box 5). Again, holding other factors including income constant, fatalities per earthquake do not appear to be lower in areas where earthquakes are more frequent (Anbarci, Escaleras and Register, 2005, see also Shaw et. al. 2004). Even repeated experience of earthquakes does not appear to foster (successful) efforts towards mitigation, then.

And that most people who suffer in natural disasters lack insurance suggests a limited role for moral hazard – under-preparation due to anticipated payments from insurers. Even in the US, where there are widespread federal insurance and generous disaster relief programs, the great majority of the financial cost of natural disasters is born by victims (Burby, 2006). In the developing world this will be even more the case, and particularly with regard to those people most at risk of dying in a natural disaster, insurance or government payments would be of little benefit regardless.⁹

⁹ It is possible that reaction to disasters by donor agencies may create at least the appearance of a considerable over-response which might fuel moral hazard in other communities which witness the largesse.

Box 5: Does lack of information drive lack of response?

In the US, information campaigns regarding disaster risk have apparently had little impact on behavior (Praeter and Lindell, 2000). In California, a 1971 law mandating that prospective buyers be informed of a property's location in a surface fault rupture zone had no impact on property prices in those zones (Palm, 1981). In Japan, Shaw et. al. (2004) find that formal education plays a limited role in promoting actions towards earthquake preparedness. A similar conclusion applies to the value of risk-reduction regarding environmental health risk in the US. A study comparing housing prices in areas that qualified for Superfund cleanups compared to areas that narrowly missed qualification found that being put on a list that suggests the need for a significant environmental cleanup effort because of health risks does not reduce rental prices and that cleanups themselves are associated with statistically insignificant changes in property values, rental rates and population (Greenstone and Gallagher, 2008).

The Benefit-Cost of Disaster Mitigation

If neither moral hazard, a lack of recognition of risks or a simplistic valuation of prevention measures as a 'luxury good' appears to fully account for limited mitigation effort on the side of individuals and frequently limited demand for public mitigation measures, might there be a role for the rational calculation of costs and benefits in explaining inaction?

Calculation of the benefits and costs of disaster risk reduction measures such as building strengthening/retrofit involves estimates and assumptions covering a range of factors – strengthening/retrofit costs, building replacement costs, the risk of a natural disaster (and of the scale of that disaster), the risk of damage if a natural disaster does occur, the cost of that damage in both financial and human terms and the discount rate. These last estimates, in particular, involve a difficult calculus regarding the economic value of a human life as well as how differently we value that life today over a life 30 years hence.

Take a base case scenario using estimates many of which are drawn from an exercise comparing costs and benefits of retrofitting apartment buildings in Istanbul to make them earthquake-resistant. This involves an apartment building with a \$250,000 reconstruction cost and \$80,000 retrofit/strengthened construction cost (that will prevent any damage in an earthquake). The probability of an earthquake in any year is set at 2%, and the chance that the building will collapse in an earthquake is 10%. If it does collapse, ten people are assumed to die, with a statistical value of life set at \$250,000. The discount rate is set at 5 percent and the span of years over which we account for costs and benefits is 30.¹⁰ Under this scenario, the benefits of retrofitting about equal costs – the benefit-cost ratio is 1.0.

¹⁰ The construction, retrofitting, deaths are taken from Smyth et. al. based on Istanbul data. Their value of a statistical life is set at \$250,000 for reasons that will be clear in the text –as opposed to the Smyth et. al. figure of \$1,000,000.

Unsurprisingly, changing the base case assumptions (sequentially) has a significant effect on benefit-cost ratios (see Table 1). Halving the retrofit/improved construction cost, doubling the chance of an earthquake or the chance of collapse or the number or value of deaths in a collapse all approximately double the ratio of benefits to retrofitting over costs. Halving the discount rate of doubling the years accounted has a smaller, but still significantly positive impact on the benefit-cost ratio. The effects are similar in magnitude and opposite in direction under the reverse adjustments.

But a significant problem with calculating the net benefit of retrofitting is that all of these numbers are open to significant uncertainty, variation and debate – the base case is very uncertain. Retrofitting costs will vary significantly by building type and location. The probability of a large earthquake strong enough to pose significant risk to buildings is of course highly location-specific and open to considerable uncertainty. How likely a particular un-retrofitted apartment building is to collapse is similarly dependent on a range of design and location factors, some known, some unknown. The number and statistical value placed on people who die in a collapse, which drives the benefit calculation far more than the cost of building replacement in developing country settings, is both uncertain and controversial. Similarly, the appropriate discount rate to use is a matter of some debate, and may vary with regard to the individual and the government.

Looking first at strengthening/retrofit costs, initial construction using designs that are less likely to collapse in earthquakes adds to building cost. One recent estimate for school buildings in a developing country is around 8 percent (Bahatia 2008a) more advanced protection for at-risk housing in Box 7 suggests a similar magnitude, but costs are likely to vary considerably depending on building type and level of protection desired.

Retrofit of existing buildings is considerably more expensive. The retrofit cost in the Istanbul base case above is assumed to be 32 percent of the rebuilding costs (see figures in Wesiner et. al., 2004). Two different approaches to apartment building retrofit retrofit in Istanbul are priced at 19% (external) and 39% (internal) by Sucuoglu et al. (2006). Some retrofit estimates climb above 50 percent (Smyth et. al. 2004b). The cost of retrofitting 3,600 public structures in Istanbul was estimated at \$1 billion – or approximately \$280,000 per structure (World Bank, 2005). Retrofitting is also technically complex, and can be botched as easily as the construction of a new building designed to withstand earthquakes in the first place (Jain, 2005). This suggests that the ‘true cost’ per measure of earthquake safety actually achieved (rather than earthquake safety paid for), may be even higher than the estimated costs.¹¹

Regarding the probability of a destructive natural disaster hitting a particular area, even risk-prone regions very rarely face a major natural disaster because the major impact of natural disasters each year is concentrated in a tiny proportion of the territory at risk from such events (see Box 6). Given that, and the comparatively limited and recent nature of

¹¹ The problem of low returns to investment is a significant one throughout the developing world. Indeed, a considerable macroeconomic literature points out that the only way one can explain Africa’s low growth despite comparatively high investment over the last fifty years is by the fact that much of the investment resources were squandered on building the wrong thing and building it badly (Pritchett, 1996).

mitigation in most countries to date, this suggests that the great majority of disaster-prone areas have seen very few deaths from disasters regardless of the extent of mitigation measures – it is not that mitigation worked, it is that disasters did not occur. In turn, this suggests something about the likely costs and benefits of mitigation measures. In many cases, such measures will go ‘unrewarded’ by saving lives in a disaster.

Box 6: The risk of a natural disaster

One analysis suggests that 3.4 billion people live in areas highly exposed to at least one natural hazard, including 2.3 billion at high risk of flooding and 328 million at high risk of earthquakes (Dilley et. al. 2005). Despite this widespread risk, a very few, very costly events account for most of the global human and economic toll from natural disasters. The top ten natural catastrophes worldwide 1970-2005 in terms of deaths (seven of which were earthquakes, with two storms and one tsunami) account for 1.2 million deaths. Figure 1 displays the cumulative death totals from the world’s biggest natural catastrophes over that period expressed as a percentage of the total natural disaster-related deaths 1970-2005.¹² The figure suggests that the top six events alone account for more than half of all catastrophe-related deaths over the period, and the top twenty disasters account for nearly two thirds of all deaths (estimated from OECD, 2008).¹³

Regarding economic damage, in 1995, over half of total global economic damage from natural disasters that year was caused by the Kobe Earthquake.¹⁴ In 2005, more than three quarters of the global total was accounted for by the effect of Hurricanes Katrina, Rita and Wilma on the US. As with deaths, very big, very rare events are the cause of the most significant damage. In the US, 66 percent of the annual financial costs of flood events involve events predicted to occur less than once every hundred years. For hurricanes, the same figure is estimated at 83 percent (Burby, 2006).¹⁵

Furthermore, the science of earthquake hazard estimation is far from exact. The analysis in the Istanbul base case assumes a 2 percent probability of a damaging earthquake each year in the city, but this number is based on a (best available) estimate. While some areas are undoubtedly more prone to particular natural disasters than others, there is considerable uncertainty as to exactly how prone. Ellwood and Ellwood (1998) note that the Northridge earthquake in California was caused by a fault unknown (and so unplanned for) at the time of the quake. Again, St Louis, Missouri has seen a protracted battle between the Federal Office of Housing and Urban Development and local officials

¹² This is based on the estimate that there are on average about 60,000 deaths from natural disasters a year, from OECD, 2008.

¹³ Similarly, over the past fifty years, about 80 percent of the one million deaths from earthquakes worldwide have been caused by ten great earthquakes (Spence, 2007).

¹⁴ Despite accounting for such a considerable percentage of total global damage from natural disasters that year, Horwich (2000) estimates that the Kobe earthquake reduced Japan’s (physical and human) capital stock by 0.08 percent, which might account for its marginal impact on the country’s GDP growth in 1995.

¹⁵ Burby also reports that repeatedly flooded properties account for 25 percent of claims payments while only two percent of NFIP policies –suggesting that payments are almost all made either to a small number of repeat-flooders or a large number of extremely (100-year)-rarely flooded.

regarding the appropriate level of earthquake building codes to apply based on different estimations of earthquake and damage risk (Praeter and Lindell, 2000).¹⁶

At the level of particular buildings, what makes for the most resistant design at a given cost is also unclear (Ellwood and Ellwood, 1998). It is possible to design buildings in such a way to make them almost immune to damage from any natural disaster foreseeable – but the appropriate level given the risk and the cost-effectiveness of particular designs will both vary considerably even at the community level and will remain uncertain.

The number of deaths caused by a building collapse depends on the type of earthquake or other disaster, building use and size, the time of day and the nature of construction. One example of the potential risks of death involves adobe buildings. About 50 percent of the population in developing countries lives in earthen dwellings, and perhaps the majority of those dwellings are in areas of moderate and high seismic risk. El Salvador and Peru are areas of particularly high seismic activity. In the 2001 earthquake in El Salvador, 1,100 people died under the rubble of 200,000 adobe buildings which were damaged or collapsed. In Peru, an earthquake that same year saw 25,000 adobe buildings collapse, killing 81 people (Blondet et. al. 2003). These numbers suggest that even if you are a householder unfortunate to be resident in an area hit by a major earthquake, and even if your house is subsequently damaged or collapses, the chance of that building damage or collapse causing a death is only between three and six in 1,000.

The estimate used in the base case above regarding retrofit in Istanbul suggests that ten people would die in the average building collapse. In the recent past in Turkey as a whole, 20,000 people have died in earthquakes in which 20,000 buildings have been destroyed (Smyth et al., 2004b). This suggests an average death per collapse ratio of one across all building types, although of course the figure would doubtless be higher with apartment buildings.

Indeed, as a rule, the retrofit costs per occupant are lower in large public buildings (primarily because they have so many more occupants). Because of this, the cost per death avoided in retrofit projects for public buildings is likely to be lower than for private dwellings. One estimate of the cost per life saved for compliance with Section 104(f) of the San Francisco Building Code, which covers earthquake retrofit, estimated that the cost per life saved in commercial buildings is \$430,000 compared to \$4,100,000 in residential buildings (Quigley, 1998).¹⁷

These estimates of lives saved bring us to a particularly contentious number required for benefit-cost analysis – the statistical value of a human life. The original study of the costs and benefits of apartment retrofit in Istanbul cited above used a \$1 million value

¹⁶ Similarly, the US National Flood Insurance Program has been unable to cover its costs as designed in part because it failed to anticipate risks associated with new construction that it insures (Burby, 2006).

¹⁷ Safety at work regulation in the US appears to demand safety measures if they are likely to save workers at a cost of below \$2.8 million per life. Applying a similar yardstick, then, the San Francisco building code makes sense for commercial buildings but not for residential buildings –although this does not account for the benefit of reduced property loss and the need for alternate accommodation in the event of building damage (Quigley, 1998).

(Smyth et al., 2004b). The base case above uses a \$250,000 value. One method to come up with the ‘value of a statistical life’ for benefit-cost is contingent valuation which attempts to place a value on life by asking people or estimating indirectly how much they would pay to avoid situations that might lead to injury or death. Using a range of contingent valuation methods, the value of a statistical life has been estimated at \$519,000 to 675,000 in Santiago Chile, \$413,000 in Taiwan and \$250,000 in rural Thailand, for example. As a rule, values are lower in poorer countries – people have fewer resources with which to avoid risky situations (Viscusi and Aldy, 2003, Liu et. al., 1997, Bowland and Beghin, 2001, Gibson et. al., 2007). One recent analysis suggests that a rule of thumb value of a statistical life would be 60 times incomes in low-income countries (Cropper and Sahin, 2008). This suggests numbers as low as \$30,000 in the very poorest countries. All of these methods are open to both methodological and moral critique, but they do suggest that, for most developing countries at least, \$1 million is an unjustifiably high figure, even if it appears low relative to safety at work requirements in the US.

A different and perhaps less contentious way to look at the issue of the efficacy of the health benefits of retrofit is to think about the relative cost effectiveness of other interventions which save lives. Using the base case above, over thirty years, the average retrofit saves a life at a cost of \$135,000. This is a considerably lower estimate than the \$430,000 figure that we saw for commercial buildings in the US. Regardless, this number suggests an approximate cost per disability-adjusted life year of \$2,600.¹⁸ Note that this does not include the benefit of injuries avoided by building collapse –but even if avoided disability accounts for a considerable part of total disability-adjusted life years saved, costs are still considerably higher than a range of other interventions. In developing countries, millions of people die each year from diseases that can be cured using a simple regime of oral antibiotics, which costs as little as \$0.25. More broadly, there are a range of interventions that cost less than \$2 per disability-adjusted life year saved (Laxminarayan et. al. 2006, Boone and Zhan, 2006). These interventions are far from universally applied in developing countries and in terms of cost efficiency they carry significantly higher health benefits per dollar than retrofit may. In terms of priorities, then, resources dedicated to improving health outcomes should probably be applied first to other interventions than building retrofit.

The focus of the above discussion has been on lives lost. In both human and economic terms, this is probably appropriate for earthquakes in developing countries, where loss of life is the major impact –and especially appropriate when discussing apartment buildings. However, such an approach will miss many of the costs of disasters and the benefits of mitigation measures. In the case of other natural disasters, floods may kill fewer people, but they destroy considerable property. In richer countries, the marginal mitigation measure is already designed to save property, because existing regulations (largely) protect against loss of life. The Northridge earthquake in California killed 72 people, but cost \$6.5 billion in terms of business interruption losses, for example (Mechler, 2005). In the case of commercial or government buildings, there is also a considerable cost of

¹⁸ Assuming the average earthquake victim would otherwise enjoyed fifty years of good health, and not allowing for discounting.

business interruption. And even with apartment buildings, there is the cost of personal property lost and the need to house survivors during reconstruction (although building retrofit itself is also considerably disruptive and may require moving occupants and this is a certain cost we have not accounted for).

Once we have accounted for costs and benefits, given that large-scale disasters are rare, the outcomes of benefit-cost calculation regarding risk reduction for such disasters depend crucially on the discount rate adopted. This is not the place for an extended discussion of the appropriate discount rate to use,¹⁹ but Box 7 suggests that it may be suitable to use higher discount rates for health outcomes in developing countries than it is in the developed world.

Box 7: What discount rate for disaster risk reduction?

Low discount rates may be appropriate if we believe that we should value people in 100 years as much as we value ourselves –this may be a good moral position but not one that individuals tend to follow. Even for public mitigation projects, if we believe that we can generate an economic rate of return of ten percent on some other project, it would be worth investing in that project and using the proceeds to fund a cost-effective health intervention rather than investing in mitigation. In other words, the benefit-cost ratio of mitigation may be positive using a low discount rate, but a low discount rate may also increase the benefit-cost ratio of a number of other investments, which should (still) be undertaken first.

Furthermore, for developing countries it is worth noting that a higher discount rate to risk mitigation measures is rational. Oster (2005, 2006) argues that responses to the AIDS epidemic in Sub-Saharan Africa can be better understood if we take account of the broader risk profile faced by potential victims. Health risks of all types are considerably higher in developing countries, and so the marginal impact of an additional health risk is lower ('if AIDS doesn't get you, malaria will'). A similar rational resignation may play a role in decisions regarding mitigation measures which may only pay off over a thirty or forty year time horizon.

Given that all of the assumptions required to make a cost-benefit analysis of the benefits of retrofit (or other disaster risk reduction investments) are open to considerable uncertainty and debate, it is perhaps safe to say that a strong conclusion in favor of an intervention would need to be based on a large benefit-cost ratio robust to conservative assumptions regarding benefits. A number of existing benefit-cost analyses in the literature regarding retrofitting may not have passed this test. Box 8 discusses two additional exercises in calculating the benefit-cost of retrofit in the case of housing.

The financial proposition facing the individual home or business owner or the government regulator or minister is extremely complex, then – involving high up-front costs for benefits likely to accrue over the long term if they accrue at all. In the aftermath

¹⁹ See Stern (2006) along with Richard Tol's response: <http://www.fcpp.org/pdf/CritiqueofSternReport.pdf> or William Nordhaus' comments: <http://nordhaus.econ.yale.edu/SternReviewD2.pdf> for a discussion of the discount rate as regards climate change risk reduction, and a discussion of the ethical implications of Stern's discounting methodology in Kenny (2007).

of the Marmara earthquake, the Turkish parliament debated enforcing existing building codes and retrofitting private buildings. It may be that concerns about risks and returns moved the Parliament towards a conclusion that such measures were beyond the means of taxpayers to carry out (Anbarci, Escaleras and Register, 2005).

Box 8: Two estimates of benefits and costs of housing retrofit on the back of an envelope

Houses built on hillsides in Los Angeles County are particularly prone to earthquake damage – during the 1994 Northridge earthquake, 4 percent of such houses were damaged.²⁰ The average retrofit cost of such houses, involving an anchored bracing system, is estimated at \$14,000. The likelihood of a hillside house being damaged by an earthquake is about 0.04 percent per year. The average cost of repair or replacement from that damage is in the region of \$100,000.²¹ In the average year, then, the payback on a \$14,000 investment is \$40 in terms of earthquake damage avoided, or a 0.28% real return (based on data in von Winterfeldt et. al. 2000). This does not account for household property damage and the cost of alternate housing while repairs/reconstruction is carried out, but even if these costs doubled repair/replacement costs, real returns would remain significantly below one percent.

Net benefits of retrofit are also likely to be higher where initial building standards are lower –this will be the case in many developing countries. Take the case of adobe buildings. There are about seven million people in El Salvador. Assuming an average household size of five, and that half of households occupy adobe buildings, this suggests that there are about 700,000 adobe houses in the country. If all of the 200,000 damaged and collapsed buildings in the 2001 earthquake were households, this suggests an upper-end estimate of a 29 percent chance of the house being damaged or destroyed by an earthquake. In the year of a major earthquake, this suggests that the chance that an adobe house would collapse and kill someone was around two per thousand. Over the past 100 years, El Salvador has been hit by at least 13 major earthquakes.²² This suggests that in the average year, the chance that an adobe house will collapse and kill someone is approximately 1 in 5,000. Assume that retrofitting costs \$250 per building (the number is estimated from the additional cost of disaster-proofing a house from ISDR and UNDP, 2007 – although note this applied to wind and flood damage). At a ten percent discount rate, this suggests a cost per life saved of around \$121,000 –although note that this does not account for the benefits of avoided rebuilding costs. This is a comparatively high return to retrofit compared to Los Angeles for example, nonetheless, compare this cost per life saved to other health interventions presented elsewhere in the paper.

Regarding public buildings, positive benefit-cost ratios for retrofitting have been estimated in a number of cases – in Colombia, for example (Ghesquiere et. al. 2006). But

²⁰ This amounts to 374 houses. Note this calculation does not include the value of statistical lives saved by retrofit. Of the deaths in LA County due to the Northridge earthquake, only six occurred in single-family homes (Peek-Asa et. al., 1998). It is not clear how many of these six deaths involved hillside houses of the type under discussion in the box. Property damage for these houses alone amounted to approximately \$19 million. Overall, the economic cost of fatal injuries is estimated at only 0.16 percent of the total economic cost of the Northridge earthquake (Porter et. al. 2006), suggesting that a calculation that did include the statistical value of human lives would not considerably alter the conclusions presented in the box.

²¹ A conservative estimate based on Figure 2.1 of von Winterfeldt et al. (2000)

²² http://www.paho.org/english/sha/be_v22n1-earthquakes.htm

how robustly positive such ratios are will depend on the same range of assumptions and estimates that we encountered above.

And despite undoubted benefits to resistant school construction, for example, it is worth comparing the cost of resistant construction to school budgets in developing countries. If school retrofit/earthquake proof construction comes at the cost of building fewer schools and excluding girls and boys from education, the long-term health effects of such construction may even be negative (See Box 9). It is worth noting that even while as many as 2,500 children worldwide die each year in school collapse, more than 10,000,000 children under the age of five die each year from other causes before they can even make it to school – and the majority of those deaths can be easily and cheaply prevented. In areas of very high risk of earthquake, where cheap engineering solutions are available, the benefit to cost ratio of such projects can look very good. If the risk of earthquake is lower, or costs higher, retrofit in particular may look less attractive than other methods of improving child health. This is particularly the case where overall levels of child health are poor, and particularly in cases where earthquake proofing will come at the expense of additional school construction and the exclusion of children from educational opportunities.

A more detailed analysis based on school retrofit in Istanbul suggested that the program would make sense at a value of \$400,000 per life saved.²³ Compare this number to education expenditures in poor countries. ‘Discretionary’ expenditure – money left over after paying teachers’ salaries used to cover supplies, teaching equipment, utility bills, building maintenance and construction—is as low as \$5 per year per primary student per year in many countries (Grace and Kenny, 2003). If the average school size is 100 children, this suggests retrofitting alone would be equal to 16 years of a school’s total discretionary expenditure in many poor countries. This expenditure will actually benefit only some small proportion of the schools which embark on it (in preventing collapse that otherwise would have occurred).

Perhaps more to the point, it is worth comparing the costs of improved school building safety to a number of other efforts to improve health outcomes in developing countries – which we have seen may save lives at far lower costs. When we add in the relative simplicity of the health interventions compared to the complex engineering often required for retrofit, likely benefits appear to skew ever more heavily to health expenditures over retrofitting. As noted in some cost benefit studies of the value of retrofitting projects, it is not uncommon to find that existing construction is substandard and quality control of building materials was limited (Smyth et. al. 2004a). These same problems will reduce the effectiveness of retrofitting projects, thereby (and perhaps severely) reducing benefit-cost ratios.

²³ This exercise by Smyth et. al. (2004a) suggests retrofit costs between \$8-20,000, the loss of fifteen lives in the event of collapse, a replacement cost of \$160,000 and a value of a statistical life of \$400,000. Using a 3% discount rate, assuming that schools are occupied one third of the time (apparently not allowing for holidays and weekends) and earthquake risk calculated for Istanbul, the estimate produces strongly positive net present values. For reasons discussed in the text, some of these estimates and assumptions may be more favorable than justified. Nonetheless, this analysis does suggest that in higher-risk areas such as Istanbul, school retrofitting projects may be justifiable.

Box 9: The costs and benefits of school retrofitting

Designing or retrofitting schools to prevent collapse in earthquakes will save lives. Bhatia (2008b) estimates that around 25,000 children died worldwide over the last decade as a result of school collapse. At the same time, education ministries with limited budgets may face the choice between earthquake safety and constructing fewer schools. If fewer schools being built leads to children going without education for lack of space, this, too, is a life and death decision. Not least, educated mothers see considerably lower child mortality amongst their children than do mothers that have not attended school. One estimate from Desai and Alva (1998) suggests that maternal primary education is related to a fourteen percent lower rate of child mortality. If girls are denied education, it is more likely that their own children will die.

Table Two presents three scenarios regarding the benefits and costs of earthquake proof design/retrofit in terms of child deaths on the assumption that increased school construction costs lead to a proportionate reduction in enrollments. The low scenario uses estimates of design/retrofit that are relatively small (8 percent of construction costs) and a relatively high risk of earthquake deaths in school.²⁴ It also assumes a low rate of overall child mortality and fertility (the rates in Turkey) to calculate the impact of primary education on general rates of child mortality amongst the children of primary students. Under such a scenario, the lives saved due to reduced earthquake deaths are more than twice the lives lost because of increased mortality amongst the children of excluded students. But changing the scenario, assuming a lower risk of earthquake death, a higher cost of earthquake proof construction/retrofit (12.5%) a higher rate of fertility and general child mortality (that in India) dramatically alters results. The lives saved due to reduced earthquake deaths are only 12 percent of the lives lost because of increased mortality amongst the children of excluded students. Using a lower earthquake risk, still, and data for Chad, this drops to around one percent.

This calculation is based on a range of simplifying assumptions. And it does not account for the other benefits of earthquake proofing beyond student deaths. At the same time, it does not account for the other benefits of education beyond reduced child mortality. It assumes that fewer schools being built will lead to a proportionate decline in enrollment –but if more children can be accommodated in each school, this questions the rationale behind a school construction process in the first place. It relies on a single estimate of the benefit of education in terms of reduced child mortality. At the same time, it assumes that retrofit/earthquake proof construction will remove all risk of student death.

Finally, it would be better to both build more schools and build or retrofit them to withstand earthquakes. But this may not be an option for resource-constrained ministers of education. Furthermore, there may be other interventions that can save children at far lower cost. The Table also presents evidence on the cost per student death averted of retrofit. The low scenario suggests this is only \$1,067, comparing very favorably to a range of other child health interventions in developing countries. But the high case suggests a per death avoided cost of \$213,000, considerably higher than many alternate approaches.

²⁴ It is based on the calculation that 2,500 children died a year worldwide over the last ten years, and only 25 million primary students worldwide were in schools at risk of earthquake damage each year –or around four percent of primary-aged children worldwide. This creates an estimate for the percentage chance of death per year for a primary student in schools at risk.

This is not to say that all earthquake mitigation measures regarding public building construction and retrofit in developing countries are an inefficient use of resources. It does suggest the importance of a focus on the most vulnerable schools and buildings, alongside those buildings that are most important in the aftermath of a disaster (not least hospitals) as well as recognition of the tradeoffs involved in expenditure on retrofitting or robust construction.²⁵ It also suggests the importance of an initial focus on disaster risk reduction around the most efficient measures which may involve disaster planning, emergency communications and public infrastructure measures rather than retrofit of individual buildings.

Indeed, to focus on retrofit or even initial design against earthquake damage in individual buildings is to look at some of the disaster risk reduction measures with the lowest benefit-cost ratios, however. Higher benefit-cost ratios perhaps unsurprisingly appear to accrue to risk reduction measures against comparatively common but relatively small scale disaster events – local flooding, for example. We have seen that the large-scale disasters that cause the most damage and kill the most people are (thankfully) particularly rare, and this very rarity reduces the benefit-cost ratios associated with risk reduction.

For FEMA mitigation projects in the US the benefit-cost ratio of flood mitigation projects is estimated at an average of around 5 compared to 1.5 for the average earthquake mitigation measure (OECD, 2008). The available evidence suggests higher benefit-cost ratios to measures that involve preparedness, community-level activities or stand-alone engineering solutions (flood walls, for example) rather than changed construction practices for all buildings or retrofit.

Such government-sponsored community-level disaster risk reduction projects in a range of settings have demonstrated high benefit-cost ratios.²⁶ In particular, there is considerable evidence of quite high returns to programs that emphasize planning and community-level preparedness for floods and cyclones – two studies of such projects in India, which involved construction of an escape route, provision of boats for evacuation, raised water pumps, a village rescue and evacuation team and a flood evacuation plan had benefit-cost ratios estimated between 3 and 20 (ERM, 2005). Similarly, the Bangladesh Cyclone Preparedness Programme (CPP) includes shelters, early warning systems and community-based preparedness measures. The annual operating cost is \$460,000. While it is hard to fully evaluate the effectiveness of the program, it is worth noting the loss of life in three cyclones of similar strength that hit Bangladesh in 1970 (prior to the CPP) and 1991. The 1970 cyclone affected 3.6 million people and killed 300,000 people. The 1991 cyclone affected far more – 15 million people. But it killed 138,000 – around a third of the number killed in 1970. A similar strength cyclone in 1997 affected 3 million people – nearly the same number as 1970. But only 11 people died (ERM, 2005).

²⁵ The October 2005 earthquake in Pakistan destroyed 50 percent of health facilities in affected areas, surely increasing the death toll from the disaster (Bhatia, 2008b).

²⁶ In the US, one estimate suggests that every dollar spent by FEMA on mitigation grants achieves savings in terms of avoided grants and tax revenue losses of \$3.65 (Burby, 2008).

Public engineering efforts to reduce disaster risk have also demonstrated cost-effectiveness. A World Bank appraisal of a flood protection project in Argentina suggested an internal rate of return of 20 percent, and a range of other flood and hurricane protection projects in the developing world (in countries including the Philippines, Argentina, Peru, Indonesia, China and Brazil) have estimated cost-benefit ratios of two and above (Moench et. al. 2007, see also OECD, 2008, Healy, 2008, Mechler, 2005).²⁷

The Role of Irrationalities, Market and Government Failures

Retrofit of private homes against earthquakes may have some of the lowest returns in the arsenal of disaster risk reduction measures, then – but even these measures may be priority investments in comparatively wealthy communities at high risk from large earthquakes and low existing building standards. And other mitigation measures involving public construction protecting against more common disaster risks, for example, carry higher benefit-cost ratios. Yet many such measures remain unimplemented.

It is unlikely that rational, fully informed calculations of the costs and benefits of the whole range of mitigation measures are the sole (or perhaps even the primary) reason for their limited adoption by individuals or governments, then. Greater expenditure on mitigation measures will make more sense in areas where natural disasters are particularly common, and yet the depressing result of cross-country analysis is that, allowing for income and other factors, areas repeatedly exposed to disasters do not see lower per-disaster mortality rates, as we have seen. This suggests mitigation measures are underutilized even where they would carry the highest returns.

It may be that the rational agent model fails with rare catastrophic events, and that consumers and citizens do not correctly evaluate the costs and benefits of (in)action regarding ‘acts of God’ (Praeter and Lindell, 2000). A number of common irrational decision-making devices used by individuals can impact the level of risk-reduction effort undertaken. Experimental and natural observation suggest that people use budgeting heuristics which pressure against mitigation spending, that they display biases in inter-temporal planning and chose inaction in the face of uncertainty, and that they ignore the risks of an event (however catastrophic it might be) if the event is seen as below some threshold of probability (Camerer and Kunreuther, 1989). It is very difficult to calculate the benefits accorded by mitigation as we have seen, suggesting an information gap. Combined with the human tendency to remain passive in the face of uncertain events, this may encourage inadequate mitigation response. For individuals and businesses, there may be excessive faith in government mitigation measures, which further reduces their own incentive to act (Box 10).

²⁷ Although studies do suggest that further flood control measures in Japan would carry very low benefit-cost ratios (OECD, 2008).

Box 10: Too much faith in public mitigation measures?

The existence of public control measures including levees in flood areas encourages construction, but Burby (2006), discussing the situation in New Orleans prior to Katrina argues that “[f]lood control and hurricane protection measures have serious limitations, most of which are not recognized by households and businesses who put themselves at risk by locating in potentially hazardous areas.” These limitations include levees being over-topped because they were not designed for large flood events or were poorly maintained or built. Both factors in the Katrina-related flooding –and more widely, levee overtopping is a factor in one third of all flood disasters in the US.

In addition, while we have seen that moral hazard appears a weak explanation for limited mitigation at the level of the individual, it may be that businesses *do* fail to fully account for the size of earthquake risk related to inadequate mitigation. The owner of an apartment or office building may not take account of the value of the lives and household possessions of renters or users – accounting only for the building value when deciding on the level of additional construction costs to reduce the risk of collapse, for example. In Istanbul, the benefit-cost ratio for bracing apartment buildings to strengthen earthquake-resistance discussed above was estimated as negative if only the value of the building itself is taken into account. Adding a (generous) estimate of the statistical value of a human life, returns became positive, as we have seen (Moench et. al. 2007). But unless apartment owners (are made to) take account of the risk to life, they are unlikely to brace their buildings.²⁸ Similarly, individual owners will take little account of the damage and risk to life presented by their buildings collapsing on its neighbors.

Given that such mitigation measures involve complex construction techniques, it is unlikely that untrained renters, users or neighbors will be able to assess if the work has been carried out correctly. This ‘information asymmetry’ applies to the building owner in addition, who may be at the mercy of a construction firm which lacks the skills, capacity or will to build structures properly. In turn, the construction firm will rely on designers and architects to provide suitable plans – through incompetence or simply to save on effort, the designers and architects may submit unsafe designs. Even if the construction firm recognizes the design flaws, collusion between builder and designer can hide these issues from the building owner – or collusion between all three can hide unsafe construction from renters and users.

Such concerns around market failure may account for the prominent role of regulation in the construction industry. In addition, government has a role in accounting for the interests of the occupants of public spaces and, more directly, the occupants and users of publicly owned buildings and transport routes. They also have a role in the provision of ‘public good’ mitigation measures – flood walls, for example. All of this suggests a considerable role for government to reduce disaster risk, but also for governance failure or poor institutional design to exacerbate the risks faced by individuals from natural

²⁸ It is worth noting that the Tokyo case cited earlier suggests that even where renters can accurately evaluate the level of mitigation effort undertaken, they still do not value it highly enough to justify the cost.

disasters. In this regard, it is worth noting that, concerns regarding benefit-cost aside, many countries do have building codes on the books that set standards for earthquake-resistant construction – and yet buildings routinely collapse in earthquakes. This suggests an important additional element to the story regarding the political economy of the implementation of regulation.

The Political Economy of Regulation

That consumers are ill-equipped to verify the quality of construction may account for the pressure for government regulation. The information asymmetry could be overcome by private agencies – on the model of credit rating agencies, for example. In public buildings in particular such a model would be likely unworkable as a tool to improve safety. Imagine an office worker relocated to an office with a higher ‘earthquake risk rating’ because of lower quality construction. Would it be plausible for them to quit? Or imagine shoppers entering a store pausing to check the earthquake risk rating register to evaluate the chance they would die while in the shop. For private houses, the risk rating model might be more plausible – indeed, publicly provided information on location-based earthquake risk is part of the approach used in Tokyo and California, as we have seen. That there is limited consumer response in these cases may be one reason why public safety advocates (and risk-averse consumers worried they won’t get a return from their safety investments) push for regulation. In addition, insurance and construction firms in strong governance environments may both benefit from such regulation. Insurers can be guaranteed a certain quality of construction in the buildings they insure without the cost of assessment. Contractors firms gain additional business from retrofit and earthquake-proof construction.²⁹

The incentives for insurers and contractors to push for such regulation are lower in weaker-governance economies. Owners can avoid regulation because of weak enforcement or bribery. So insurers can’t be confident that buildings will be constructed according to code. And contractors may lose out to informal construction techniques or less scrupulous firms if they insist on building to code. But for a corrupt senior official in charge of construction, passage and non-enforcement of codes may be an optimal approach to the regulation of construction. Overseeing an enforcement regime allows for the collection of payments from construction firms that flout the codes. The complexity of construction will mean that shoddy construction is unlikely to be detected in the short term. Buildings may subsequently fail but this is likely to be some time in the future when the official has moved on to another position. Regardless, the official can blame limited capacity or construction firm obfuscation and is unlikely to face significant risk of penalty.

These factors may explain why poorer countries are less likely to have regulations which comply with international earthquake design codes and standards, and less likely to enforce them if they are on the books (Anbarci, Escaleras and Register, 2005). A review of natural hazard-related building codes in developing countries found that the existence

²⁹ Thanks to Phil Keefer for this observation.

of such codes varied significantly across countries –the two countries surveyed in Africa had a total lack of hazard-related codes (World Bank 2008).³⁰ Even where codes existed, they were frequently hard to access and their legal status was often unclear (as to being a guideline or a legal requirement).

Istanbul lacked significant seismic building codes until 1997, but even when enacted, Istanbul’s codes were rarely enforced – which suggests an additional problem with regulatory institutions. The Marmara quake in Turkey which killed 17,000 was of a magnitude and type accounted for by existing design specifications in the Turkish seismic code (Sezen et. al. 2002) – it was not lack of regulation but lack of enforcement which led to deaths. In Istanbul prior to the quake ‘amnesties’ for buildings known to be sub-code were passed repeatedly, and municipalities responsible for enforcement lacked the capacity to do so. An estimated 70 percent of housing did not conform with extant standards of resistance to seismic risk (Escaleras, Anbarci and Register, 2007, Anbarci, Escaleras and Register, 2005, World Bank, 2005).

Problems went beyond official amnesties to limited capacities and rent-seeking. Correct construction of reinforced buildings is technically complex, and in many developing countries the requisite skills are scarce not only to construct but also to monitor construction (Anbarci, Escaleras and Register, 2005).³¹ Municipalities including Istanbul had weak and underfunded municipal engineering and planning departments staffed with unaccredited engineers prone to corruption. In 2006, 40 municipal officials in three towns in Turkey were arrested for taking bribes in return for allowing unlicensed construction (Escaleras, Anbarci and Register, 2007)

Again, this problem is far from unique to Turkey. Cross-country statistical analysis by Escaleras, Anbarci and Register (2007) suggests that, allowing for income and a range of other factors, countries perceived as more corrupt see higher earthquake fatalities. Jain (2005) discussing “the Indian earthquake problem” suggests why this may be the case. He notes that seismic code building certificates are “easy to procure, sometimes on payment of small money, and need not have any correlation with how a building is built.”³² After the 2001 Bhuj quake in India, it emerged that no on-site inspection of the

³⁰ This is not to say the problem is unique to developing countries. Counties and cities in the US located in states which have adopted comprehensive land planning requirements for local government have seen lower national flood insurance program claims and payments. This is true even if the requirements do not explicitly require attention to natural hazards. Despite this, less than half of US states have adopted such planning requirements (Burby, 2006).

³¹ Again, this is not a problem specific to developing countries. Dade County, Florida which suffered the greatest damage during Hurricane Andrew in 1992, had 60 building inspectors to police 20,000 new buildings constructed each year –suggesting an average of 35 inspections per inspector per day (IRC and IPLR, 1995). Furthermore, as many as one half of local building officials working on the Gulf coast did not understand or did not enforce hurricane-related codes in 1992. Dade County’s failure to enforce codes alone accounted for \$4 billion of additional damage to insured buildings caused by Hurricane Andrew. (Burby, 2006)

³² It is worth noting that, at least within countries, the causal relationship between corruption and natural disasters may run both ways. Leeson and Sobel (2008) find that in the United States, states which have more natural disasters see more corruption-related convictions per capita. They provide some evidence that this is because poorly managed windfalls in the form of Federal Emergency Management Agency relief

construction process had been required, supporting widespread evasion of building codes. Within a week of the quake, 37 builders, architects and engineers of failed buildings were charged with culpable homicide and criminal conspiracy.³³ Similarly, in the 2002 earthquake in Changureh, Iran (which claimed 261 lives) and the 2003 earthquake in Bam, Iran (41,000 deaths) a major factor was the non-enforcement of building codes.

Indeed, construction is an industry that is perceived as particularly poorly governed worldwide. Transparency International's 15 country poll ranked construction as the most corrupt industry of all (see Figure Two).³⁴ Similarly, a Control Risks survey of international companies which asked if they had lost a bid in the past year because a competitor paid a bribe found that public works/construction firms were most likely to suggest this had occurred (Bray, 2005). Again, construction firms surveyed in Eastern Europe have significantly larger bribe budgets than the average firm, and they bribe more often. In particular, they reported themselves more likely than the average firm to make payments for licenses and permits. Data from global enterprise surveys similarly suggests that across a range of countries, construction permitting appears to be a regulatory area particularly prone to corruption. Once again, poorer countries appear to have more corrupt contracting, permitting and licensing procedures on average – see Figure 3 (from Kenny, 2008).³⁵

This all suggests caution in assuming that additional regulation involving earthquake resistant design will necessarily translate into safer buildings rather than additional rents (see Box 11). Indeed, regulation can provide competitive advantage to those firms best at corrupting officials rather than those firms best at constructing buildings, driving down the quality of all construction. Because non-code construction is illegal, it provides ongoing opportunities for rent-seeking from officials while denying many owners legal title. In Addis Ababa, for example, high construction standards have relegated many low-income households to ownership of illegal property with no rights to sale or transfer (Buckley and Kalarickal, 2006). In Turkey and Karachi in Pakistan at the turn of the Millennium as much as half of the urban population lived in illegal settlements for similar reasons (World Bank, 1999).³⁶ And householders without legal title face further disincentive to invest in improving the quality and safety of their home.

increase the level of local corruption –they suggest each \$1 increase in per capita average annual FEMA relief to a state increases the corruption convictions per capita by 2.5 percent in that state. In other words, at least within countries, natural disasters can be a cause of corruption.

³³ Again, this is also a problem in wealthy countries. In the US, local governments were forced to adopt zoning and building regulations to reduce potential flood damage as part of the conditions for communities to access national flood insurance. But code violations are rife, as we have seen in the case of Dade county above.

³⁴ http://www.transparency.org/policy_research/surveys_indices/global/bpi

³⁵ The nature of the causality between weak institutions and low income is a topic of considerable debate. See Sachs (2003) versus Rodrik et. al. (2002). Regardless of the exact nature of the link (and surely causality runs in both directions), the correlation remains and is persuasively strong.

³⁶ A second set of perverse incentives can involve rent control. If building owners cannot raise rents on current tenants, in extreme cases it might be advantageous to them for buildings to collapse so that they can put up a new structure with new tenants who will pay higher rents (this suggested by Apurva Sanghi)

Box 11: Does regulation improve construction outcomes in developing countries?

Weak oversight and corruption in construction regulation may help to account for the apparently fragile relationship between regulations on the books and outcomes on the ground. *Doing Business* surveys suggest that the number of procedures required in order to get permission to build a warehouse varies considerably between countries. The average number of procedures was 16 in rich countries, and 20 in low income countries, with the time taken to comply 157 days in rich countries and 229 in poor countries. It is not clear that this extra regulatory burden is improving outcomes -there is no correlation between the number of procedures and the number of worker accidents across countries, for example. More broadly, greater regulation in countries at similar levels of income is associated with lower compliance with international quality standards as measured by ISO 9000 compliance, more perceived corruption and a larger informal economy (Djankov, La Porta Lopez-de-Silanes and Shleifer, 2000).

These results should not be taken to suggest that regulation is an unnecessary burden in developing countries, but it should instill caution regarding solutions which involve even greater regulation –will that regulation be enforced fairly, or will it act as one more source of rents for officials, with little impact on quality and safety?

Given the high cost of complying with regulations regarding retrofit and earthquake proofing, their comparatively low benefit, and the significant negative side-effects of such regulation in environments prone to corruption, the optimal solution may be to focus, simplify and limit such regulation – alongside similarly complex rules regarding land use. In particular it might be best to focus limited regulation and oversight capacity in areas where potential returns are highest – large public buildings, for example.

The Political Economy of Public Construction Projects

In addition to their role as regulators, government officials are the largest customers for construction firms around the world. Given the repeated accusations regarding the particular fragility of government buildings such as schools and hospitals in recent earthquakes, it appears likely that there are a particularly acute set of political economy factors related to such construction.

Benefit-cost analysis may bring further clarity to the tradeoffs presented to an official deciding on construction methods as much as for private individuals. As it is more expensive to construct earthquake-resistant buildings, the official faces a choice between construction of more buildings with a risk of collapse at some point in the next 100 years or construction of fewer buildings with lower risk of collapse. These costs of mitigation are immediate, then, but the visibility of such measures is low, and any benefits are likely to accrue to a politician's successors. And we have seen that public appetite for such construction appears to be limited.³⁷

³⁷ An additional element that applies to local construction projects is the potential moral hazard presented by levels of government. Local governments may feel able to skimp on mitigation on the implicit

Furthermore, given the limited visibility of poor construction, officials can benefit from a strategy of promising disaster-resistant (or at least good quality) construction without delivering on that promise. Officials and/or construction firms can share the savings from skimping on materials in the form of corrupt payments. The problem is particularly acute because of the diffuse nature of the ‘clients’ of a government construction project who could monitor the quality of delivery. Generations of primary school children, most as yet unborn, are perhaps not the most informed observers of shoddy construction practices in the schools they will occupy, nor the most powerful constituency to counter such practices and demand restitution, for example. The ‘long chain of accountability’ bedevils all public provision of services – service providers are separated from accountability to citizens by layers of government. The chain of accountability is particularly fragile when it is not yet clear which citizens will benefit from the government services to be provided and it is difficult for non-experts to judge the quality of construction.

In part because of the opaque nature of public construction projects, construction firm bribery related to public building contracts is very common according to an Eastern European firm survey. Of a construction firm’s total bribe budget – which we have seen is larger than the average – a larger percentage goes to gain government contracts – an average of 23 percent for construction compared to 15 percent for all firms in the sample. Construction firms in Eastern Europe believe that a typical payoff made for securing a government contract in their industry is around seven percent of the contract value (Kenny, 2008).

Investigations of World Bank-financed projects frequently reveal shoddy construction practices related to corrupt payoffs (see Kenny and Musatova, 2008 for a review). In Indonesia, for example, a physical audit of a World Bank financed community-driven development program that focused on road construction found that an estimated 24 percent of expenditures were ‘lost’ in materials theft, probably orchestrated by village heads who oversaw projects (Olken, 2004). Figures 4 and 5 illustrate two concrete beams that have been poorly constructed in ways that significantly reduce structural integrity of the building – in these cases due to ‘honeycombing’ and debris embedded in the concrete. Both are photos of work financed by Bank projects which are suspected to have been victim to corruption.

It should be noted that there is also considerable scope for shoddy construction linked to political pressure, limited capacity and straightforward incompetence. Poor design and construction was a factor in the failure of levees in New Orleans after Katrina, for example – this may well have been due to innocent incompetence rather than corrupt payoffs. But the result is the same – government buildings and infrastructure are often poorly constructed in a manner that reduces the life of the investment and considerably increases the risk that buildings will collapse or be damaged in natural disasters. This

understanding that national government will provide in the event of a disaster. The post-Katrina blame game between local, state and national government in the US regarding both preparation and response suggests that such a strategy can be at least partially successful.

emphasizes the importance of using simple designs more robust to poor construction practices and (hopefully) more easily overseen by non-engineers in terms of quality of construction.

Responses

Figure 6 presents an *illustrative* mapping of disaster risk reduction measures on two axes – benefit/cost of the measure and institutional complexity. The placement of particular mitigation measures within the map will depend on geographic location, country context and so on. For individual cities or communities, a first step in thinking about disaster risk reduction might be to develop a context specific mapping of potential measures along these axes. The measures that are to be prioritized are those that save the most lives at least cost with the minimum requirements in terms of institutional capacity. The arrows to the right of the chart suggest some factors that will change the priority – not least, the risk posed by disasters, and (for building retrofit) the occupancy level of the building – with mitigation measures for high occupancy structures producing higher returns. One arrow also suggests that the decision regarding implementation of any particular mitigation measure should also take into account other methods to achieve the same end. If the goal is to protect lives, it may be the same resources are better spent on an expanded vaccination program, for example. Overall, it will be a decision based on available resources, capacities and priorities exactly how far cities and communities move from top left (cheap and simple) to bottom right (expensive and complex), but, regardless, it would be best to *start* with solutions in the top left quadrant.

This will be a decision that will be highly location specific. Figure 7 provides a map of earthquake risk for Central America, with white and green representing low risk and red high risk. Clearly, there is considerable regional and sub-regional variation. Decisions on the level of mitigation may not need to be taken at the local level, but they should clearly respond to local conditions – a uniform national standard is unlikely to be appropriate (this is clearly also the case for cyclone and flood damage).

While country and community context will lead to different mapping of individual responses, we have seen that retrofit of private homes against earthquake damage can be very expensive and technically complex to complete and enforce worldwide. By comparison, regardless of context, emergency communications systems which can be utilized in a range of disaster conditions and require little in the way of complex (re-) construction are likely to be both comparatively cost-effective and institutionally simple to implement. This suggests priorities for international agencies seeking to reduce the risk from future disasters. It also suggests that measures are not, in reality, always prioritized in a reasonable manner. In countries rich and poor, the simple logic of prioritizing cheap, institutionally simple responses does not always operate.

A broad concern with the comparative cost-effectiveness of some mitigation measures in some circumstances should not overshadow the efficacy of a number of simple approaches that will save both property and lives in a wide range of circumstances.

Furthermore, the apparent difficulties of regulating construction do not imply that the best regulation is no regulation. Especially for large public buildings, a lack of appropriate codes for construction would be a derogation of government responsibility (it is a derogation that remains in a number of developing countries). It may be that some regulations are better abandoned than left as mere tools for rent-seeking, but many regulations are undoubtedly necessary, and this highlights the importance of improving the efficacy of regulatory bodies.

Regarding building regulations in developing countries, for private homes and other small buildings, it may be that the best default approach is to educate rather than regulate, leaving regulatory construction engineers and planners to focus their efforts on relatively few high-traffic public buildings. Where much construction is informal, demand for risk mitigation is low and governance is poor, regulation is far more likely to be a source of bribe payments than improved safety and may have indirect impacts which actually reduce the quality of construction. In particular, with adobe buildings, home to fifty percent of people in developing countries, as we have seen, the majority are built by the householders themselves. This suggests the importance of education and outreach (instead of regulation) regarding simple techniques to improve construction quality such as ensuring the soil contains enough clay (using the ‘dry strength test’), designing buildings with suitably sized wall openings and heights, considering the use of cane reinforcement and so on (Blondet et. al., 2003).

With larger buildings and public spaces, cheap and simple approaches to mitigation need to be developed and put in place, and in environments where capacity is low and the risk of corruption is large, this suggests a radically different approach than adopting US or EU regulations and codes en bloc. There has been considerable research and development regarding comparatively simple building practices that can reduce risk of collapse – governing issues such as window and door size and placement, wall width and building heights. Such approaches have the advantage of being comparatively straightforward for even unskilled labor to implement, and comparatively straightforward for unskilled and ex-post evaluation. This not only reduces the burden on regulatory agencies, but also allows for simple and independent civil society review of the performance of the regulator itself.

Improvements in the regulatory regime will involve abandonment of codes that can not, should not, or will not be enforced as well as replacing codes which rely considerably on subjective judgment or are complex to verify with codes that are low-discretion and easily verified ex-post by unskilled third parties. This may involve moving the regulatory burden from the construction phase to later or earlier phases (perhaps monitoring material quality at the factory gate, for example, rather than on the building site).

Of course, this will not be possible in many cases – codes regarding reinforced concrete structures are likely to require expert monitoring during construction whatever the circumstances, for example. Because of this the range of tools to strengthen performance of regulatory agencies need to be applied. This might include that:

- The construction regulatory body should be housed in a separate Ministry from the major government clients of construction services (for example, the Ministry of Transport) and the major providers (the Ministry of Public Works). This is the case in Chile, for example.
- Officials should be appointed on the grounds that they have the right skills for the job, using competitive HR processes. They should be paid at rates that reflect the market value of their skills. Regulatory bodies and regulatory staff should be subject to audit and lifestyle checks. They should be held accountable to published standards of behavior and performance targets. They might be rotated from one geographic or sectoral focus to another at regular intervals to reduce the risk of capture by a particular set of firms. All of this is standard good practice in the public sector as a whole.
- Decision-making regarding regulations and regulatory enforcement should be transparent – with public hearings and stakeholder input combined with publication of deliberations, code changes and enforcement paperwork. There should be a clear and transparent appeals process. Regulatory enforcement should be subject to periodic (unannounced) third party oversight or review by suitably skilled professionals independent of the regular management structure of the regulator. Again, much of this is standard good practice for regulatory bodies worldwide.

In addition to regulatory tools designed to reduce the risk of building collapse and regulatory reforms designed to improve the implementation of regulation, an additional tool is deterrence through criminal penalties for firms and owners who construct unsafe buildings that subsequently collapse. The UK already allows for conviction of senior company officials in cases where gross negligence leads to death. A law to extend the culpability of senior company officers in cases where the way a company’s “activities are managed or organized” is causally related to a death and “amounts to a gross breach of duty of care” is working its way through the UK Parliament (Kenny, 2008). In addition, there should be clear civil liability for damage caused by such collapse, perhaps combined with a requirement for liability insurance for construction firms which work on large public buildings.

For government construction, bid documents and contracts should specify costs and obligations related to regulatory compliance in areas such as building codes and standards. By inserting compliance obligations in bid documents and contracts, regulatory compliance moves from a burden on a competitive bid to a service to be paid for and monitored during implementation (Kenny, 2008). But if it is likely to be impossible to monitor construction to high standards in areas such as the correct use of complex building approaches (such as the use of reinforced concrete), it may be better for particularly sensitive buildings to lower specifications (abandon the use of steel, for example) which can be more easily overseen.

Government construction operations should also operate under a similar set of oversight and transparency mechanisms that have been described for regulators. Chile is one country that has moved a considerable way towards reform of public works – including

private competitive provision measured on performance and overseen by an independent regulator (see Box 12).

Box 12: Chile's reform of public works

Chile's Ministry of Public Works relies heavily on private provision, with 65 percent of investment resources for public works provided by the private sector. An independent regulatory body, the Superintendent of Public Works, will oversee transparent concession contracts oriented towards outputs and performance rather than inputs or investment mandates. A new set of benchmarked service standards will drive contract design and oversight, leading to 'conservation' concessions for road networks, for example. Model contracts will be designed to maximize competitiveness in the bidding process as well as focus on outcomes. The regulator will oversee both implementation and any contract renegotiation

Construction procurement and infrastructure operation should be designed to improve the transparency of the project cycle, increase civil society participation, reduce the discretionary power of individual bureaucrats and improve financial and physical auditing improve the design of competitive processes. With the government as customer, in addition, the full range of procurement oversight and transparency tools can play a role in improving the delivery of a quality building.

In order to help monitoring groups to determine if citizens are getting what they paid for, contracts and amendments should be published. Many countries provide access to contracts if a specific case is made under a Freedom of Information law, and the government of the Australian State of Victoria publishes all contracts (including contract revisions) for contracts worth in excess of AUS\$10m (around USD \$7.7m) as a matter of course (Kenny, 2006).³⁸ DfID's Construction Sector Transparency Initiative, which the Bank is supporting, is loosely modeled on the Extractive Industries Transparency Initiative and is designed to bring a greater level of openness to government contracting in construction. It will foster publication and review of key project details including budgeted and actual payments, a project description and any project evaluation.

A number of public construction projects have involved civil society oversight, and this includes projects designed to improve resistance to natural disasters. The program designed to avoid school building collapse in India discussed earlier incorporated oversight. Headmasters and community leaders were briefly trained to detect variation from approved building design during school construction, using pictures of incorrect and correct building models to illustrate the difference (Bhatia, 2008a).

Conclusion

The sad fact is that people in developing countries die from a range of easily preventable causes all the time. Indeed, they all too often die from causes that are more easily prevented than disaster-related mortality. One million people die directly from malaria, and the disease contributes to another two million deaths, each year. That's about 50

³⁸ Maximum disclosure of contract details surrounding consultants is perhaps particularly important, because this is the area where price-based selection for well-defined deliverables is least plausible (which in turn provides considerable discretion to selection committees).

times the burden of natural disasters. And highly cost effective anti-malarial measures include treated bed nets that can be produced and delivered for around \$10 – without the need for advanced engineering talent and advanced regulatory oversight. It may be that relatively low expenditure on costly endeavors like earthquake-proofing low-occupancy buildings makes sense for many in developing countries –even those in quite high-risk areas. If the goal is to save lives, the money could be better spent on nutrition, bed-nets or antibiotics.

Having said that, for high-occupancy buildings in areas of particularly high risk, considerable expenditure may well be justified. Furthermore, even in areas of moderate risk, low cost building and siting practices to reduce the risk of disaster damage may well make considerable social and financial sense. And the benefits of improved building practice are likely to extend beyond their role in disaster risk-reduction – to lower maintenance and longer building life, for example.

This suggests a multi-prong strategy for construction stakeholders in the developing world: (a) the development and dissemination of low-cost techniques to strengthen buildings, (b) the passage of simple, low-discretion and (preferably) transparent regulations regarding construction practices on large public buildings and improvements in the quality of regulatory enforcement, and (c) the incorporation of appropriate mitigation measures in government contracts, transparency in that contracting and oversight in its implementation.

More fundamentally, a range of other public disaster risk reduction measures are likely to carry particularly high returns – measures such as emergency preparedness and emergency communications systems are likely to make a significant, cost-effective difference in the poorest of communities. Attempts to reduce the human toll of natural disasters should focus on these areas first, and consider more expensive and complex solutions only after analysis of economic and technical feasibility.

Table 1: Benefit-cost ratios for retrofitting buildings

	Base Case Value	B/C if costs/rates halved, benefits/time doubled (sequential)	B/C if costs/rates doubled, benefits/time halved (sequential)
Retrofit cost	\$80,000	2.0	0.5
Probability of earthquake	2%	2.1	0.5
Chance of collapse	10%	2.1	0.5
Deaths in collapse	10	2.0	0.6
Value of statistical life	\$250,000	2.0	0.6
Discount rate	5%	1.4	0.6
Years accounted	30	1.3	0.7

Table 2: Relative Benefits of School Proofing/Retrofit Under Three Cost Scenarios

	low	medium	high	Notes
Retrofit/build cost addition (over non-proof) (%)	8	12.5	20	Costs of construction/retrofit to make building strong enough to avoid death in the event of an earthquake. India estimate from Bhatia, 2008 for low case, Istanbul estimate from Smyth et. al., 2004a for medium case, Algeria estimate from Wisner et. al. 2004 for high case
Related reduction in attendance (%)	7	11	17	Assuming retrofit/improved build costs lead to the construction of fewer schools and (therefore) lower school attendance.
Child mortality reduction associated with female education (%)	14	14	14	Reduction in child mortality taken from Desai and Alva, 1998
Current child mortality rate per 1000	32	85	200	Current child mortality rates from World Bank (2008). Low is for Turkey, medium for India, high for Chad.
Child mortality rate change per 1000	4	12	28	Absolute change expected based on expanded primary education.
Fertility rate (per woman)	2.2	2.9	6.4	Current fertility rates from World Bank (2008). Low is for Turkey, medium for India, high for Chad.
Fertility rate (per student)	0.9	1.3	1.9	Fertility rate per student, allowing for percentage of primary students that are girls from World Bank (2008). Low is for Turkey, medium for India, high for Chad.
Child mortality due to school absence (deaths/1,000 students)	0.31	1.69	8.66	Student fertility rate multiplied by mortality rate change and reduction in attendance
School earthquake deaths/yr (per 1,000 students)	0.1	0.025	0.0125	Based on global data on deaths in schools from earthquakes from Bhatia, 2008 (2,500/year) and estimates of students in schools potentially at risk of earthquake - -25m at risk for the low rate, 100m for medium, 200m for high.
Risk of death over eight years (per 1,000 students)	0.8	0.2	0.1	Based on an eight year primary curriculum
<i>Deaths saved from retrofit % lives lost from school absence</i>	<i>258</i>	<i>12</i>	<i>1</i>	
Basic build cost/ student place (\$)		100	400	Using percentage retrofit costs from above and school construction costs in low case based on India from Bhatia, 2008, high case based on Algeria from Wisner et al 2004.
Risk of death over 30 year building life (per 1,000 places)		0.75	0.375	
<i>Cost per student death averted (not discounted) (\$)</i>	<i>40</i>	<i>16,667</i>	<i>213,333</i>	

Figure 1: The concentration of deaths from natural catastrophes, 1970-2005

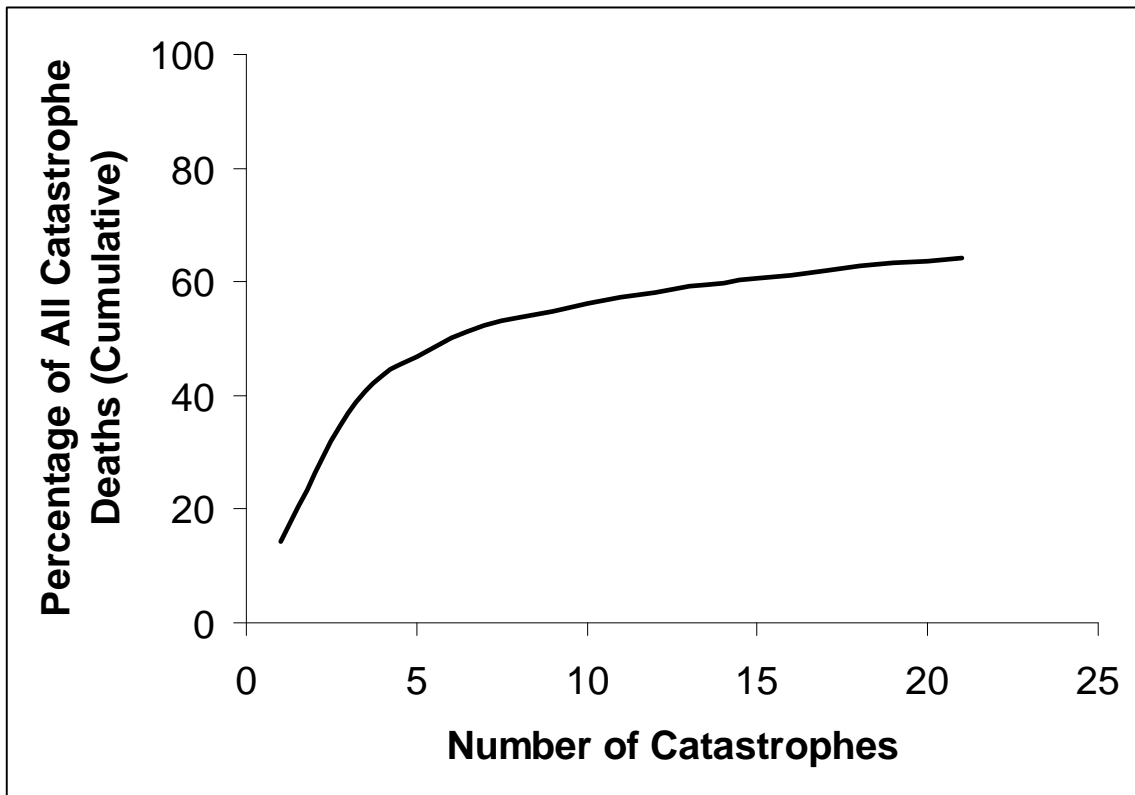


Figure 2: Relative Corruption of Construction

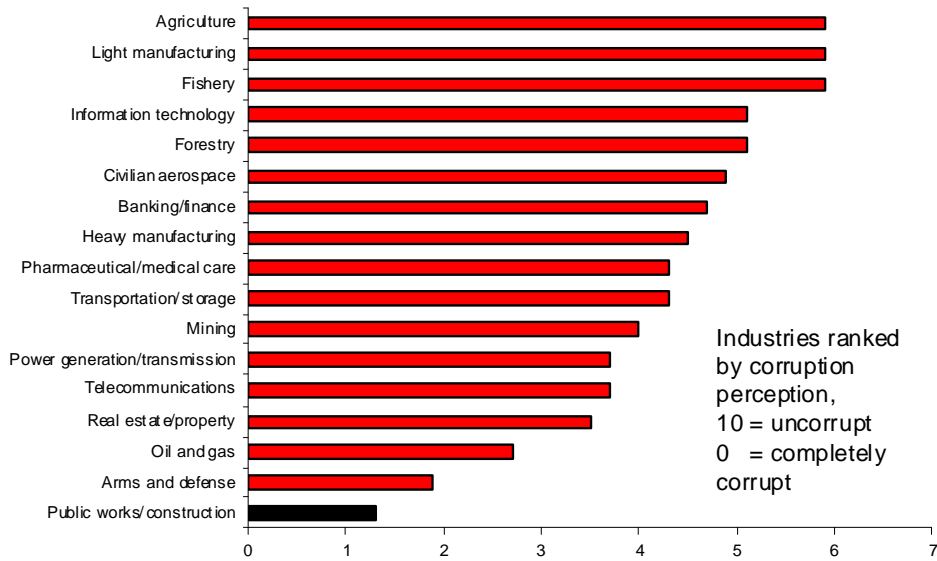


Figure 3: Construction-related corruption across countries

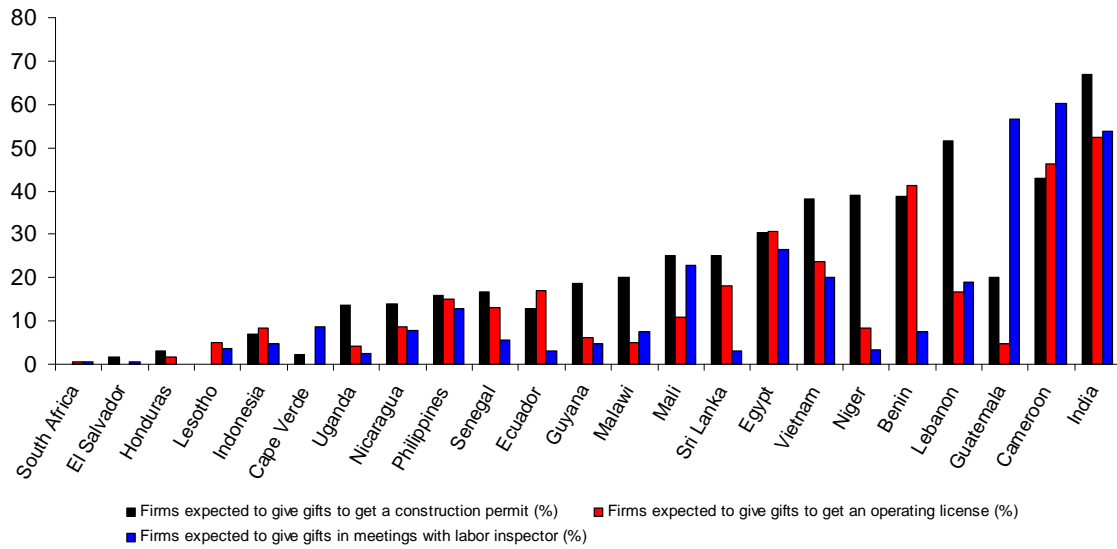


Figure 4: Debris embedded in a concrete support beam



Figure 5: "Honeycombing" - caused by shoddy, cost-cutting construction practices



Figure 6: Illustrative mapping of cost and complexity of mitigation measures

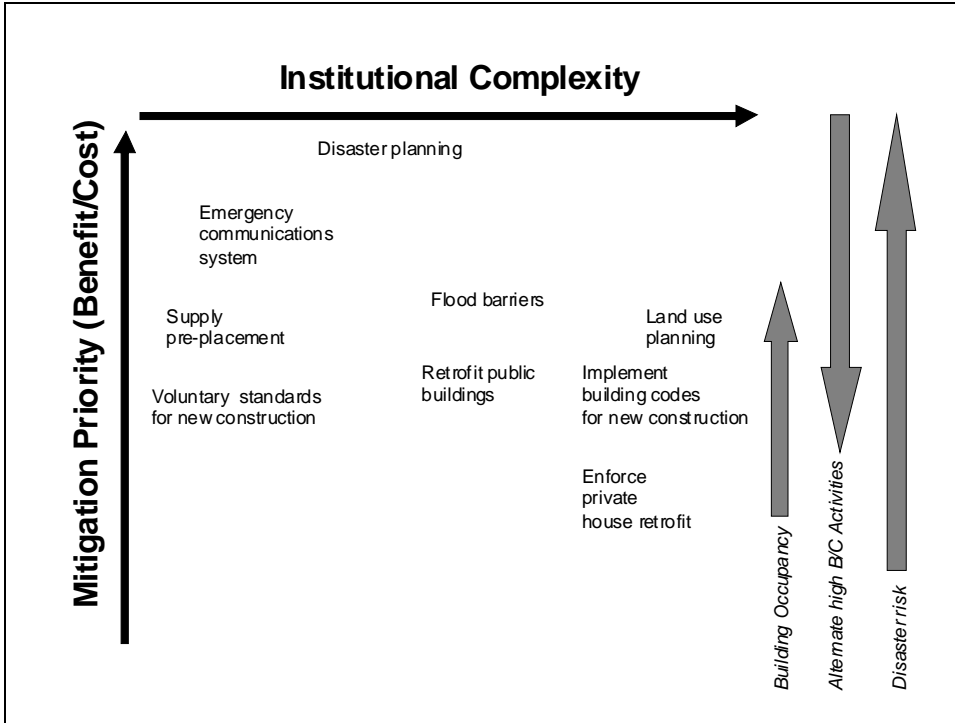
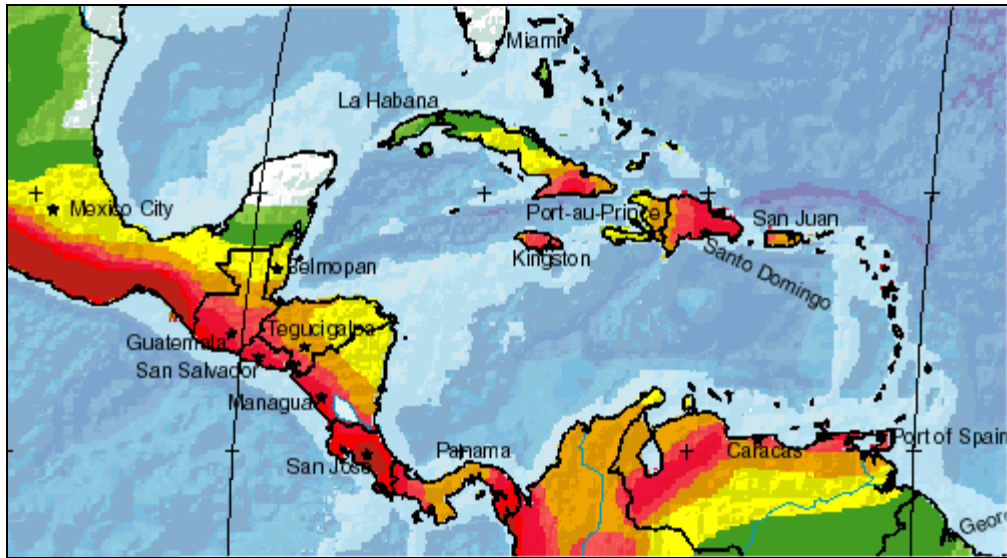


Figure 7 : Central America Earthquake Risk



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