***Reviewing estimates of the economic efficiency of disaster risk***

 **Supplementary Material:**

**Box 2: The MMC (2005) study**

Mandated by the US Senate to better understand the benefits of risk management investments, the Federal Emergency Management Agency (FEMA) commissioned the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS) to perform a study on the costs and benefits of DRM using CBA. Carried out by an interdisciplinary team of more than 30 experts, the study comprised of two elements: (i) a benefit cost analysis of FEMA grants given post disaster to affected communities to build future resilience, and quantitative and qualitative research on the impacts of the grants in 8 sample communities. The benefit-cost analysis of the future savings from FEMA mitigation grants, for which over the years 1993 to 2003 $3.5 billion were given to states and communities examined a sample of 357 out of 5,479 grants. The MMC review based its benefit estimates of the reduced impacts across seismic risk, windstorm (hurricane and tornado) and flood risk on the comprehensive HAZUS risk model. The review estimated a substantial number of impacts as follows:

* Reduced direct property damage (e.g., buildings, contents, bridges, pipelines);
* Reduced direct business interruption loss (e.g., damaged industrial, commercial, and retail facilities);
* Reduced indirect business interruption loss (e.g., ordinary economic ripple effects);
* Reduced (nonmarket) environmental damage (e.g., wetlands, parks, wildlife);
* Reduced other nonmarket damage (e.g., historic sites);
* Reduced societal losses (casualties, homelessness); and
* Reduced need for emergency response (e.g., ambulance service, fire protection).

An estimate for the sample of 357 grants was scaled up leading to a total discounted present value of $14 billion in terms of societal benefits, which overall would mean a B/C ratio of about 4. There is important variation across hazard, interventions and locations. Importantly, work funded by these grants was divided into projects building *hard resilience* (hazard-proofing or relocating buildings, lifelines and infrastructures, improving drainage systems and land conditions), as well as process-based activities leading to stimulating *soft resilience* by means of hazards, vulnerability, and risk assessments, planning, raising awareness and strengthening institutions.

Table: Summary results of the MMC (2005) study

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Hazard  | Average B/C Ratio  | Average B/C Ratio Project | Average B/C Ratio Process | Range of estimates overall |
| Earthquake  | 1.5 | 1.4 | 2.5 | 0-4.0 |
| Wind  | 3.9 | 4.7 | 1.7 | 0.05-50 |
| Flood  | 5.0 | 5.1 | 1.3 | 1.3-7.6 |
| Average  | 4.0 |   |   |   |

The study also estimated the present value of potential annual savings of the FEMA to the federal treasury alone due to an annual budget investment on these grants of $265 million to amount to $967 million, which leads to an average B/C ratio of fiscal benefits only of 3.7. In general, flood risk exhibited highest returns, as flooding is considered more frequent than wind and earthquake risk. Results were crosschecked and indicated in terms of ranges. A very few of the grants for earthquake and wind risk did actually not produce positive net returns (or B/C ratios larger than 1), while some interventions such as for wind risk produced very large effects in terms of B/C ratios in the range of 50.

Source: MMC, 2005

**Additional detail on CBA studies**

Table A1: Key characteristics of key CBA studies on DRM

| **Study-detail** | **Hazard** | **Risk and Intervention studied** | **Benefits** | **Results** |
| --- | --- | --- | --- | --- |
| EVALUATIONS |
| Vermeiren and Stichter (1998). Hurricane risk prevention - Dominica and Jamaica | Tropical cyclones | Evaluation of benefits of consideration of risk prevention in design and construction of port (Dominica) and school (Jamaica) | Potentially avoided reconstruction costs in one hurricane event each | Large reconstruction costs savings had measures been considered in design and construction |
| FEMA (1998). Ex-post evaluation of implemented mitigation measures in the paper and feed industries in USA | Hurricanes | Risk prevention  | Reduction in direct losses between 1972 and 1975 hurricanes | C/B ratio: ca. 100 |
| BTRE (2002). Flood risk management (Australia) | Flood | Structural and non-structural urban riverine flood prevention measures: Land use planning, building controls, voluntary purchase, levees, road sealing; preparedness  | Direct and indirect (clean-up, disruption of business, emergency costs), losses reduced | Substantial net benefits in terms of tangible direct and indirect losses reduced |
| IFRC (2002). Windstorm risk prevention (Vietnam) | Tropical cyclones | IFRC (2002): Mangrove planting project in Vietnam for protection of coastal population against typhoons and storms  | Savings in terms ofreduced costs of dikemaintenance | Annual net benefits: 7.2 mill. USDB/C ratio: 52(over period 1994-2001) |
| Venton & Venton (2004)Risk management of floods, Bihar and Andhra Pradesh (India) | Floods | Combined disaster mitigation and preparedness program in Bihar, India and Andhra Pradesh, India | Reduced losses of household possessions and livestock, reduced loss of life and reduced health impacts, reduced emergency spending | Bihar:B/C ratio: 3.8(range: 3.2-4.6)Andhra Pradesh:B/C ratio: 13.4(range: 3.7-20.1) |
| MMC (2005). Review of wide set of risk management grant programs (USA) | Flood, Wind, earthquake | Structural and non-structural interventions | Direct and indirect (clean-up, disruption of business, emergency costs) losses reduced | Average B/C ratio: 4 based on a review of 5,479 grant based activities (flood 1.3-5; wind 0.05-50; earthquake 0.1-4) |
| Ghesquiere et al. (2006). EQ- risk management - Colombia | Earthquake | Risk prevention coupled with preparedness and risk financing | Reduction in fatalities andstructural losses | B/C ratios range from: 0.9 – 2.5 |
| Fuchs et al. (2006). Avalanche risk reduction strategies - Davos, Switzerland | Avalanche | Wide variety of measures from land use planningand zoning, snow fences, capacity building, to reducing soil erosion | Reduction in fatalities andstructural losses  | B/C ratios range from 0.1 – 3.7 |
| Nabiul and Mechler (2009). Flood-proofing - Bangladesh | Flood | Flood-proofing of roads and highways and individual homesteads | Direct and indirect income losses | Best estimates are 1.6 for both options with range of 0.5 to 1.6 |
| Kull et al. (2009). Food risk prevention- India | Flood | Past flood risk performance of embankment | Direct and indirect as well as intangible benefits  | Embankment has not been cost-effective if a range of benefits and disbenefits considered: best estimate of BC 0.9 at 12% discounting |
| White&Rorick (2010). DRM flood interventions in Kalali district, Nepal | Flood | Capacity building, and training early warning system, flood risk prevention | Reduced losses to homes and content, increased yield due to distribution of hybrid rice seeds | B/C ratios range from 1.9-3.5 |
| IFRC (2011). Coastal afforestation in Viet Nam | Wind | Mangrove afforestation along coastline for protecting sea-dykes | Reduced costs in sea-dyke maintenance and repair, reduced disaster-induced material losses, ecological benefits due to carbon sink function of mangroves | Wide range of B/C ratios from 3–69 (excluding sink benefits) and 29–105 (including carbon sink benefits) at discount rate of 7.2%, but hazard occurrence is assumed (every ten years) |
| Kahn et al (2012). installation of boat winch system, Vietnam | Wind | Installation of a boat winch system | Avoided losses of boats during windstorms | 3.5, with 12% discount rate |
| Eucker et al. (2012). Community-based flood risk management in 4 districts in Bangladesh | Flood | Community-awareness, risk prevention (through house plinth), livelihood support (rice distribution), emergency training | Reduced losses to homes and content, increased yield due to distribution of hybrid rice seeds | B/C ratios range from 1.2-4.9 |
| APPRAISALS   |
| Kramer (1995). Windproofing banana trees in St. Lucia | Tropical cyclones | Appraisal of strengthening of roots of banana trees against windstorms. | Reduced yield losses | Expected internal rate of return: 20.4% (range of 7.5%-30.6%) |
| World Bank (1996). Flood protection - Argentina | Flood | Appraisal of Argentinean Flood Protection Project involving the construction of flood defense facilities | Reduction in direct flood damages to homes, and avoided expenses of evacuation and relocation | Economic rate of return: 20.4% (range of 7.5%-30.6%) |
| Dedeurwaerdere (1998). flood prevention measures -Pampanga province- Philippines | Flood | Appraisal of different prevention measures against floods and lahars in the Philippines | Avoided direct economic losses in agriculture, residential buildings and infrastructure | B/C ratio: 3.5 – 30 |
| Smyth et al. (2004). Seismic retrofit - Istanbul (Turkey) | Earthquake | Smyth et al. (2004). Seismic retrofit In Istanbul | Reduced structural losses and fatalities | Cost-efficient (in terms of NPV) only when loss of life considered |
| Mechler (2004). Sovereign risk transfer - Honduras and Argentina | Earthquake, tropical cyclones | Appraisal of sovereign risk transfer for public infrastructure in Honduras and Argentina | Reduced effect on GDP | Sovereign insurance beneficial for Honduras, and less so for Argentina  |
| Mechler (2005). Flood risk prevention - Piura (Peru), Integrated water management and flood protection scheme -  | Flood | Prefeasibility appraisal of Polder system against flooding, integrated water management and flood protection scheme for Semarang, Indonesia | Reduction in direct social and economic and indirect impacts | PeruB/C ratio: 3.8Range: 2.2-3.8Indonesia:Best estimate: 2.5B/C ratio: 1.9-2.5 |
| Kull et al. (2009). Flood risk prevention - Uttar Pradesh, India | Flood | Flood risk prevention | Direct and indirect as well as intangible benefits  | Flood risk prevention cost-effective given a future climate with more heavy precipitation. Range of 2-2.5 for BC ratio for today and future conditions |
| Schroeter et al. (2008).Early Warning in the Traisen Basin, Lower Austria& Besos Basin, Catalunya, Spain | Flood | Reduction of losses due to installatin of early warning system |  Damage avoided in industry gathered from surveys  | Austria11.7, range: 5.8-20.5Spain4.6, range: 2.6-9.0 |
| ECA (2009) and CCRIF (2010). Climate risk adaptation cost curves applied to national and subnational level DRM options | Tropical cyclones, floods, drought | Climate risk adaptation cost curves applied to national and subnational level DRM options | Avoided losses in to residential, industrial, commercial and public assets | Wide variety of measures for different locations are considered economically efficient, while others are not |
| Mora et al. (2009). Retrofitting three groups of public buildings- Bogota, Colombia | Earthquake | Seismic retrofit | Direct, content and business interruption costs | Probability of benefit-cost ratio greater than one is 44%, 73%, 12% for education, health and administrative buildings.  |
| Mechler et al. (2009). Integrated drought risk management -Uttar Pradesh, India | Drought | Combined drought prevention and micro insurance portfolio | Reduced impact on farmer's livelihoods | Combined drought prevention and microinsurance portfolio more effective than options individually, and range of 1.9 to 2.0 for combined option |
| Subbiah et al. (2008). Potential benefits of early warning for hurricanes and floods across a number of case studies (Bangladesh, Sri Lanka, Vietnam, Thailand, Indonesia, India, Philippines) | Tropical cyclones, flood | Setting up and improving early warning systems for sudden onset events, as well as improved seasonal forecasts | Reduced physical and economic losses | Mostly very high returns calculated (up to BC ratio of 559), but no discounting conducted |
| Pinelli et al (2009): Multiple hurricane Mitigation measures for residential buildings in Florida | Wind | Multiple measures | Reduction in losses | 0.4-1.7 for the most vulnerable regions. Difference is due to retrofit measures |
| Hochrainer-Stigler et al. (2010), Comparison of structural risk reduction against hurricane, flood, and earthquake hazard- St. Lucia, Indonesia, Turkey, and India | Flood, tropical cyclones, drought |  Improving or retrofitting residential structures in highly exposed developing countries | Direct structural and loss of life (Turkey) | Wide spectrum of results. Simple averages: Floods (India): 3.1 (0.04-6.2);Floods (Indonesia): 1.9 (0.07-3.75);Tropical cyclones (St. Lucia): 0.8 (0.07-1.5); EQ (Turkey): 2.5 (0.09-4.9) at 12% discount rate |
| Venton et al. (2010). Flood prevention as part of safer islands programme - Maldives  | Floods | Coastal flood prevention for three islands and three interventions ranging from coastal protection to disaster risk awareness in the Maldives in light of climate change | Avoided losses in to residential, industrial, commercial and public assets | BC ratio ranges from 0.28-3.65 when summarized across all cases and interventions, simple average across all results: 1.3 |
| ERN-AL (2010). retrofitting schools in Latin America | Earthquake | Seismic retrofit | Reduced losses to buildings | Generally not economically efficient in Bolivia, Honduras, Nicaragua, Argentina, Colombia, Mexico and Venezuela. Efficient in Costa Rica, El Salvador and Peru due to low costs of retrofitting. |
| Venton et al. (2012). Building drought resilience for pastoralists in Kenya and Ethiopia | Drought | Options building resilience: Livestock (improving access to markets, veterinary care, adequate feed and water), water (wells hand pumps, boreholes), education (school construction) | Avoided aid expenditure, animal losses (livestock), reduced water borne diseases, reduced water collection time, increased school attendance (water), increased revenue and reduced reliance on food aid (education) | Kenya: Livestock: 5.5; Water: 1.1-26; Education: 0.4 Ethiopia: Livestock: 3.8; Water: 5.5-27; Education: 0.4  |
| Kahn et al (2012).Earthquake-safe construction in Nepal | Earthquake | Utilizing straw bale in building construction instead of using brick | Financial benefits of constructing straw-bale houses  | 2, with 12% discount rate |
| Zarine et al. (2015b): Building of tidal channel in the Seychelles | Flood | Building of tidal channel running 1.5 km to prevent against flooding | Reduction in losses | Range: 0.5- 4.0; best estimate: 1.2 |
| Lazamanana et al. (2015). Evaluating Wind proofing options in Madagascar | Wind | retrofitting wood and unrefined masonry homes against cyclone wind | Reduction in losses | Range of B/C ratios: 0.4- 3.4. Best estimate: 1.5 |
| Leste-De Périndorge et al. (2015): Evaluating residential wind proofing options in Mauritius | Wind | Retrofitting concrete, iron and wood framed homes against cyclone wind | Reduction in losses | B/C ratios for different frames: concrete: 0.3- 1.65; iron: 1.3-9.3; wood: 1.2-6.4 |