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Risk Nexus

Making communities more flood resilient: the role of cost-benefit analysis and other decision-support tools

Many issues need to be considered when deciding how best to help protect a community from floods. In this paper, Zurich flood resilience alliance members examine methodologies that can support the decision-making process to help those when and where it matters most.

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Making the case for pre-event disaster risk reduction

Large-scale flood disasters in recent years vividly demonstrate the need to invest in risk reduction measures before such events happen. It can be difficult, however, for a community to decide to invest in such measures, as these decisions usually involve several options and multiple stakeholders with different short- and long-term objectives and priorities. As a result, intense discussions often produce little real progress, or there is simply a return to the status quo.

A variety of decision-support tools are available to organize and evaluate options, which can assist in making the case for pre-event risk reduction to flooding and other hazards. Among these tools, the most widely-used for assessing flood risk reduction measures is cost-benefit analysis (CBA). Other tools that can be used to aid decision-making include cost-effectiveness analysis (CEA), multi-criteria analysis (MCA) and robust decision-making approaches (RDMA).

In this issue brief we outline three key findings that provide information for research, policy, and implementing decisions on reducing flood risk. The analysis provides a foundation for work under the Zurich flood resilience alliance, allowing it to integrate a decision-support toolbox for community activities focused on implementing flood risk reduction in different parts of the world. This publication is based on a white paper developed by two members of the alliance, the International Institute for Applied Systems Analysis (IIASA) and the Wharton School's Risk Management and Decision Processes Center at the University of Pennsylvania (Wharton). It is available at: http://opim.wharton.upenn.edu/risk/library/ZAlliance-decisiontools-WP.pdf.

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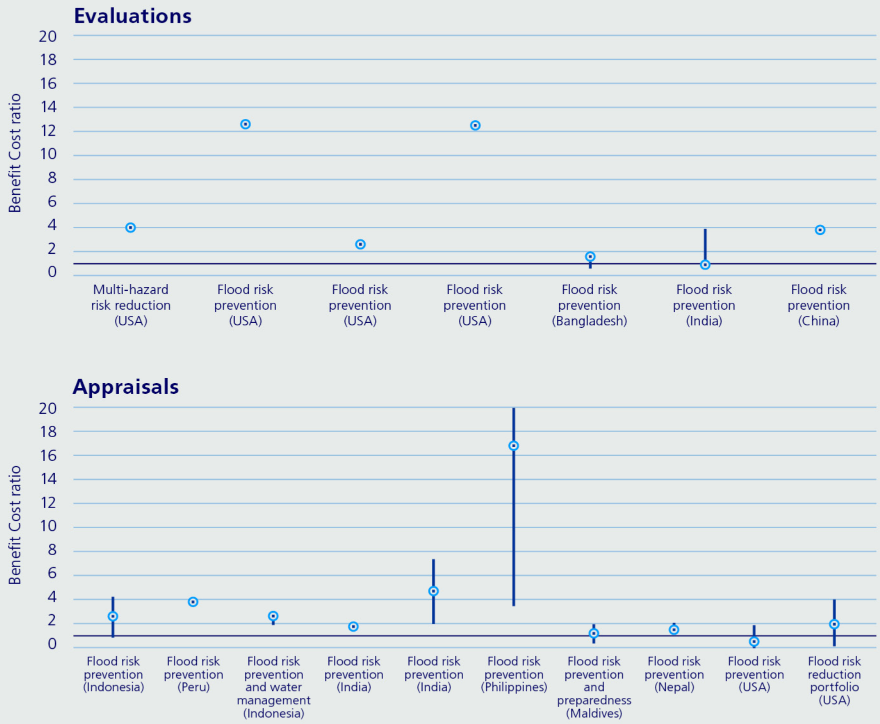
Finding 1: CBA studies show that for every dollar spent on selected flood risk reduction measures, an average of five dollars is saved through avoided and reduced losses.
Cost-benefit analysis is based on the economic efficiency criteria of maximizing benefits net of costs over time. CBA has been the primary analytical approach to provide quantitative information when prioritizing risk reduction solutions.

Using CBA in the context of analyzing risk reduction requires four main steps: (1) Estimating the amount of flood losses expected in the future under the status quo (that is, without risk reduction); (2) identifying possible risk reduction measures and their associated costs; (3) estimating how much of the future flood losses would be reduced with such measures in place (that is, estimation of benefits); (4) calculating the economic efficiency of the measures. The measures are said to be economically efficient if benefits exceed cost.

We conducted a review of published disaster risk reduction (DRR) studies utilizing CBA and concluded that investing in flood risk reduction pays off for many types of interventions. This holds true for project appraisals aiming to understand whether a particular investment should be made, as well as project evaluations determining whether a project produced positive net benefits after it was implemented.

Taking a simple average across all studies reviewed (Figure 1) leads to a benefit-cost (B/C) ratio for flood hazard close to 5; in other words, for every one dollar spent on flood risk reduction, on average, five dollars is saved through avoided and reduced losses.

Figure 1: Summary of key studies on the economic efficiency of investments in flood risk reduction



Source: Mechler et al., 2014[1]

[1] http://opim.wharton.upenn.edu/risk/library/ZAlliance-decisiontools-WP.pdf

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Many of the largest economic returns can be achieved through flood risk reduction measures designed to improve residents' readiness; these measures include providing information and targeted education to increase flood risk awareness, forecasts, and early warning systems. While in some cases, flood risk reduction measures have failed to offer benefits greater than their costs, in most cases, it is possible to find economically-efficient risk reduction measures that can increase the flood protection provided to a given community.

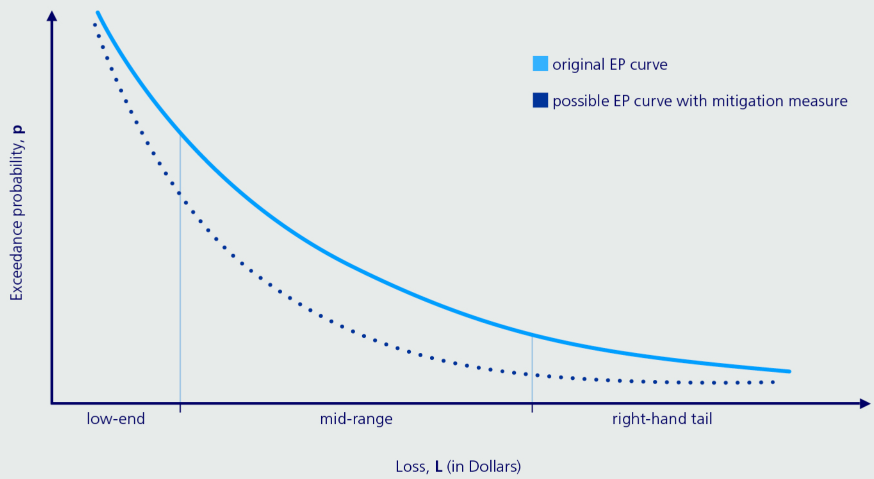
Finding 2: A flood risk reduction assessment needs to properly account for high-impact, low-frequency flood events, and also tackle key challenges such as intangible impacts.

In recent years, there has been growing interest in probabilistic cost-benefit analysis, which goes beyond simply looking at a single flood event to capture the entire set of possible events a community might face in the future. This involves assessing flood return periods, i.e., annual likelihood, of all possible flood scenarios.

This more comprehensive approach to quantifying the flood hazard is also useful, in that flood risk reduction options may be efficient for certain levels of risk, but not necessarily for all. For example, a flood risk reduction option may best reduce 50-year return period risk, while risk financing such as insurance may be the best solution to address higher-level risk from a return period that is 100 years or greater.

This type of risk-based methodology produces 'exceedance probability' (EP) curves as shown in Figure 2. The EP curve represents the probability that losses will be a given amount, and the area underneath the curve represents the total expected annual losses. In a four-step risk-based CBA approach, such EP curves can be used to estimate the magnitude of future expected losses without flood risk reduction in place, and importantly, by how much these future losses are projected to be reduced by implementing flood risk reduction measures. Flood risk reduction intervention shifts the EP curve to the left (lower risk) and therefore reduces the expected loss. Benefits from a particular flood risk reduction measure may affect different parts of an EP curve (low-end, mid-range or right hand tail), as illustrated here. This makes it easier to compare the expected benefits of different risk reduction

Figure 2: Exceedance probability curve showing potential benefits of disaster risk reduction



The EP curve represents the probability that losses will be a given amount. Flood risk reduction intervention shifts the EP curve to the left, reducing the expected loss.

Source: Grossi, P., and H. Kunreuther, eds. (2005). Catastrophe modeling: A new approach to managing risk. New York: Springer

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options. By selecting a particular type of risk reduction intervention to enhance community flood resilience from a suite of possible options, this layering of risk consideration is likely to be a significant factor when choosing the preferred measure.

The EP curve results are sensitive to several factors, including (1) how well hazard probabilities are identified, (2) whether vulnerability assessments are reliable, and (3) whether the analysis is based on the most up-to-date data (for instance, how asset and population exposure has changed as a result of urban development). Significant changes in infrastructure, population and vulnerabilities over time are often such that damage estimates from events that occurred long ago may no longer be relevant today. Comprehensive and accurate data are necessary for a probabilistic analysis, and in some contexts this can become a key constraint in doing a proper risk-based CBA of flood risk reduction options.

Considering indirect and intangible impacts

Even when available evidence makes a strong case for flood risk reduction, a CBA may be of limited value if fundamental challenges are not addressed, or at least considered.

In an ideal world, a comprehensive CBA should include all relevant impacts – physical, social, economic and ecological. It should also analyze both direct impacts from the event, such as loss of life and damage to structures and infrastructure, as well as indirect losses including any increased mortality due to lack of sanitation facilities, or unemployment and reduced income related to business interruption losses.

CBA's defining feature is that it requires every impact to be monetized so that like can be compared with like. But it is challenging to estimate how an event affects the value of goods that are not traded in the marketplace. These intangibles include the values of community cohesion, the value that a community places on its significant cultural or historical heritage sites, and the benefits derived from living in a beautiful place (for example, water views). This type of analysis requires many resources to assess the complex impacts that a disaster has on the well-being of a regional economy or the social fabric of a community.

Those aspects are indeed often more difficult to quantify with a high level of accuracy, yet are very important, as discussed in the white paper on Operationalizing Community Disaster Resilience.[2]

The question of how and whether to incorporate mortality and morbidity risks into a CBA is another key consideration, especially in the developing world where an estimated 95 percent of deaths from natural disasters occur. The common approach to quantifying fatality is 'value of statistical life' (VSL) estimates, typically based on projections of lost future earnings. Such comparisons within a region or country with similar levels of income can be defended (and often is done explicitly or implicitly), but undertaking such analyses across high- and low-income countries introduces ethical concerns. For instance, the average income per capita in Luxembourg is 50 times higher than in Nepal; should the VSL of a life in Nepal be 50 times less than a life in Luxembourg?

Assessing portfolios of options and systemic interventions

While assessments of the economic efficiency of flood risk reduction may focus on hazard and risk-specific interventions, there is increasing evidence that the best risk reduction solutions comprise a portfolio of interventions. What's more, these options may be part of broader developmental contexts, for example, investments in education, health or infrastructure, which may significantly contribute to benefits related to flood risk reduction by building resilience. One example is more robust medical facilities that are likely to lessen the healthcare burden post-disaster.

Two case studies were recently carried out by the research team in different economic and geographic contexts. These two examples illustrate the significant opportunities a risk-

[2] www.iiasa.ac.at/web/home/research/researchPrograms/RiskPolicyandVulnerability/Operationalizing_Resilience_Against_Natural_Disaster_Risk_II.pdf;
http://opim.wharton.upenn.edu/risk/library/zurichfloodresiliencealliance_ResilienceWhitePaper_2014.pdf

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based CBA offers, while at the same time tackling some of these key challenges.

Example 1: A comprehensive and spatially-detailed flood risk cost-benefit analysis on a metropolis: Case of New York City.

After Hurricane Sandy in 2012, which led to losses of nearly USD 80 billion, different flood risk reduction strategies have been proposed for New York City by scientists, engineers, NGOs and policy makers. Some structural measures (e.g., flood barriers) are effective in lowering the probability of the flood hazard and protecting large parts of the city, but come at a very high initial investment cost (as much as USD 20 billion to build, not accounting for annual maintenance costs over the life of the structure). 'Softer' measures such as introducing more stringent building codes support current initiatives to reduce exposure and vulnerability, and entail lower investment costs, but these changes will not keep flood waters from entering the city. This case study, undertaken by Wharton and focusing on storm surge flood hazard only, was published in Science in May 2014.[3] It combines several strengths and tackles many of the CBA challenges: (1) it is done for a large area (the entire New York/New Jersey coastal area); (2) it covers residential, commercial, and industrial assets as well as public infrastructure; (3) it builds on the most advanced techniques of storm surge simulation, which itself builds on the more recent modelling from hurricane science; it also builds on the most recent flood vulnerability analyses (i.e., how assets are damage by a flood); (4) it compares several comprehensive, feasible flood protection options that have been discussed with the local decision makers (i.e., the mayor's office); (5) it accounts for both direct and indirect losses; (6) since CBA results are sensitive to the selected discount rate and uncertainties inherent to modelling, the study provides transparent sensitivity analysis (i.e., varying parameters) and compares the results; and (7) since investment in flood protection can last for several decades and must then account for future conditions, after the CBAs were done under current climate conditions, the entire analysis was done again for 2040 and 2080 climate and urban development scenarios.

The CBA results suggest that flood risk reduction strategies for coastal cities should be flexible enough to allow for a change in policy when more detailed and reliable information becomes available on, for example, rising sea levels.

Example 2: A cost-benefit analysis linked to participatory decision-making for flood-exposed farming households: case of Uttar Pradesh in northern India.[4]

This study tackled two key challenges: estimating a broad array of direct and indirect, and tangible and intangible impacts and measures; and a lack of integration of CBA within the decision-making process. The study integrated CBA in a participatory and iterative community-based decision-making process evaluating the historical as well as future performance of investments made to build the embankment of the Rohini River in northern India. The study showed that deriving realistic and relevant impact information must be supported by a participatory process involving communities that have been affected by floods and other hazards. It also demonstrated the value of taking such a broad-based approach to improve the robustness of results. While strict flood-engineering-based estimates of direct, structural losses showed high benefit-cost ratios, when the stress on the community's values was included in the analysis, the project became less efficient, and eventually even inefficient (costs higher than benefits). The assessment took into account a host of tangible and intangible effects on society and related costs (such as land compensation costs, chance of embankment failure, as well as disbenefits associated with waterlogging), which traditional engineering analysis of infrastructure projects tends to ignore. This has important implications when considering revisions to the design and implementation of the project; any further investments will provide solid and comprehensive benefits to those protected by this flood protection project.

[3] Aerts, Botzen, Emanuel, Lin, de Moel and Michel-Kerjan (2014). Evaluating Flood Resilience Strategies for Coastal Megacities, Science 344: 473–475.

[4] Kull, Mechler, Hochrainer-Stigler (2013). Probabilistic Cost-Benefit Analysis of Disaster Risk Management in a Development Context. Disasters 37(3): 374–400.

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Overall then it is possible to overcome some of the challenges associated with CBA by applying the latest insights from science and existing risk reduction applications. Figure 3 shows how a number of challenges were addressed: the CBA studies we reviewed mostly look at risk probabilistically (24 out of 27), yet often rely on incomplete distributions of flood return periods, or may only look at the annual average losses (the average across all possible flood events, which is not representative of high-level disasters, such as the 100-year event). Often studies looked at portfolios of options rather than individual solutions. Indirect effects were also often included. Considering intangibles remains a challenge for CBA (13 studies did, 14 did not), and systemic intervention methods are rarely included (two studies), as these are the most difficult to tackle.

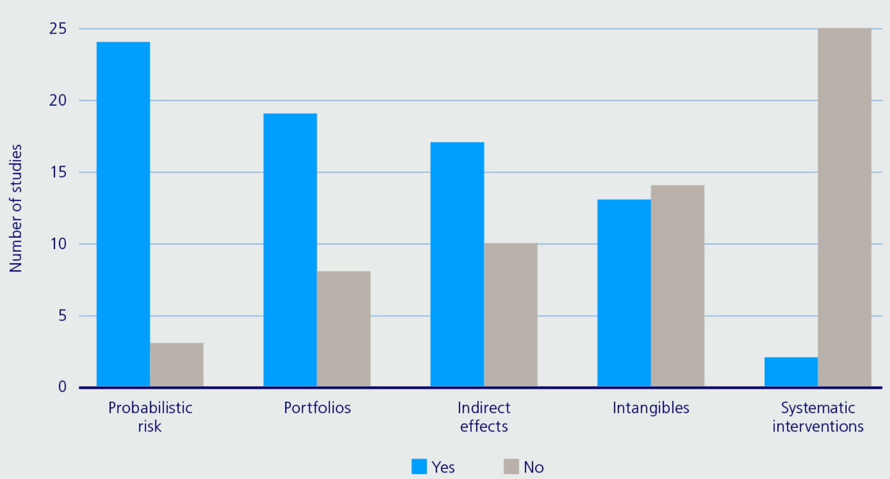
Finding 3: Decision-making can be improved by using various decision-support tools tailored to the desired outcomes and contexts.

A CBA analysis of economic efficiency is only one of the relevant decision-making criteria for prioritizing flood risk reduction investments. Decisions on investments to increase resilience to floods are likely to be based multiple criteria.

Criteria such as cost-effectiveness (reducing risk to a certain threshold), robustness (reliability of estimates), equitable treatment (people equally benefiting from a project), and acceptability are also key for decision-making on flood risk reduction interventions. Other decision-support techniques that can be used to measure achievement of these criteria include cost-effectiveness analysis (CEA), multi-criteria analysis (MCA) and robust decision-making approaches (RDMA). These tools can be used to make a more comprehensive case for flood risk reduction, despite the challenge that, unlike benefit-cost ratios, they do not offer metrics that are as easy to communicate when presenting results.

The various decision-support techniques are applicable for different objectives and contexts, and it is possible to combine approaches. Table 1 (page 7) provides an overview of the opportunities and challenges inherent in different tools, which may help to guide practitioners to select among them. Selection depends on the desired objective, the circumstances, data available, time and money required to conduct the analysis, the level of detail, and other considerations.

Figure 3: Uptake of best practice of CBA for risk-based DRR studies



Source: Mechler et al, 2014

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A way forward: Applying a decision-support toolbox to the work of the Zurich flood resilience alliance

CBA and other decision-making tools are valuable not only when selecting flood risk reduction interventions or evaluating interventions ex-post; they can also help risk managers and key stakeholders identify and agree on the most important benefit and cost aspects of a project. These tools are also useful when defining common values and objectives as part of a wider assessment and decision-making process. This process could include several different considerations and aspects: stakeholder participation; detailed participatory analysis of the factors contributing to flood risk and vulnerability; quantitative and qualitative methods for evaluating the impacts of flood disasters; and transparent and inclusive processes for qualitative and quantitative data collection and analysis. From a resilience perspective, the usefulness of decision-making tools is determined by their acceptance by the communities; it is imperative that a transparent, impartial, credible and consistent process be used.

The Zurich flood resilience alliance's work will analyze how decision-making techniques discussed here can be included in existing approaches that involve community participation, such as the vulnerability capacity assessments (VCA) used by the International Federation of the Red Cross and Red Crescent Societies (IFRC), or Practical Action's participatory capacity and vulnerability assessment (PCVA) to ensure that community-based work makes best use of these tools. These 'participatory processes' are conducted in conjunction with collecting secondary information to provide a baseline in assessing communities' risk exposure to different hazards. In particular, linking to VCA/PCVA provides a good entry point for collecting baseline information and monitoring data on risk and resilience. It also incorporates community views on potential

Table 1: Applicability of different decision-support tools for addressing flood risk reduction

Tool	Opportunities	Challenges	Typical application
CBA cost-benefit analysis	Rigorous framework based on comparing costs with benefits	Need to monetize all benefits, difficulty in representing intangible impacts, such as value of life	Well-specified hard-resilience projects with economic benefits (e.g., flood risk prevention)
CEA cost-effectiveness analysis	Ambition level fixed and only costs to be compared. Intangible benefits, particularly loss of life, do not need to be monetized	Ambition level needs to be fixed and agreed upon	Well-specified interventions with important intangible impacts which should not be exceeded (loss of life, etc.)
MCA multi-criteria analysis	Consideration of multiple objectives and plural values	Subjective judgments of values required, which hinder replication	Multiple and systemic interventions involving plural benefits (e.g., investing in infrastructure and education)
RDMA robust decision-making approaches	Address uncertainty and robustness of decisions	Technical and computing skills required	Projects with large uncertainties and long timeframes (context of climate change where flood return periods may become more uncertain)

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costs and benefits to enable communities to gain additional perspective on their own vulnerability and risk. This takes into account especially indirect risk, allowing them to develop innovative approaches to community-based flood risk reduction and resilience.

Figure 4 gives examples of how CBA and other tools might be built into the Zurich flood resilience alliance decision-support processes, beginning with community selection and extending to monitoring and evaluating the benefits of the flood resilience solutions implemented. For example, when selecting communities, existing CBA information on the returns of various flood risk reduction initiatives could be used to highlight areas where current investments are insufficient. Once the VCA/PCVA process has started in the selected communities, CBAs and other tools have the potential to offer two useful functions: they can assist in the process of deciding which flood risk reduction strategies to employ, based upon the community's objectives; they can provide insight into the intangible benefits of the various flood risk reduction initiatives to assist in prioritizing them for a further quantitative analysis. Finally, systematic tools such as CBA and others are useful in monitoring how effective the various flood risk reduction initiatives were that were implemented.

Importantly, this research will be directly linked to the other work being done by members of the Zurich flood resilience alliance (see our earlier white paper on operationalizing community disaster resilience).[5] Increasing our understanding of the decision-making tools available and developing, applying and testing them in the communities where we work will be the focus of future activities of the Zurich flood resilience alliance.

[5] The work being done by Zurich's flood resilience alliance is discussed in detail in 'Enhancing community flood resilience: a way forward.' May 2014. Available at http://www.zurich.com/en/corporate-responsibility/flood-resilience/research-programs

Figure 4: Entry points for using decision-support tools to build flood resilience

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About the Zurich flood resilience alliance

An increase in severe flooding around the world has focused greater attention on finding practical ways to address flood risk management. In response, Zurich Insurance Group launched a global flood resilience program in 2013. The program aims to advance knowledge, develop robust expertise and design strategies that can be implemented to help communities in developed and developing countries strengthen their resilience to flood risk.

To achieve these objectives, Zurich has entered into a multi-year alliance with the International Federation of Red Cross and Red Crescent Societies, the International Institute for Applied Systems Analysis (IIASA), the Wharton Business School's Risk Management and Decision Processes Center (Wharton) and the international development non-governmental organization Practical Action. The alliance builds on the complementary strengths of these institutions. It brings an interdisciplinary approach to flood research, community-based programs and risk expertise with the aim of creating a comprehensive framework that will help to promote community flood resilience. It seeks to improve the public dialogue around flood resilience, while measuring the success of our efforts and demonstrating the benefits of pre-event risk reduction, as opposed to post-event disaster relief.

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