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Estimating the Value of Foresight: Aggregate Analysis of Natural Hazard Mitigation Benefits and Costs

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Abstract
Hazard mitigation planners claim that foresighted present actions and investments produce significant future benefits. However, they have difficulty in supporting their claims, since previously their evidence typically was derived from individual case studies. Constituents and decision makers are often skeptical, believing that individual cases are either inapplicable to their situation or non-randomly selected to support a particular view. Planners need objective evidence based on a large body of experience to support the case for mitigation. Such is the unique contribution of a recent congressionally-mandated study, *Natural Hazard Mitigation Saves* (MMC, 2005). Using an *aggregate* of project-level benefit-cost analyses (estimation of average benefit-cost efficiency based on a random sample from a large data set), the study found that each dollar spent in three federal natural hazard mitigation grant programs--the Hazard Mitigation Grant Program, Project Impact, and the Flood Mitigation Assistance Program-- saves society an average of $4 in future avoided losses. Complementing the aggregate benefit-cost analysis with community-based evaluations, the study yielded valuable insights on how planners can improve long-term community resilience in the face of extreme events. To conduct the overall study, a number of methodological innovations were necessary, including developing a consistent methodology based on modifications and extensions of HAZUS-MH loss estimation software to cover wind damage, business interruption from lifelines, and population displacement. Valuable lessons for mitigation planners and policy makers emerged: the need to consider a wide variety of losses, the importance of mixing qualitative with quantitative analysis, the value of averaging results over a large number of projects, and the need to more explicitly address social issues and data collection in order to reduce vulnerability and enhance resilience to cope with twenty-first century hazards.

Claiming the Value of Foresight

Planners work in the future tense--claiming that foresighted present actions and investments produce significant future benefits. They argue that common sense supports the wisdom of acting today to provide a better tomorrow. The core concept of planning is that actions informed by foresight can provide more benefits and incur fewer costs than after-the-fact responses that involve relatively more expensive retrofit, repair or reconstruction.

Foresighted action is particularly relevant in the field of natural hazard mitigation, where it is often stated that "an ounce of prevention is worth a pound of cure." But hazard mitigation planners have difficulty pinning down the differences in benefits and costs between prevention and cure. The difficulty springs from analytical challenges and future uncertainties, which have long plagued practitioners of emergency management. Future disaster probabilities are reckoned over many decades, and, in some cases, in hundreds of years. Hazard mitigation projects, such as relocating households from floodplains, often have high up-front price tags and require challenging behavior changes. And public understanding of the benefits of, and support for, investing in mitigation is limited, as shown in post-Katrina experience in Gulf coast communities that have resisted land use and structural safety recommendations in their haste to rebuild (see e.g., Roig-Franzia, 2006). Appeals for foresighted action based on single case studies (e.g., Association of State Floodplain Managers, 2000) are questioned as either inapplicable to differing situations or non-randomly selected by advocates to inflate the value of mitigation.

Benefit-cost analysis (BCA) offers a rigorous, widely applied tool for assessing public policy and public investment proposals (see, e.g., Campbell and Brown, 2003; National Research Council, 2004; Moore and Thorsnes, 2007). Basically, benefit cost analysis is concerned with efficiency. Public investments are considered to be efficient if their benefits exceed their costs. Given that these investments are intended to last and need to be maintained for many years, they are efficient if the present discounted value of the estimated future stream of positive impacts (benefits from the investment) is greater than the present discounted value of the estimated future stream of negative impacts (costs of the investment). Thus, a project is deemed efficient if its benefit/cost ratio is greater than one.

Skeptics about BCA note that it attempts to measure everything in dollars, ignoring the qualitative aspects of public policy actions; that its focus on a single numerical ratio overlooks associated impacts; that quantification leads to a false sense of confidence in the estimates; that internal rate of return or other measures better inform financial decision-making, and that its focus on efficiency fails to consider the important equity or distributional issues involved in policy decisions (see, e.g., arguments discussed in Stokey and Zeckhauser, 1978; Boardman et al., 2001). Thus, it fails to reckon with the comprehensive nature of planning, which recognizes that government actions must be judged both qualitatively and quantitatively.

These are indeed valid criticisms of using traditional benefit-cost analysis as the sole evaluative tool for a prospective project. However, in a random sample of a large number of projects, and using a consistent valuation methodology, individual under-estimates and over-estimates tend to be off-setting, yielding useful information on the average efficiency of the planning activity. In addition, when the benefit-cost analysis is augmented by community-based studies, interpretations and implications of the economic numbers are enhanced by setting them within the more comprehensive context where planners actually operate. The combination of aggregate BCA and community studies effectively incorporates the advantages of the argument by “anecdotal analogy”—namely, its richness in scope of factors considered—but mitigates the shortcomings of that approach which detract from its credibility—namely, lack of scientific objectivity and failure to systematically draw on a large body of existing experience.

Aggregate BCA has been used to evaluate other public policies. For example, Austin, Anderson, Courant, and Litan (2007) used it to analyze the benefits of restoring the Great Lakes ecosystem. So why had it not been used to evaluate U.S. mitigation policy? The short answer is that it is difficult to do correctly, given a number of methodological challenges.

However, aggregate BCA was successfully employed in the study responding to the 1999 Congressional request that the Federal Emergency Management Agency (FEMA) sponsor an independent study to assess the future savings resulting from hazard mitigation activities (U.S. Senate, 1999).[1] To overcome the limitations of traditional project-by-project analysis, an innovative methodology based on aggregate benefit-cost analysis supplemented with community-wide studies was developed to respond to the Congressional request.[2] The resulting study by the Multi-hazard Mitigation Council (MMC), *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*, analyzed the effectiveness of more than $3.5 billion spent in individual grants under FEMA's Hazard Mitigation Grant Program, Project Impact, and Flood Mitigation Assistance Program to mitigate risks from floods, windstorms, and earthquakes between 1993 and 2003 (MMC, 2005).

In this article, we discuss the importance to planners and policy makers of assessing the aggregate benefits and costs of hazard mitigation and describe the MMC study and its findings. In terms of study methodology, we demonstrate that aggregate BCA is a valuable way to quantify mitigation impacts and that supplementary community studies are a valuable approach to uncover qualitative mitigation impacts, especially on overall community resilience. In terms of study findings, we highlight implications for both local planners and for federal mitigation policy

Assessing Mitigation Benefits and Costs

Effective assessment of the benefits and costs of hazard mitigation is important to planners and policy makers, since nearly every U.S. community is subject to risks from natural hazards (FEMA 2004).[3] Floods are the most prevalent natural hazard; most U.S. counties have experienced at least one Flood Presidential Disaster Declaration and some have experienced as many as twelve during the 1965 to 2000 period (FEMA, 2004). And many communities are also subject to one or more of the other six major natural hazards—earthquakes, tsunamis, tornados, coastal storms, landslides, and wildfires. Mitigating the risks from these hazards involves projects that affect land use and environmental management, public facilities, building codes, retrofitting existing structures, relocating threatened households from hazard areas, and other aspects of comprehensive planning, development regulation, and capital programming.

Paying for flood, earthquake, and high wind disasters in the U.S. costs the federal government nearly $5 billion on average each year for disaster relief and recovery (FEMA, 2004a) Most of the expenditures to cover these disaster costs come from special appropriations in the wake of disasters, which can be problematic for a Congress burdened by record budget deficits. It is important to select for funding those mitigation projects most likely to reduce the impacts of future disasters.

Early U.S. disaster policy employed a *reactive* approach, treating disasters as acts of God, with the federal government as the lead response and recovery agency when a disaster exceeded states' response capabilities. Over time this reactive stance has been changed to a *proactive* approach. The Disaster Mitigation Act of 2000 (P.L. 106-390) now requires state and local governments to prepare and implement pre-disaster mitigation plans. The Act, which is implemented through the Hazard Mitigation Grant Program, defines natural hazard mitigation as sustained action taken before a disaster strikes in order to reduce future property damage, human casualties, and other disaster impacts. Pre-disaster mitigation plans seek to reduce hazard vulnerability and strengthen hazard defenses (Burby, 1998; Godschalk et al., 1999; Mileti, 1999; Waugh and Tierney, 2007). Such plans incorporate a slate of hazard reduction techniques (Godschalk, 2007; Puszkin-Chevlin, Hernandez, and Murley, 2007).

State pre-disaster mitigation plans are evaluated and approved by FEMA and local pre-disaster mitigation plans are evaluated and approved by state emergency management agencies and FEMA. Hazard Mitigation Program grants to implement the plans are evaluated individually and funding is awarded on a competitive basis. However, until now there has been no systematic analysis of the *overall* natural hazard mitigation program.

Conventional mitigation assessment analyses have relied on case studies of the outcomes of individual communities' mitigation efforts. Not surprisingly, many case studies tend to focus selectively on successful efforts. The literature contains a number of such success stories, which describe best practices and lessons learned.[4] For example, Berkeley, California, is described as a community that has used a combination of federal mitigation grants and local government funding to develop and implement a coordinated array of earthquake mitigation projects guided by mitigation policies adopted in their comprehensive plan (see Chakos, Schulz, and Tobin, 2002; and Berkeley, 2002). While success stories can be useful motivation devices and exemplars of best practices, they do not provide reliable estimates of overall mitigation program benefits and costs.

The literature also contains examples of failure stories. Among the recent ones are accounts of what went wrong during Hurricane Katrina in 2005. The most costly U.S. natural disaster, in terms of death and injury, property damage, and community destruction, Katrina showed the world that despite ample warnings the Gulf Coast region failed to implement mitigation measures adequate to cope with a major hurricane strike (U.S. House of Representatives, 2006; Nolon and Rodriguez, 2007; Birch and Wachter, 2006; Hartman and Squires, 2006; Cutter, 2005; Laska and Morrow, 2007). Katrina and other recent disasters also vividly demonstrated that individual mitigation measures may be immaterial absent comprehensive mitigation planning and programs. It does little good to strengthen roofing requirements in building codes or to provide emergency generators in hospitals if the buildings and emergency equipment are likely to be destroyed by flooding due to levee failure. Land use, flood and fire protection, transportation, environment, building construction, and community and economic development all affect disaster resilience and catastrophe potential.

Despite the availability of individual case studies of success and failure, prior to the MMC study we lacked a broad systematic assessment of natural hazard mitigation benefits and costs. Thus, the nation had no evidence-based analysis of the future savings from hazard mitigation activities.

Aggregate Benefit-Cost Methodology and Findings

Seeking objective evidence about the benefits and costs of natural hazard mitigation, Congress directed the Federal Emergency Management Agency (FEMA) to sponsor an independent study to assess the future savings resulting from hazard mitigation activities (U.S. Senate, 1999).[5] The resulting study found a wide array of mitigation benefits, concluding that these expenditures generated savings to society at a rate of $4 on average for every $1 spent (Ganderton et al., 2006; Rose et al., 2007).[6] Both the study methodology and its findings have begun to affect public policy. The Congressional Budget Office built on the MMC approach in its subsequent study of potential cost savings from the pre-disaster mitigation program (CBO, 2007).[7] The Administration's 2006 Budget based a $100 million budget increase for FEMA pre-disaster mitigation grants on them (DHS, 2006). The Oregon Legislative Assembly cited them in a 2007 bill directing governments in the state to develop plans for mitigating and recovering from catastrophic disasters (Senate Bill 1038).[8]

A Congressionally-mandated policy study must stand up to hard critical analysis. Individual case studies have documented substantial savings from mitigation, but they cannot be generalized to overall federal program outcomes and they are subject to the charge of "cherry picking"—the practice of looking only at the most successful mitigation cases. To deal with these issues, the study developed an aggregate methodology that analyzed and aggregated a systematically sampled group of hazard mitigation grant drawn randomly from FEMA's National Emergency Management Information System (NEMIS).[9]

Benefit-cost analysis (BCA) was selected to provide credible results to the Congressional Budget Office, the Government Accountability Office, and other fiscal experts (see Rose, 2004a; Ganderton, 2006; Rose et al., 2007). Every FEMA-funded mitigation project application must present an argument that its benefit-cost ratio is greater than 1.0. Given competing demands for taxpayer dollars, however, it matters whether the ratio is 1.1., 3.8, or 15.1.[10] And, since BCA has not in the past been applied systematically to an *aggregate* set of mitigation activities, we do not know the scale of effectiveness of overall FEMA mitigation activities in terms of use of society's resources.

Two types of FEMA mitigation grants were analyzed--*project* grants and *process* grants. Project grants invest in physical capital (drainage enhancement, acquisition and relocation of at-risk structures, structural improvements, nonstructural improvements, lifeline improvements, and land-improvement projects). They generate tangible physical change to the built or natural environment and can be quantitatively assessed. Process grants invest in human, social, or institutional capital (e.g., vulnerability assessments, community priorities, action plans, education campaigns, and the development of codes and regulations). They support actions that reduce risk and increase community resilience, but their outcomes are more difficult to quantify.

The study finding of an average benefit-cost ratio of 4 to 1 means that each dollar spent on mitigation grants saves society an average of $4 in real resource costs. As expected, benefit-cost ratios varied across hazards, reflecting individual hazard characteristics and local mitigation priorities. Rapid onset hazards (earthquakes and wind) pose more risks to people; slower onset hazards (floods) primarily damage property. Thus, seismic mitigation grants to rehabilitate school buildings to protect school children reduced risks to people but did not generate large monetary savings. But flood mitigation grants for buyout and relocation of houses from flood zones generated large monetary benefits from avoided property losses.

Table 1 summarizes the outcomes. Note that project grants are by far the largest category, accounting for 95% of grant costs, and that flood mitigation grants are the dominant project category. Hazard specific benefit-cost ratios range from a low of 1.4 for earthquakes through 4.7 for wind to a high of 5.1 for floods. In all categories except earthquakes, project grants had higher benefit-cost ratios than process grants.[11] The lower benefit-cost ratios for process grants may be due to less developed techniques for estimating process benefits, rather than actual benefits.[12]

Table 1. Estimated FEMA Hazard Mitigation Grant Benefit-Cost Ratios
(All $ figures in 2004 constant dollars)

	Project Grants			Process Grants			
	Quake	**Wind**	**Flood**	**Quake**	**Wind**	**Flood**	**Total**
Total grant cost ($M)	$ 867	$ 280	$ 2,204	$ 80	$ 94	$ 13	$ 3,538
Total grant benefit ($M)	$1,194	$1,307	$11,172	$ 198	$161	$ 17	$ 14,049
Total benefit-cost ratio (BCR)*	1.4	4.7	5.1	2.5	1.7	1.3	4.0
Standard deviation of BCR	1.3	7.0	1.1	n.a.	n.a.	n.a.	n.a.

*Row 2 (benefit) divided by row 1 (cost) equals row 3 (benefit-cost ratio)
n.a. = not applicable because of estimation method used
Source: MMC, 2005.

It is important to understand definitions and procedures used in the methodology.[13] Costs were acquired from the FEMA database; benefits were estimated as expected losses that could be avoided by the mitigation activity, considering the various intensity events that could occur to the mitigated facilities in the future, and the probabilistic likelihood of each level of intensity. (We emphasize that these intensities are *predictive*, meaning that theoretical hazard models are used to estimate the effects of future floods, hurricanes, etc., not past events. Of course, the theoretical hazard models are developed from knowledge of past events.) These expected savings typically accrue over a 50-100 year period, depending on the nature of the mitigated structure involved. Savings are systematically estimated using the original version and various refinements of HAZUS-MH, FEMA's loss estimation software,[14] and basic input data from each grant application. Benefits include expected: (1) reduced direct property damage; (2) reduced direct business interruption loss (e.g., damaged factory shutdown); (3) reduced indirect business interruption (e.g., factory A is shut down so B can't operate and it must shut down); (4) reduced casualty losses; (5) reduced emergency response; and (6) reduced non-market damage (e.g., reduced environmental damage and reduced damage to historical sites).[15]

For each grant in the sample, benefits were compared with costs to yield a grant-specific benefit-cost ratio. Since grants were selected with probability in proportion to their cost, using strata of equal cumulative cost, the expected value of the population benefit is calculated as $C * \sum_{i=1}^{N} \beta_i / N$ where β_i denotes benefit-cost ratio of grant i of N in a group (e.g., wind) and C is total population cost in the group (e.g., the total cost of all project grants aimed at flood mitigation; determined from NEMIS records).[16]

The study developed a number of innovations and refinements to overcome the challenges of aggregate BCA for natural hazard mitigation (see MMC, 2005, chapter 4 and appendices for details of methodology). In addition to the use of community studies, innovations included use of a consistent methodology[17], a solid sampling strategy, collection of primary data[18], an appropriate aggregation measure, sensitivity analysis, consideration of indirect benefits[19], and use of reproducible methods[20].

Equity was not addressed head-on in the MMC study because of lack of data on socioeconomic, race/ethnicity, or other relevant status of the affected population.

However, several inferences can be made. On the cost side, payment for FEMA grants came from tax dollars based on "progressive" principles, where the well to do pay relatively more than the poor. On the benefit side, most of the grants were applied to public facilities or semi-public private facilities (hospital and utilities) that provide services to the public in an even manner. Since the poor, racial/ethnic minorities, children, the aged, and the infirm are more vulnerable to hazards, reducing the threat is an improved benefit. Lower income groups typically reside in areas with lower property values, such as flood plains (Cutter, 2005; Bankoff, Frerks, and Hilhorst, 2004), so they are likely to benefit disproportionately by FEMA buyouts. At the same time, mitigation projects can have negative impacts on the poor by raising their property taxes and encouraging redevelopment that may displace them.

Community Case Studies Methodology and Findings

The MMC study paired aggregate BCA with in-depth community case studies to provide a more complete picture of the benefits and costs of mitigation projects and to supplement quantitative findings (MMC, 2005). The community studies explored community perceptions of mitigation and looked for synergistic effects of mitigation grants on other community mitigation efforts and overall community resilience. Community study methodology involved four phases: pre-interview data collection, formal telephone interviews, site visits and face-to-face interviews, and data and information processing. In each community, data was collected about all mitigation grants received from FEMA, other federal agencies, and state agencies, investments made by the community to mitigate disasters (both required local shares of government grants and projects fully funded by the communities). Data was also collected about state mitigation laws and local ordinances as well as public-private partnerships that led to mitigation actions (i.e., the adoption of local building codes beyond state requirements and the concomitant adoption of related building practices by developers). Unlike the aggregated BCA analysis, which evaluated single mitigation grants in isolation, the community studies were able to evaluate all community mitigation activities in total, identify community mitigation capacity, and, using time lines, plot the longitudinal development of comprehensive community mitigation programs. Following interviews with community officials and the collection of relevant documents and data, benefit-cost ratios were computed for mitigation projects and cost effectiveness was determined for activities with qualitative characteristics (MMC, 2005, ch. 5. pp. 59-121).

The MMC study used purposive sampling techniques to select eight cities and counties that represented the characteristics of communities that had received grants from FEMA for mitigation activities.[21] These eight communities were selected from a group of 113 (single jurisdictions identified with a legal title as a city, town, borough, village or county within one of the 50 states) using multiple criteria, including having received over $500,000 in mitigation grants and being at high risk from at least one of three major natural disasters (wind, flood, earthquake). The selected communities were: Freeport, New York; Hayward, California; Horry County, South Carolina; Jamestown, North Dakota; Jefferson County, Alabama; Multnomah County, Oregon; City of Orange, California; and Tuscola County, Michigan.

A BCA was performed on all FEMA-funded activities identified in the community studies analysis, along with review of background information. The analysis benefited from the vast amounts of background engineering and science investigations and analyses, not available in NEMIS and therefore not used in the aggregated BCA analysis, which assisted in the development of benefit-cost evaluations. Not only did FEMA regional offices and local communities help in gathering such background information, they also provided materials for additional analyses, such as the identification of synergistic community activities (i.e., spin-offs and spill-over effects) related to activities funded by FEMA.

One question addressed by the community studies concerned the contributions to resilience of FEMA mitigation grants. Mitigation impacts may be analyzed from several viewpoints, including the disaster performance of physical structures (e.g., levees, dams, buildings, and other built environment elements), deaths and injuries to occupants or protected populations, and direct and indirect losses due to business interruption resulting from physical damage. A more comprehensive approach focuses on the ability of mitigation actions to increase the physical, social, environmental, and economic *resilience* of communities under stress. The goal is to assist communities in withstanding an extreme event without suffering devastating losses and without requiring a great deal of outside assistance (Godschalk, 2007; Godschalk, 2003; Mileti, 1999). The impacted communities survive and continue to function; they might bend from disaster stresses, but they do not break. Instead of repeated damage and continual demands for federal disaster assistance, resilient communities proactively protect themselves against hazards, build self sufficiency, and become more sustainable. Resilience is the capacity to absorb severe shock and return to a desired state following a disaster. It involves technical, organizational, social, and economic dimensions (Tierney and Bruneau, 2007; Rose, 2007; Buckle, 2006; SDR, 2005).[22] It is fostered not only by government, but also by individual, organization, and business actions.

In each community, the study determined the impact on community resilience of the individual FEMA mitigation grants as well as the impact of all related mitigation programs. Individual grants tended to have a positive benefit irrespective of community context but resilience was dependent on the type and robustness of the overall community mitigation programs, which varied considerably.

The selection process produced three types of communities: 1) two communities with no existing mitigation program and no previous mitigation activities prior to receiving their FEMA grants; 2) five communities with no existing mitigation program but that had completed or were involved in isolated mitigation activities; and 3) one community that had carried out a successful, robust mitigation program for over 20 years.

More effective community mitigation programs exhibited seven attributes (Mittler et. al., 2008):

1) Presence of a mitigation champion,
2) Constant support of elected officials and agency heads,
3) Institutionalized mitigation programs, engrained in local government budgets,
4) Earmarked funding sources to support mitigation,
5) Community involvement and support, including use of local consultants to supplement city or county agency staff,
6) Opportunistic strategies seeking grants from various private, state, and federal sources,

7) Requests from other communities for mitigation champions to train their officials and staff.

The role of FEMA hazard mitigation grants depended on the type of community. For communities with no or limited mitigation experience, the grants provided funds to either resolve a contained problem or to be a catalyst for the development of a long-term community program. Experience with mitigation laid the foundation for these communities to expand their mitigation efforts (spin off activities) or promote economic development in those areas that benefited from mitigation activities (spill over effects). For communities with an established mitigation program, the grants either accelerated planned mitigation projects or permitted the community to divert funds to other pressing problems, thereby broadening their mitigation efforts. These grants were seamlessly integrated into existing mitigation programs.

In all eight communities, federal hazard mitigation grants played a significant role in the community's mitigation history, often leading to additional activities. These grants acted as *catalysts*, demonstrating the benefits of mitigation to community decision makers. Interviewees reported that FEMA grants were important in reducing community risks, preventing future damage, and increasing mitigation capacity. They believed that the benefits of mitigation projects and processes went beyond what could be measured quantitatively to include increased awareness, esprit de corps, and peace of mind.

The community case study interviews did not assess economic resilience from the private sector viewpoint (although the project analysis did include economic resilience). Typically neglected in assessing hazard losses and mitigation, economic resilience refers to the ability of an organization or system to retain its function and continue producing, as well as to increase its speed of recovery (Rose, 2004b; Rose, 2007). Strategies include conservation of scarce inputs, input and import substitution, relocation of facilities, recapturing lost business by rescheduling production at a later date, and provision for repair and reconstruction of capital stock. Resilience was accounted for in the MMC study primarily through the inclusion of the potential of businesses to reschedule lost production after recovery has begun.[23]

Economic resilience strategies can reduce both direct and indirect business interruption losses. Direct business interruption, even in major disasters such as the Northridge earthquake, affects a limited number of firms. A larger, but still limited, number of businesses are affected by the loss of utility lifeline services, though this is often for a relatively short period (following the Northridge earthquake, 99 percent of the power was restored within 36 hours). Every business in the region, however, is likely to be affected more lastingly by indirect, or multiplier, effects stemming from curtailment of critical inputs from suppliers or cancellation of orders by customers. Even businesses that are physically unscathed may be forced to shut down because of these ripple effects.[24]

This situation is illustrated by the high benefit-cost ratios of FEMA mitigation grants to protect power supplies. Grants for underground placement of electricity transmission lines to protect against wind damage had the highest benefit-cost ratios in the MMC study sample, with some exceeding 50! This is not surprising given the relatively small investment (often less than a few million dollars) capable of preventing a power outage that shuts down a major city. These grants explain why business interruption benefits are the dominant category for wind hazards.

Economic resilience may be inherent--built into the ordinary workings of the system (e.g., ability to substitute bottled or trucked water for water utility services); or adaptive—dependent on coping ability or ingenuity in a disaster situation (Rose, 2004b; Rose, 2007). Both forms of resilience can be enhanced prior to disasters. For example, distributed electricity generation (e.g., a firm's own co-generation facility or a smaller, diesel-powered back-up generator) can reduce the risks of centralized power station interruption. Prior contracting with business continuity consultants (who provide help in duplicating the data bases in communication services off site, facilitating relocation, and post-disaster clean up) can enhance a business's ability to recover. Given the interdependencies between businesses, a single business needs to be concerned not only with its own resilience but also that of its suppliers and customers. Prior planning, including large-scale aspects of city design (e.g., land use and public facility systems), along with integrating business emergency response plans into more general multi-hazard community-wide mitigation plans, can promote economic resilience.

In summary, the community studies highlighted the importance of FEMA mitigation grants as catalysts for local mitigation efforts, as well as key elements of long-term community resilience.

Planning and Policy Implications—Coping with Future Disasters

What do the findings of the MMC study imply for planning and public policy? As a national study averaging over a large number of local geographic areas and grants, it is tempting to overstate the study's significance for national policy makers and to offer unjustifiably definitive conclusions. Conversely, one might underestimate its significance for local policy makers because the robustness of its conclusions rests to some extent on the law of large numbers, i.e., the tendency of the sum of uncorrelated random samples to become highly certain as the number of samples increases. The study in fact provides lessons and raises challenges for both sets of policy makers, and also warns both against simplistic conclusions.

Federal Mitigation Issues and Recommendations

Certainly the economic bottom line of the MMC aggregate BC ratios affirms that FEMA funds have been well spent. Indeed, with an average BCR of 4.0, the suggestion is that more similar funding would be appropriate or even that major funding increases would be warranted. However, conclusions are not so easily drawn if we raise the policy bar from "well spent economically" to "optimally spent in a broad economic and social context." National policy has yet to define the latter with a clear federal mitigation objective.

Policy makers need to ask further questions. Should the public goal be to achieve the highest average return, to protect against catastrophic economic collapse of a region, to protect those most in need, or some combination of these objectives? Highest average return implies funding projects with the highest benefit-cost ratios. Protecting against economic catastrophes implies funding mitigation efforts for lifelines and systems that protect society and local economies as a whole. For example, preventing the Katrina catastrophe would have required $3 to $6 billion levee improvements (USACE, 2006), i.e., a single effort costing approximately the same as all the FEMA-funded natural-hazard mitigation grants between 1993 and 2003 (and notably preventing some $20 billion in property losses alone, approximately the same as all the 1993-2003 FEMA-funded grants are estimated to save).

Should future mitigation grant programs consider individual ability to pay, rather than treating all economic savings equally, as in BCA? For example, should well-to-do people who can afford to live on the coast of Florida or in the plush wooded hills of California be treated the same as disadvantaged inner city residents of Louisiana or Iowa? Under current policy, preventing loss to a fully insured million dollar home is considered a benefit on a par with preventing loss to 50 uninsured or only partially insured $20,000 homes. Equitable mitigation policy should recognize social and economic issues. HAZUS-MH contains economic impact data, but more extensive private sector impacts and social impact data should be added. In particular, the risks faced by poor and disadvantaged populations, who often live in high risk areas in communities and have the least capacity to cope with hazards, should be calculated. Methodologies are being developed to refine the necessary data and to simulate the distributional impacts of hazards and their mitigation (Oladosu and Rose, 2008). These tools generate disaggregated benefit-cost analysis results according to various socioeconomic groups in a manner that can facilitate public participation in the decision process (Rose, Stevens, and Davis, 1988).

Even without fully answering these difficult mitigation objective questions, the study supports previous calls for expansions of federal mitigation funding criteria. The community case studies demonstrated the value of a comprehensive approach to hazard mitigation. Present federal mitigation efforts fall short of achieving the necessary comprehensive framework (GAO, 2007; Waugh, 2006; Godschalk et al., 1999). The mitigation grant process lacks a requirement for comprehensive strategies to build community resilience.[25] Mitigation of natural hazards,[26] as well as man-made hazards[27], is not coordinated under one umbrella in an all hazards approach administered through a comprehensive emergency management organization. Such a comprehensive approach will require vigorous efforts to overcome the stove-piped nature of current disaster and homeland security preparedness efforts (Tierney, 2007).

Local Mitigation Issues and Recommendations

For local planners, the 4.0 national BCR can be an effective sound-bite to draw people to the mitigation discussion table.[28] However, they are not likely to be able to do a similar aggregate BC analysis (although some state level agencies will have the necessary capacity). Local planners in specific places at specific times are not evaluating a large random sample of mitigation projects; they are concerned with evaluating a few plausible alternatives. Nonetheless, the MMC analysis provides lessons and raises challenges for local planners that go beyond the sound-bite. Direct lessons relate to the framework of potential losses avoided by mitigation and the importance of mixing qualitative with quantitative analysis.

In the MMC study, all major categories of losses potentially avoided by mitigation—disaster response costs, human injury and loss of life, property damage and business interruption—entered significantly in determining aggregate benefit-cost ratios, but varied substantially in importance for individual projects or classes of projects. The results highlight the importance of starting with a framework that considers potential losses very broadly, but simultaneously not expecting all cells of such a framework to emerge with significant entries in any particular application.

The limitations of the MMC study and the augmentation of the aggregate BC analysis with community studies emphasize the importance of mixing qualitative with quantitative analysis. The MMC study focused on integrating current best practices across multiple areas, not advancing understanding in a particular area. Reflecting the limitations of current science, valuing items such as avoiding mental anguish and family stress or preventing destruction of non-replaceable historical treasures are not covered well in the study. The inability to confidently quantify items such as these does not mean they should be ignored in plan analysis. Similarly, the study found process grants less amenable to analysis by current BC techniques than project grants and this calls for augmenting BC analysis with qualitative observations on potential impact.

While the small number of community studies limits conclusions that can be drawn from them, they do point to the need to consider individual initiatives in a broader, long-run context. Lining up individual projects by individually calculated BCR and starting implementation from the top may not be optimal if a project or process lower on the list might contribute more to developing a community dynamic that raises the return to future mitigation endeavors.

From two perspectives, the MMC study raises challenges for the local planner. First, while the national 4.0 BCR can be an effective call for local action, there is the danger of its becoming an unintended benchmark. For a local project with a BCR greater than 4.0, the existence of such a benchmark is a plus by providing ready appeal to "being above national average." The problem is if local constituents and/or funding agencies become skeptical of a particular mitigation project with a BCR of "only" 2.5.[29]

The lesson of the study is to return to the fundamentals that gave the 4.0 validity—it was an average over a large number of projects, not the result of potentially "cherry-picked" anecdotal evidence. Planners in particular places at particular points in time cannot similarly average over a large number of projects—they are usually contemplating a few alternatives. Nonetheless, robustness can be introduced by increased sensitivity testing of the BCR analysis, asking whether the BCR greater than one holds over a range of reasonable variation in study parameters—i.e., by demonstrating that BC analysis parameters were not "cherry picked."

Second, it is important to recognize that averaging across areas eliminated the need for certain types of sensitivity testing in the MMC study that most definitely is not eliminated for the local planner focused on one region. "Benefits" in the study are very different in nature from "costs." The latter are typically current certain items—cash paid now for program implementation—but benefits are statistically expected avoided losses from natural disasters in the future. "Statistically expected" and "in the future" introduce questions of what statistical distribution of potential hazard intensity is embedded in the analysis and how to discount future loss savings to make them comparable with costs paid now.

There is no definitive consensus on either issue, rendering both important candidates for BC parameter sensitivity analysis. In fact, the statistical distribution of hazard intensity at any given location changes both as our understanding of earth science and meteorology advance—witness the recent development of next-generation seismic attenuation relationships summarized by Power et al. (2008)—and as the natural processes themselves change over time as a result of climate change, urbanization impacts on hydrology, crustal stress redistribution after earthquakes, etc.

The MMC study tested the sensitivity of the benefit estimates to important hazard uncertainties (e.g., site soil classification, terrain roughness, and flood depth), as well as uncertainties in values exposed to loss, vulnerability of assets, and socioeconomic parameters such as discount rate. Though the study did not test *all* uncertainties in hazard and other distributions, it did test the ones considered likely to most strongly affect the results, with the goal of estimating benefits given best-estimate, upper-bound, and lower-bound values of each uncertain input parameter (as opposed to selecting values that estimate benefits as highly as possible, which was explicitly not the goal of the study). The robustness of the MMC study's benefits estimates depend to some extent on the large variety of places in the analysis (which makes the grant benefits have low correlation) and from the size of the sample.[30]

The planner concerned with one particular geographic region and a smaller number of mitigation efforts might not benefit as much from the law of large numbers, and the uncertainty in benefits is likely to be greater from a smaller, more concentrated portfolio of efforts. In the latter case, it is critical to examine and question the statistical hazard intensity distribution, especially in regions potentially subject to very low probability, but highly devastating earthquake or wind events. Just how low the "very low probability" is can be the statistical tail that wags the benefit dog.

The Bottom Line for Federal and Local Planners and Policy Makers

On an economic benefit-cost basis, mitigation pays, and, on that basis alone, more needs to be spent to ensure a safe future. By spending $3.5 billion on hazard mitigation between 1993 and 2003, the federal government saved society $14 billion in estimated losses. Simultaneously, however, we need to explicitly address more difficult issues of social factors in mitigation objectives and community issues in mitigation planning and to continually "raise the bar" at all levels of analysis in this critical endeavor. This will entail improving FEMA data collection and carrying out research on the effectiveness of both project and process mitigation in the context of reducing vulnerability and building the resilience necessary to cope with twenty-first century hazards. Only then will "well spent" money become "optimally spent" money.

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End Notes

[1] FEMA charged the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences—a nonprofit, nongovernmental organization chartered by the federal government in 1974 to bring together representatives of government, the professions, industry, labor, and consumer interests to develop findings on technical building-related matters--with conducting the study. MMC specified the study parameters, set up a project management committee, and contracted with Applied Technology Council (ATC) to convene a research team to perform the analysis. Godschalk and West served on the MMC project management committee. Mittler led the ATC community studies team. Rose led and Porter co-led the ATC benefit-cost analysis team.
[2] FEMA does require a rudimentary benefit-cost analysis for each proposed hazard mitigation project. However, applicants typically do not carry out the specialized sophisticated computer simulation techniques used in the MMC study. BCA information listed on the FEMA applications was not used in the MMC study.
[3] Important research also has been conducted on management of natural hazards in Europe (e.g., Greiving, Fleischhauer, and Luckenkotter 2006; Greiving, Fleischhauer, and Wanczura 2006).
[4] For examples of reports on successful mitigation efforts, see North Carolina Division of Emergency Management Success Stories, available at http://www.dem.dcc.state.nc.us/Mitigation/Library/Success_Stories/Perf%20Assessment%20NC%20Print.pdf. Accessed May 21, 2007. See also Association of State Floodplain Managers, "Mitigation Success Stories in the United States," December 2000. Available at: http://floods.org/Publications. Accessed May **16,** 2008.
[5] The study was directed at FEMA's three major natural hazard mitigation grant programs: the Hazard Mitigation Grant Program, Project Impact, and the Flood Mitigation Assistance Program. It did not cover other federal hazard mitigation efforts, such as those of the U.S. Army Corps of Engineers.
[6] This aggregate benefit-cost finding does not imply that every local mitigation program will achieve the same benefit-cost ratio. Local circumstances may result in either higher or lower benefit-cost ratios.
[7] The CBO study, completed after the MMC study, was required by the Predisaster Mitigation Program (PDM) Reauthorization Act of 2005 to estimate the reduction in Federal disaster assistance attributable to the PDM program. It built on the MMC study findings, though it analyzes only PDM grants awarded since 2004, uses a different discount rate (7 percent), discounts the value of reduced injuries and deaths, and has some other differences. The CBO study estimated an overall benefit-cost ratio of three to one (CBO, 2009, p. 2). It noted that when the MMC estimated ratios are converted to a 7 percent discount rate, the flood and wind benefit-cost ratios are within about 15 percent

of each other, although it found a higher BC ratio for earthquake mitigation, speculating that the 25 MMC projects might have been an unrepresentative sample.

[8] The Oregon bill required state agencies to develop plans for mitigating effects of natural disasters and for recovery and reconstruction efforts after a natural disaster has occurred.

[9] The data base of the population of grants for the study time period (June 1993-July 2003) was the National Emergency Management Information System (NEMIS) used by FEMA to monitor the status of hazard mitigation grants. A stratified random sample of grants was drawn to assure representation by hazard type (flood, earthquake, wind), mitigation type (project or process), and grant monetary size. The final sample consisted of 136 grants out of a total population of 5,479, although for purposes of reducing uncertainty the grants were selected to represent a much larger fraction of the total mitigation expenditures. For each grant in the sample, a total cost was calculated that included state, local and private resources, as well as FEMA resources used to carry out the project.

[10] California's Office of Emergency Services does give project applications with a higher benefit/cost ratio a higher ranking factor (*State of California Multi-Hazard Mitigation Plan*, 2007) www.oes.ca.gov. Accessed July 25, 2008.

[11] Earthquake findings are skewed because of the preponderance of school ceiling projects that appeared in the sample.

[12] Standard methodologies like HAZUS do not lend themselves to the estimation of the benefits from process grants. Moreover, there is only a very thin literature on their actual measurement, such that a standard alternative--benefits transfer (adapting the results of a benefit estimation for an activity in one place and time to another context)--could not be used. Therefore, the research team was forced to adapt results from more general analogs to the process grants in the sample (e.g., using information dissemination campaigns aimed at risks in general, rather than those just pointed at natural hazards).

[13] See the Multihazard Mitigation Council (2005) and Rose et al. (2007) for specifics of the research methodology.

[14] For information on HAZUS-MH, see the FEMA web site at: http://www.fema.gov/plan/prevent/hazus. Accessed June 8, 2007.

[15] Short-term economic stimulation from post-disaster reconstruction was not netted from benefits since it essentially represents a transfer in time/place expenditures (e.g., from individual future to current expenditures, from insurance company profits to the region, from general taxpayers to disaster aid recipients). Benefits, except prevented casualties, were discounted at a rate of 2% and all benefits and costs were expressed in constant 2004 dollars. Following the common tenet that a future life is not less valuable than a current one, casualties were not discounted.

[16] Alternative methods of sampling and scaling were considered and tested using NEMIS-reported BCR, with the method selected based on a balance between low bias and low uncertainty (see MMC, 2005, Appendix N).

[17] To ensure consistency, project grants benefits were estimated using HAZUS-MH, which is applicable to earthquakes, hurricanes, and floods. Since the flood version of HAZUS was incomplete, it was necessary to extract the flood property damage functions that were available and to apply them to individual projects in a "reduced form" manner. In a similar fashion, HAZUS equations on wind damage had to be modified for

estimating tornado-related property and casualty losses prevented by mitigation grants. Also, since HAZUS-MH lacks the ability to estimate most of the direct and indirect business interruption impact stemming from damage to utility systems, the study developed a HAZUS Extension, or "patch," using data on direct customer demand for utility services and input-output multipliers for indirect effects. Another HAZUS Extension was developed to estimate population displacement for tornados and floods.

[18] HAZUS is often applied to national averages or generic data. However, a major contribution of this study was the collection of primary data on relevant structures from the associated project grant application.

[19] The largest category of indirect benefits refers to business interruption of customers and suppliers of firms, non-profit organizations or government agencies that would otherwise be damaged. These "multiplier" effects were included through the use of the Indirect Economic Loss Module of HAZUS-MH, as well as through the use of HAZUS Extensions developed for public utility related projects. Other categories often lumped into "indirect benefits" include societal impacts (displacement and trauma) and environmental benefits, many of which were estimated in their own right, rather than relegated to the secondary status of indirect effects.

[20] A standard criticism of BCA is that results cannot be replicated. MMC study data are available from FEMA in sanitized form (so as not to reveal any specific entity). HAZUS-MH reduced form and extended versions are available from the study authors. Process grant estimation methodology is spelled out MMC (2005). The MMC study was evaluated by the Congressional Budget Office in its recent evaluation of FEMA mitigation grant programs (CBO, 2007), including detailed questions on its methodology, data, assumptions, and results. The CBO study arrived at an overall benefit-cost ratio of 3:1, reasonably close to the MMC study’s 4:1 BCR.

[21] One pilot city also was studied to test the methodology, but its results were not included in the overall analysis.

[22] Tierney and Bruneau (2007) describe a four part resilience framework based on robustness (ability to withstand disasters without significant degradation or loss of performance), redundancy (extent to which system elements are substitutable), resourcefulness (ability to diagnose and solve problems), and rapidity (capacity to restore functionality in a timely way).

[23] Production rescheduling is one of the most effective of all post-disaster resilience actions (Rose and Lim, 2002). It was computed by invoking the production “recapture factor” contained in HAZUS-MH.

[24] As evidenced by Hurricane Katrina, households suffer significant losses as well. Property damage to housing stock, loss of income, and death and injury are included in loss estimates, but inconvenience or social/psychological damages are difficult to measure and typically not incorporated into major economic indicators. For a review of evaluation of impacts on the general population not stemming from the business sector, see Rose and Oladosu (2007).

[25] As the *Mitigation Saves* (2005, p. 6, Volume 1) report stated: “Mitigation is most effective when it is carried out on a comprehensive, community-wide, long-term basis. Single projects can help, but carrying out a slate of coordinated mitigation activities over

time is the best way to ensure that communities will by physically, socially, and economically resilient in coping with future hazard impacts."

[26] Foresighted mitigation policy should look beyond past experience to consider risks from more severe storms, climate change, and sea level rise (IPCC, 2007). A recent study found that California local governments, along with those in other coastal states, are unprepared to cope with climate change and sea level rise (Moser and Tribia, 2007), although the 2007 *State of California Multi-Hazard Mitigation Plan* emphasizes resilience from climate change, levee failure, and tsunamis, as well as earthquake, flood, wildfire, and other hazards. Accessed July 25, 2008: http://www.oes.ca.gov.

[27] See FEMA 386-7, *Integrating human-caused hazards into mitigation planning*, Mitigation Planning, How-To Guide #7, September 2002. Accessed July 25, 2008: http://www.fema.gov/plan/mitigation/howto7.shtm.

[28] Engaging the public in hazard mitigation planning can be a challenge. See Brody, Godschalk, and Burby, 2003; and Godschalk, Brody, and Burby, 2003)

[29] California has adopted a BCA of 4 as a planning standard for mitigation. Its OES HMGP Review Form gives an application with a BCA of 1-3 zero points, 4-6 one point, and 6 or higher two points. (www.oes.ca.gov. Accessed July 25, 2008.) Because BCA is one of many criteria, a low BCA will not kill a project but it may be important in funding decisions if there is insufficient money to fund all projects.

[30] A preliminary statistical test indicated that a sample of at least 25 grants was required in each hazard to assert with high confidence that benefits exceed cost. A statistical test (termed tornado-diagram analysis) performed after estimating benefits indicates that, using the selected sampling scheme and sample size for each hazard, the aggregate uncertainty in benefit for flood-related grants exceeded cost with more than 99% confidence; in the cases of wind and earthquake, the probabilities were 99% and 83%, respectively. Because not all uncertainties are reflected in the sensitivity tests, these figures might be considered upper-bound probabilities, but since the study tested what were considered to be the largest uncertainties, the degree of possible overestimation is probably small.