Enhancing efficiency in humanitarian action through reducing risk

A study on cost-benefit of disaster risk reduction

Aktion Deutschland Hilft
Germany's Relief Coalition

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Executive summary

Natural hazards are a constant threat across the world. In 2019 alone, almost 400 disasters triggered by natural hazards were recorded across the globe and there is a clear increasing trend of disasters; while between 1980 and 1999 4,212 disasters were reported, this number rose to a total of 7,349 between 2000 and 2019. This trend is to a large extent driven by climate-related disasters (e.g. floods, storms or extreme temperature events) and is expected to continue. The global economic costs of those disasters are enormous. Munich Re estimates that in 2019 disasters caused economic losses of 150 billion USD. During the first half of 2020 (latest available figures), losses already reached 68 billion USD. Those numbers are also steadily increasing.

Disaster risk is a function of the vulnerability of exposed elements and the hazard. It is possible to reduce the risk of disasters happening through a wide range of strategies and measures which focus on decreasing either the exposure to the hazard (by physically separating the hazard and society, e. g. through a damn keeping a flood in check) or the vulnerability (through preparatory measures and trainings) of the exposed population.

In fact, the role of the human element in the risk equation (i.e. the vulnerability) has taken a more central role in managing disaster risk over the last years. This contrasts with a prior heavier focus on hazard-based approaches which were often followed in the past and which focused more on reduction of exposure to hazards. Finally, in more recent years, resilience has taken a more central role in risk management. It is broader and more holistic concept than "classical" disaster risk reduction: While classical disaster risk reduction typically focuses on one hazard and how to decrease the risk from this hazard, resilience thinking focuses more on strengthening a system (e. g. a community) and to give it the capacity to face multiple hazards, also unknown ones.

It is commonly accepted that disaster risk reduction measures can be effective in reducing risks. However, investments in disaster risk reduction are globally very low. Especially in countries which would be most in need of reducing disaster risks (countries with a low Human Development Index and a high share of vulnerable population) there seems to be an enormous funding gap; the local governments usually do not have the necessary resources, and official development assistance by the international community lags behind its own aspirations . Part of this funding gap can be explained by the hesitation of decision makers and donors to invest in disaster risk reduction due to a lack of clarity about the cost-effectiveness of disaster risk reduction measures; while there is a lot of anecdotal evidence about the cost effectiveness, this remains highly context specific, the information is scattered and the methodology of existing case studies is sometimes of low quality.

Aktion Deutschland Hilft e. V. has commissioned this study to address this evidence gap. The objective is to provide a robust empirical basis to decision makers, donors, and other stakeholders about the cost-effectiveness of disaster risk reduction measures. To this end, the study assessed a total of 157 existing case studies of disaster risk reduction measures to draw general conclusions. Given the challenges mentioned above (context-specific analysis, scattered information, low methodological quality) the study developed a methodological framework which allowed the study team to "dissect" the existing case studies and make them – to the extent possible – comparable.

The study concludes that there is strong evidence that disaster risk reduction in general pays off – i.e. that the socio-economic benefits of such interventions are in general higher than the costs. From a total of 157 case studies, 139 report benefit-cost-ratios above, meaning that the benefits outweigh the costs. This suggests that there are strong indications that in the vast majority of cases – beyond the obvious benefits of avoiding casualties, suffering and economic loss – disaster risk reduction is a cost-effective way of managing disaster risk. This is substantiated by the fact that often a large range of benefits is not included in the benefit-cost calculations due to methodological challenges while costs are usually fully accounted for.

Based on this finding and others, the study recommends the following actions:

- **Invest more into disaster risk reduction.** The analysis has shown that disaster risk reduction in the vast majority of cases is cost-effective and "pays off". For disaster risk reduction measures, it is important to take cumulative risks into account (as for example currently demonstrated by the COVID-19 pandemic) and to focus on building resilience where it makes sense. To address the risk of an intervention being eventually not cost-effective because the expected hazards did not strike it is advisable to invest in "no-regret" options, e. g. through focussing on creating co-benefits. Such interventions generate benefits even if no hazard extreme events occur. The analysis of the case studies further suggests that portfolios of different measures, as well as non-structural and preparedness measures in general are the most cost-effective ones.
- **Increase investments in disaster risk reduction in poorest countries.** The evidence shows that disaster risk reduction measures are most cost-effective in countries with a low Human Development Index. At the same time, those are the countries with the lowest investment in disaster risk reduction. To avoid loss and suffering, and to save future costs for disaster relief, investments should be increased in those countries. For climate change adaptation measures this is also integral part of the Paris Agreement which stipulates that wealthier countries should provide financial resources to assist poorer countries and prioritise those which are particularly vulnerable to the adverse effects of climate change and have significant capacity constraints.
- **Increase evidence base** for the topic through more cost-effectiveness assessments across all hazards and for all risk management strategies (including resilience building, anticipatory action, and for risk transfer mechanisms); those assessments should be conducted by independent evaluators.
- **Increase methodological rigour of cost-benefit-analyses in disaster risk reduction** by more stringently taking climate change into account for ex-ante assessments looking into the future; and by using the methodological framework proposed in this study as guideline of what to include and, even more importantly, to identify steps and methods that are not incorporated in an assessment due to methodological difficulties or poor data conditions. Those limitations should be clearly lined out in the analysis to contextualise it and provide best-possible transparency to decision makers.

1. INTRODUCTION

In 2016, Aktion Deutschland Hilft e.V. published the report "Cost-benefit analysis of disaster risk reduction – A synthesis for informed decision making" (the "2016 report"; see: HUGENBUSCH & NEUMANN 2016). The objective of that report was to provide a robust empirical basis to decision makers, donors and other stakeholders about the cost-effectiveness of disaster risk reduction (DRR) measures.

To achieve this, the 2016 report merged evidence from 117 case studies from the literature. In 102 out of those 117 analysed case studies the socio-economic benefits gained from DRR projects outweighed the invested resources, and often significantly so. Based on this thorough evidence review the study concluded that, beyond the obvious DRR benefits of avoiding casualties, suffering and economic loss, there are strong indications that DRR is in general a cost-effective way of managing disaster risk.

The 2016 study was published shortly after the Hyogo Framework for Action 2005-2015[1] had concluded and the Sendai Framework for Disaster Risk Reduction 2015 2030 was adopted. Both frames were and are lynchpins in the international strife and actions against an increasingly "risky" world. The urgency of those actions is to this day repeatedly demonstrated by a high number of disasters occurring across the globe. Global changes such as climate change and a growing world population will only exacerbate this in the future.

Further, the publication of the Grand Bargain[2] against the backdrop of the World Humanitarian Summit (WHS) in 2016 marks an important cornerstone in the international strive to address the root causes of the growing humanitarian needs. It proposes that the major donors of humanitarian aid and the largest humanitarian organizations should commit to make their spending more flexible, transparent and effective in order to address the growing gap between humanitarian needs and available funds. Countries at risk of disasters should have emergency reserve funds and dedicated DRR budget lines for risk-reduction activities available.

The Sendai Framework and WHS/Grand Bargain also reflect a paradigm change of the time by shifting emphasis from reactive disaster management more towards proactive DRR. This shift is also evident in the coalition Aktion Deutschland Hilft e.V. and the 2016 report was part of the coalition's strategical opening towards more preventive work. Today, in 2021, the international discourse has developed even further and often focuses on building resilience or innovative concepts such as anticipatory action. The present study is published against this backdrop. It outlines major developments that have occurred since 2016, both in terms of "problems" (disasters and losses) and approaches for tackling those problems (DRR, building resilience and anticipatory action). The main objective of this study is to further the evidence on the cost-effectiveness of DRR base by assessing 40 additional case studies and drawing general conclusions based on this assessment. The methodology for assessing cost effectiveness in this expanded study is cost-benefit analysis (CBA). Given that CBA is methodologically complex, and results are highly contextual, the 2016 report has developed a methodological framework which is also used in this study and allows to "dissect", analyse and compare CBA case studies.

[1] See https://www.preventionweb.net/sendai-framework/hyogo/
[2] See https://reliefweb.int/report/world/high-level-panel-humanitarian-financing-report-secretary-general-too-important-fail

2. BACKGROUND

2.1. A global increase of disasters

A natural hazard such as a flood, an earthquake or a storm becomes a disaster when it impacts a vulnerable society.

Natural hazards are a constant threat in the world. In 2019 alone, almost 400 disasters triggered by natural hazards were recorded across the globe (CRED 2020)[3]. While the number of disasters is fluctuating annually, a comparison between the last 20 years (2000 – 2019) and the period before that (1980 – 1999) shows that there is a clear trend of increasing disasters; while between 1980 and 1999 4,212 disasters were reported, this number rose to a total of 7,349 between 2000 and 2019.

This trend is clearly driven by climate-related disasters. For example, the number of recorded flood events has more than doubled between those two periods (from 1,389 to 3,254 events), the number of storm events increased by 40 %, and the number of extreme temperature events (e.g. heat waves or cold waves) increased by a staggering 230 % (CRED & UNDRR 2020). In terms of total numbers, during both periods floods and storms cause by far the most disasters.

Already today, the global economic costs of those disasters are enormous. Munich Re estimates that in 2019 disasters caused economic losses of 150 billion USD[4]; during the first half of 2020 (latest available figures), losses already reached 68 billion USD.[5] Those numbers are also steadily increasing. However, while the number of disasters is increasing, there seems to be a decreasing trend in terms of human losses from those disasters (CRED & UNDRR 2020).

Unfortunately, the trend of increasing disasters is certain to continue in the future, fuelled – among others – by climate change leading to an increase in intensity and frequency of extreme weather and climate events.

The risk stemming from climate change is a proven reality and the United Nations Framework Convention on Climate Change set up in 1992 put in place a series of global agreements to tackle climate change. This process culminated at the 2015 Paris Climate Change Conference with the adoption of the Paris Agreement, which introduced a new global regime for climate change, moving into a new approach post-2020. Under the Paris Agreement countries are expected by 2050 to pursue efforts to limit the increase to 1.5 °C. However, given current emissions, and even if current pledges under the Paris Agreement on climate change are met, the world is still on track to see a global temperature rise of 3 to 5 °C by 2100 (IFRC 2020).

In September 2015, two months before the Paris Climate Change Conference, the 2030 Agenda for Sustainable Development, including the Sustainable Development Goals (SDGs), was adopted by the heads of state and government at United Nations level. The 2030 Agenda is a commitment to achieve sustainable development by 2030 worldwide and in the 2018 report of the Intergovernmental Panel on Climate Change (IPCC) on limiting global warming to 1.5 degrees, the close connection between combating climate change and taking sustainability into account and implementing the SDG is clearly emphasised.

Due to inevitable consequences of climate change, such as the expected increase in the intensity and frequency of extreme events, an adaptation to climate change is necessary, which underlines the importance of and in line with the efforts within the Sendai Disaster Risk Reduction Framework.

[3] EM-DAT (Emergency Events Database) defines natural disasters as events triggered by natural hazards causing more than 10 deaths and/or affecting more than 100 people.

[4] https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/mediainformation/2020/causing-billions-in-losses-dominate-nat-cat-picture-2019.html

[5] https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/mediainformation/2020/natural-disaster-figures-first-half-2020.html

2.2. Reducing risks of disasters

What is disaster risk?

A natural hazard triggers a disaster when it hits vulnerable populations and man-made structures. The disaster risk is a function of the vulnerability of exposed elements and the hazard.[6]

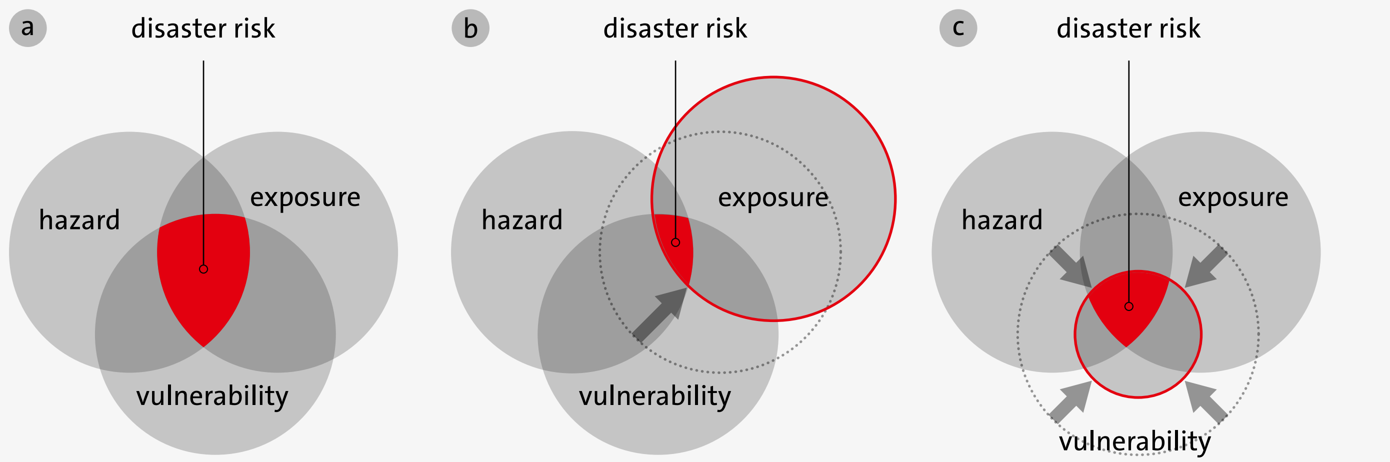


Figure 1: Graphical representation of the a) concept of disaster risk b) Reducing disaster risk by changing the exposure to the hazard c) Reducing disaster risk by minimising vulnerability

Disaster risk can be reduced by limiting exposure or by decreasing vulnerability. This concept acknowledges that the vulnerability of humans or society plays a key role in determining if a hazard becomes a disaster.

Disaster risk reduction and resilience

In fact, the role of the human element in the risk equation has taken a more central role in managing disaster risk over the last years. This contrasts with a prior heavier focus on hazard-based approaches which were often followed in the past and which focused more on reduction of exposure to hazards, which often includes the construction of structural measures such as dykes or shelters against certain hazards.

In more recent years, resilience has taken a more central role in risk management. While there is no one agreed definition of "resilience", in general it is accepted that it entails the abilities of a system (country, community, household etc.) to resist or absorb extreme hazards, as well as adapt to and recover from hazard impacts; this is reached by strengthening and transforming this system. As such it is broader and more holistic than "classical" DRR and, as stated in a recent assessment "resilience is not a simple re-branding but is a concept that goes well beyond mitigation to embrace adaptation, change and transformation" (PARKER, 2020). While classical disaster risk reduction typically focuses on one hazard and how to decrease the risk from this hazard, resilience thinking focuses more on strengthening a system (e.g. a community) and to give it the capacity to face multiple hazards, also unknown ones.

Also, Aktion Deutschland Hilft e. V. has recently adopted a definition of disaster risk reduction which takes this broader perspective in consideration and focus on capacity building and resilience.

[6] The terminological understanding of this study is based on UNDRR definitions. Please refer to: https://www.undrr.org/terminology

In 2020, Aktion Deutschland Hilft e. V. and its member organisations launched a process to synchronize existing understandings and approaches in DRR work within the coalition.

The result of the process[7], the conceptual frame of reference depicted in the Figure below, shows that the coalition lives a resilience-focused DRR work with a broad portfolio of interventions.

At the core of the conceptual framework is a nuanced understanding of disaster risk. The objective of the DRR work of the coalition is the strengthening of resilience by reducing vulnerability and foster capacities through a people-centred approach. The DRR work of the collation can be characterised by at least ten priority measures which reflect the wide variety of actions undertaken by the coalitions' member organizations. Finally, the outer ring depicts the common quality characteristics. These are the guiding characteristics which safeguard the successful implementation of the coalition's DRR work.

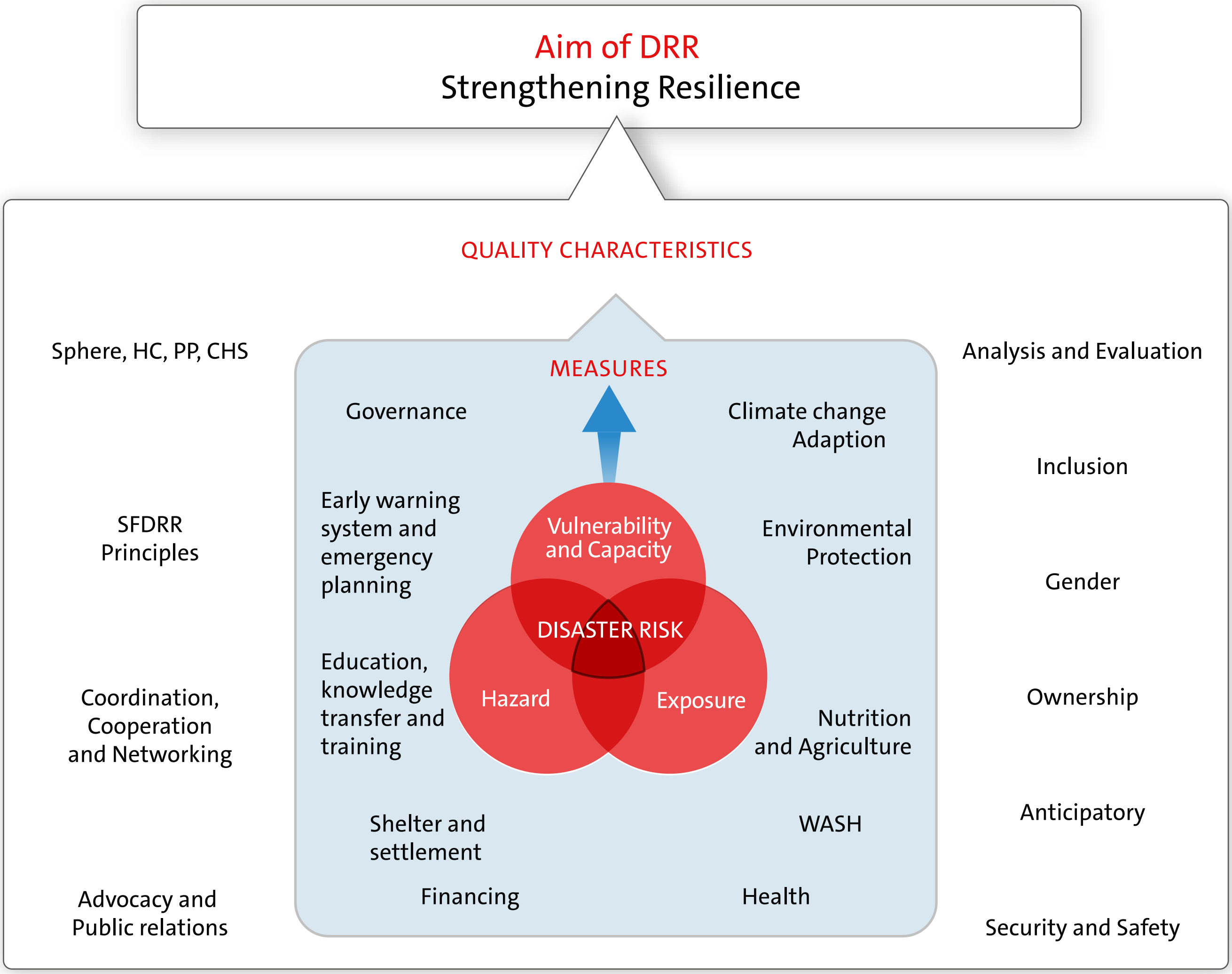


Figure 2: Conceptual framework for DRR work developed by Aktion Deutschland Hilft e. V.

[7] More information can be found here:
https://www.aktion-deutschland-hilft.de/de/wir-ueber-uns/qualitaetssicherung/katastrophenvorsorge-unser-orientierungsrahmen/
(only available in German)

Cumulative risks

Improvements have been made in managing the risks of single-hazard scenarios, as evident e.g. from the decrease of fatalities from disasters despite an increased occurrence of disasters. However, it is clear that the increasingly systemic nature of disaster risk, i.e. the overlap of events, the interdependency of various systems (e.g. supply systems, important sectors) and the interplay between risk drivers such as poverty or climate change requires greater strengthening of the governance of disaster risk management (CRED & USAID 2020). For example, the current COVID-19 global pandemic showcased the limitations of a hazard-by-hazard, siloed, fragmented view of risk management.[8]

The pandemic also has shown that the world is not prepared for major shocks which are foreseeable but uncertain in timing and effects – such as i.e. climate change. Even though most governments, but also society have reacted decisive to the current pandemic, it still caused major impacts across the globe. It has shown that in an interlinked world, taking a systemic view for managing risks is paramount (VAN DEN HURK ET AL. 2020) since events such as COVID-19, climate change, but also more localised major events with transboundary effects, can cause serious direct and indirect impacts leading to disruptions in society and wider macroeconomic effects which need to be taken into account when managing risks.

Anticipatory approaches

Another more recent development in the area of risk management are so-called anticipatory approaches. Those approaches are forecast-based and trigger assistance ahead of an imminent disaster in order to limit the adverse effects from extreme events. They are usually based on pre-planned action plans which govern the details of such interventions. In recent years, such approaches have spread widely and are adopted by a wide range of actors (IFRC 2020).

2.3. Spending on reducing the risks of disasters

Even though it is today well understood that preventive risk reduction can be a powerful tool for avoiding losses while at the same time being cost-effective, there seems to be a serious lack of funding for it to this date.

Recent research (ALCAYNA 2020) has shown that between 2010-2018 an average of 535 million USD of official development assistance were spent globally on DRR; in contrast, for emergency response (i.e. the response after a disaster strikes) a total of 11 billion USD where spent globally throughout this period. It was also shown that the resources for DRR are often not spent in the countries where they would be most needed, i.e. the most disaster vulnerable countries. The average DRR financing provided by official development assistance per capita of the extreme poor countries was 66 cents per year over the period 2010–2018. Those countries are also least likely to be able to spend domestic resources on DRR measures and are thus especially depended on international financing.

Also, for anticipatory action, while funding is growing, it remains small compared with post-disaster humanitarian spending. Investments are proportionally small-scale, fragmented and agency specific. Moreover, they are rarely anchored in government systems or linked to more systematic investments in meteorological services, early warning systems, risk analyses or disaster preparedness (IFRC 2020).

[8] https://www.preventionweb.net/go/71228

3. COST-BENEFIT ANALYSIS IN THE CONTEXT OF DRR

Cost-benefit analysis (CBA) is a common and proven tool for assessing the cost-effectiveness of projects, programmes, policies, or other interventions. The results of a CBA give an indication if such an investment is cost-effective from a socio-economic perspective – meaning, that the benefits of the investment outweigh the costs. If the costs outweigh the benefits this does not mean that an investment is not effective since it still can potentially save lives and property. In fact, ideally a CBA should be conducted before an intervention is implemented, to serve as a decision-making tool to choose between different interventions.

One specific feature of CBA in a DRR context is that the benefits of measures are expressed in terms of avoided losses and avoided damage to man-made structures such as buildings, property, machines etc. as well as the avoidance of fatalities, injuries, pain, business interruptions or the loss of or damage to culturally and historically important items.

The widespread success of CBA can be attributed to a number of factors, including on the one hand because it allows for detailed assessment and inclusion of a number of different social, economic and environmental effects such as the ones listed above, and on the other hand due to the intuitiveness of the results that it produces. The intuitiveness of the results of a CBA also allows to compare a wide variety of DRR measures.

There are different ways to present the result of the CBA, including the cost-benefit ratio, benefit-cost ratio, net present value or the internal rate of return. In this study the benefit-cost-ratio is used to present the results. The cost-benefit ratio is calculated by dividing the DRR costs through the DRR benefits. The result is presented as a ratio (such as 1:10 or 1:2). A project is considered cost-effective when the benefits are higher than the costs.

However, CBA also has clear and well-known limitations. Those include e.g. the strong simplification of various attributes and their relationships, the reliance on several assumptions, and the frequent lack of data which would allow the inclusion of more indirect effects.

CBA is methodologically complex and should thus be seen as a decision facilitator rather than the sole criterion for decision making. It should be applied within a wider decision framework that includes social, ecological and cultural concerns.

One way to mitigate the methodological challenges is by putting a CBA in a wider context by embedding the quantitative results into a qualitative narrative which contextualises and explains the results while also clearly outlining the limitations of the quantitative CBA results. In general, embracing uncertainty and preparing several scenarios strengthens the credibility of any CBA (LAZAMANANA ET AL. 2015). This could be e.g. be done through including the following information in CBAs in a DRR context:

- Highlight sources of uncertainty;
- State reasons for all assumptions made; and
- Express all types of avoided damage which have not been included in the analysis and the reasons for the exclusion.

These points provide the reader with the necessary tools to interpret the results correctly.

4. METHODOLOGY

4.1. Methodological framework

This study uses a methodological framework which permits to ‘dissect’ existing CBA case studies.[9] The objective of this approach is to allow drawing conclusions from the case study catalogue beyond just comparing and summarising their end results; instead, where possible, this approach allows to contextualise results and analyse if the cost-effectiveness of interventions differ e.g. per type of intervention (structural or non-structural) or per hazard.

The framework also allows to assess the methodological quality of the case studies since it includes the crucial steps in carrying out a methodologically sound CBA in the context of DRR. As such, the framework can also be used by CBA practitioners as an orientation for conducting a CBA to ensure that all steps are included in an assessment.

Finally, it can also be used by practitioners to identify steps and methods that are not incorporated in an assessment due to methodological difficulties or poor data conditions; as described in the last step “Handling uncertainties” (see chapter 5.5), the description of such limitations is crucial when presenting the results of an assessment.

The Figure below shows the structure of the methodological framework which frames the analysis done in chapter 5.

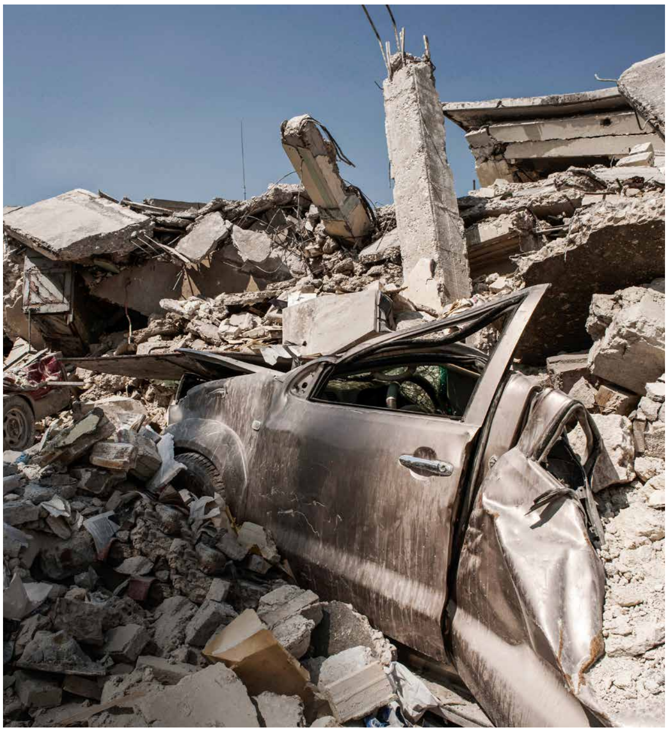
The risk	The measures to address the risk	The cornerstones of the CBA	Assessment of costs and benefits	Handling uncertainty
• Hazard • Risk assessment • Future changes due to climate change	• Strategies to reduce risk • Structural and non-structural	• Evaluation type • Time horizon • Discount rate • Area of analysis	• Assessment of costs • Assesment of benefits	• Co-benefits • Sensitivity analysis

Figure 3: Methodological framework for assessing the case studies

In addition, chapter 5 presents:

- Specific findings per hazard (chapter 5.6);
- Findings on relations between the case study authors and the case study results (chapter 5.7);
- Findings on relations between case study locations and the case study results (chapter 5.8); and
- An overview of observations on trends and priorities in the analysed case studies (chapter 5.9).

[9] The methodology has been developed for the original 2016-report. For this report the methodology has been refined and 40 case studies have been added spanning the time frame from 2015 to 2020.



4.2. Case study catalogue

The methodological framework forms the basis for a comprehensive analysis of CBA studies on DRR projects.

Case studies have been identified through a desk research. Albeit the analysed literature spans a wide variety of research and policy briefs, project reports and scientific literature, the present meta-analysis does not claim to be complete or exhaustive. Selection criteria for case studies include that analysed case studies need to provide clear reference to a hazard and the intervention needs to have a clear risk management focus. Furthermore, case studies need to express the result as a ration of benefits and costs. Some studies only reported benefits and costs in monetary terms; in those cases, the benefit-cost-ratios of the interventions were calculated based on those numbers.

In case a publication includes different study areas, measures against different hazards or compares different interventions, the publication is split into different CBA case studies.

This study includes a total of 157 case studies from 91 publications ranging over the last 25 years (period under review: 1996 – 2020). The case studies stem from a total of 49 countries. Some studies (e. g. KUNREUTHER ET AL. 2012) encompass not one single country but provide CBA for up to 80 different countries. Reviews have only been conducted on literature in English and German language.

The benefit-cost ratios in 139 of the 157 case studies are above the value of one – i.e. **89% of all case studies report that the benefits of the assessed DRR measures outweigh the costs.**

5. FINDINGS AND DISCUSSION

5.1. What is the risk

Hazard

A hazard is "a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation"[10] This paper follows the EM-DAT hazard classification of the Centre for the Research on the Epidemiology of Disasters (CRED)[11].

Case studies covering the following hazards were identified through a literature review:

- Earthquakes;
- Floods;
- Landslides;
- Storms; and
- Droughts.

To incorporate all case studies, the analysis includes two additional "types" of hazards which are not reflected in the EM-DAT classification. The first additional type is "multi-hazards". This includes case studies which address more than one hazard. The second is called "hydro-meteorological hazards". This incorporates case studies that focus on the benefits of implementing meteorological services. These meteorological services are implemented to forecast a variety of hydrological, meteorological and climatological hazards.

Figure 4 below shows the number of analysed case studies per hazard. The focus on flood hazard interventions is striking. Nearly 40 % of all analysed case studies refer to flood hazards, followed by droughts and storms.

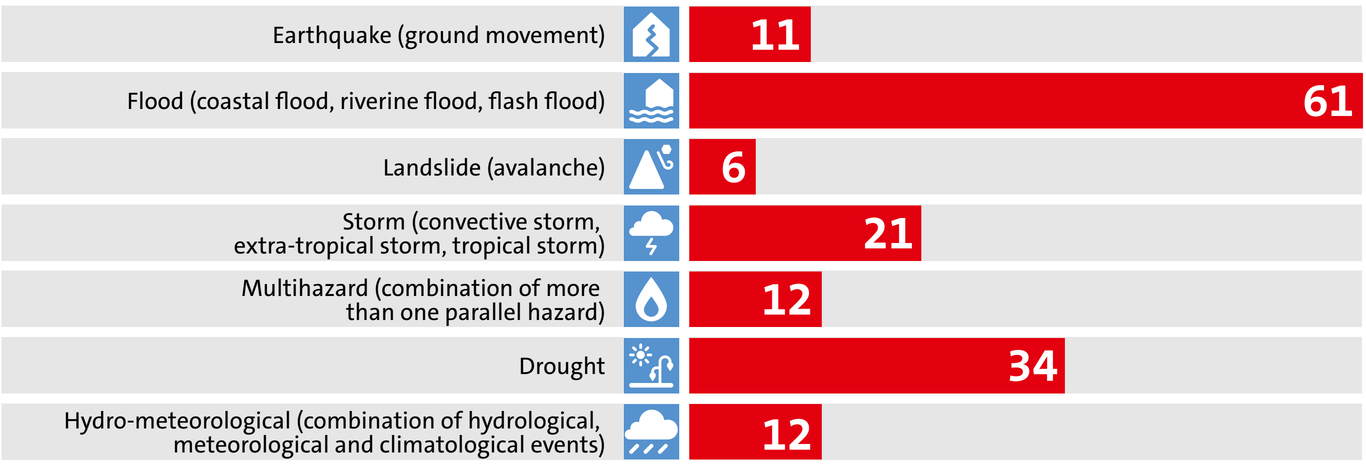


Figure 4: Count of case studies per hazard (157 case studies)

As can be seen, many hazards are not reflected in the analysis since no case studies were identified through the literature review. These include volcanic activity, extreme temperatures (heat and cold waves) and wildfire hazards or biological hazards and pandemics.[12] Those gaps do not imply that case studies on these hazard

[10] Definition adapted from UNDRR. See: https://www.undrr.org/terminology/hazard
[11] See: https://www.emdat.be/classification. CRED defines six sub-groups of natural hazards. These are called geophysical, meteorological, hydrological, climatological, biological and extra-terrestrial. Each of these sub-groups comprises of several disaster main-types and disaster sub-types. Storm, for example is a disaster main type in the "meteorological" sub-group and is further divided into three disaster sub-types: tropical storms, extra-tropical storms and convective storms.
[12] Albeit, it needs to be stressed that the latter two hazards are grounded in the medical research literature. This meta-analysis put an emphasis on non-biological driven hazards.

types do not exist but are nevertheless an indication that case studies are primarily conducted for some specific hazard types.

Riverine floods are the hazard which impacts the largest proportion of people worldwide (2.5 billion resp. 55 % of all people affected between 1994 and 2013) which can be a reason for the high number of case studies for this hazard. However, other hazards such as earthquakes or storms result in higher number of casualties than riverine flooding hazards (CRED 2020) while only a few case studies exist for them.

The Figure below visualizes the CBA results per hazard for all 157 case studies.

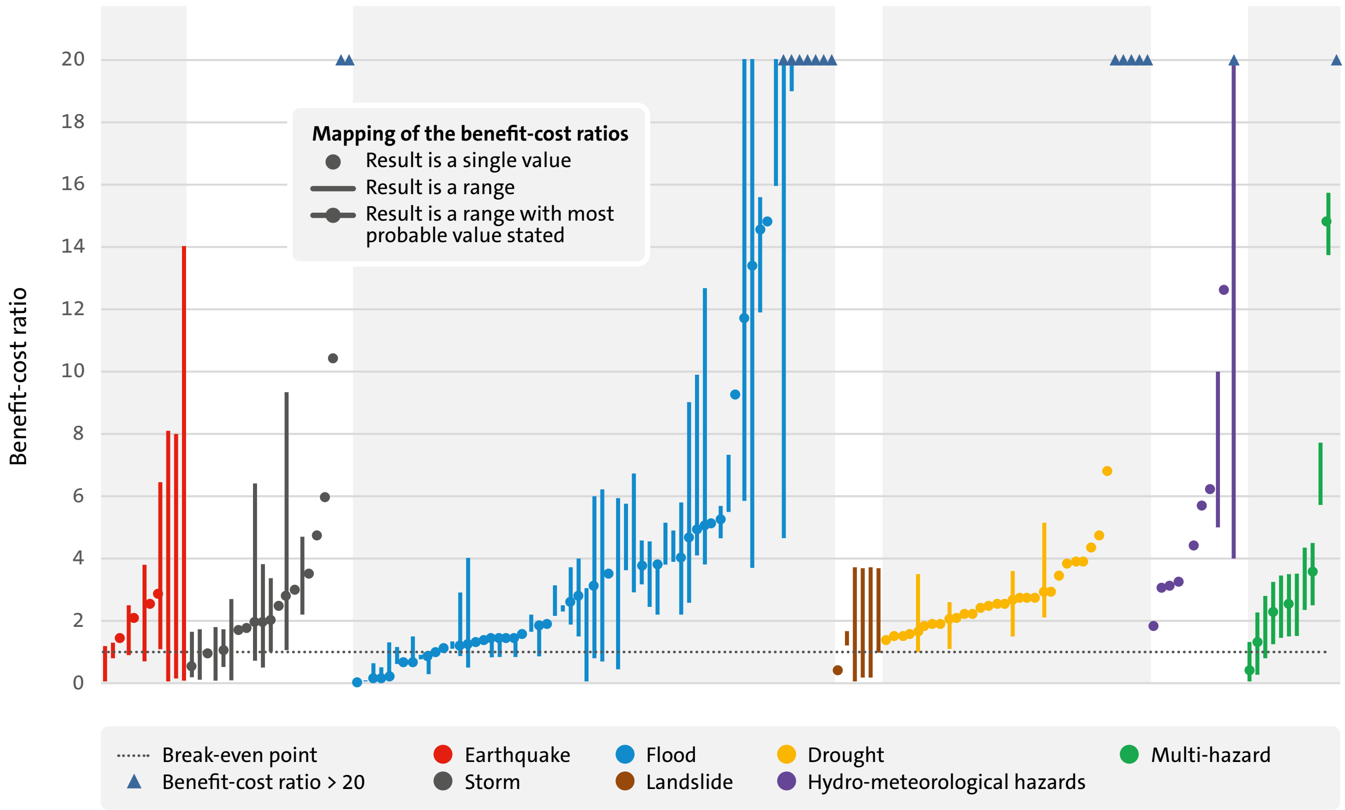


Figure 5: CBA results grouped by hazard

The results show that DRR measures are overall cost-effective; only in 18 case studies the mean value of the benefit-cost-ratio is below one.

Section 5.6 provides a more detailed description of the results per hazard.

Risk assessment

> *i* Following the concept of defining risk as a function of hazard, exposure and vulnerability, those three dimensions need to be thoroughly assessed in order to understand the risk, plan for managing it, and assess and compare the potential benefits of different DRR measures.

A hazard analysis[13] is a stochastic representation of the specific intensities and frequencies of the hazard(s) against which the DRR measure is implemented. This is an important factor in a CBA for DRR measures since in most cases (expect for cases with frequent hazard events) it is not sure when, how often – and even if – a hazard event will affect the case study area. Thus, probability distributions of hazards are necessary to determine the costs and benefits of investments. However, the majority of case studies present only a basic hazard analysis. This is often due to poor data conditions resulting in the utilisation of existing secondary

[13] In an ex-ante perspective (see chapter 5.3); if the CBA is conducted ex-post, the actual hazard patterns are used in the analysis.

data from other projects or statistics from other actors and previous studies resulting in fairly generic assumptions. In most cases, the source of the data or the survey method is not specified (66 case studies, i. e. 42 % of all case studies). Comprehensive data is almost exclusively available in riverine flood case studies which usually refer to official gauge data. 35 case studies collect primary data through measurements, field visits and surveys. They usually refer to specific historic events of high magnitude which are retained in the memory of the local communities and where a wide range of data is available.

Assessing the exposure of values in the case study area is another crucial part of the risk assessment since the cost and benefits of interventions naturally depend on "how many" values (e. g. people or assets) are present in the study area; and, importantly, how this will develop within the lifetime of the intervention. In the assessed case studies, only very little information is available on if and how exposure trends were taken into account in the CBA.

Finally, the vulnerability needs to be assessed, which depends on a multitude of social, economic, political, cultural, institutional and physical factors. Thus, the results of the vulnerability analysis are highly site- and context-specific. There is no established or standardised way of conducting vulnerability analysis and the approaches in the case studies vary significantly in extent and scientific quality.

Future changes due to Climate Change

> Ex-ante CBA need to take climate change into account in the scenarios. At the current time future emission pathways are unknown – and even if known, substantial climate model uncertainties would remain.

Lately, there is an interesting and ongoing debate about the links between Climate Change Adaptation (CCA) and DRR provoked by the IPCC SREX Report (CARDONA ET AL. 2012). The discussion focuses on strengthening CCA through effective DRR. Hence, effective – climate-proofed – DRR should aim to improve the understanding of disaster risk and continually improve preparedness by incorporation community- and ecosystem-based measures. Doing so has led to a change in the framing around adaptation options, moving away from an impact-assessment framework towards iterative climate risk management (PRICE 2018, CHIABAI ET AL. 2015, OECD 2015).

Many **of the earlier studies with very high ratios of benefits and costs (sometimes above 50 or even 100) used classic impact assessments of technical options without taking uncertainty associated with future climate change into account.** This is to say that to date the majority of case studies are theoretical (ex-ante) and focus on technical adaptation without considering future uncertainties. These case studies conclude that adaptation is (potentially) highly beneficial with very low costs.

More recent studies may provide a more realistic – albeit still positive – assessment and benefit-cost-ratio because they take into account climate change, other human-related disruptions of the environment, second-order and macroeconomic impacts of large disasters, risk aversion and damage heterogeneity (see also SAVAGE 2015). On the other hand, it is not always the case that earlier studies tend to be over-optimistic. A detailed and climate risk-driven CBA might reveal that a DRR measure is favourable, albeit a classical impact-assessment-based CBA has rendered the same DRR measure as economically unfavourable. One such example is the study of HALLEGATTE (2006) on the implementation of a flood protection system in New Orleans. This shows "how climate change creates an additional layer of uncertainty in infrastructure design that increases the probability of either under-adaptation (increased risk) or over-adaptation (and sunk costs)."

In total, out of the 157 case studies only 33 take into account possible impacts of climate change (16 drought, eleven flood, five multi-hazard as well as one storm case study). Depending on the context of the case study this could lead to two scenarios: either the intervention becomes less effective because it is not properly designed to withstand those changing conditions; or the benefit-cost ratio is underestimated since the intervention prevents more disasters.

5.2. The measures to address the risk

Strategies to reduce risk

General groups of DRR strategies include mitigation[14], preparedness and risk transfer measures. The table below summarises key features of each of those groups

Table 1: Overview of key features of general strategies[15]

	MITIGATION	PREPAREDNESS	RISK TRANSFER
Effect	Reduce risk	Reduce risk	Transfer risk
Key measures	› Physical works like dikes (to prevent flooding) or irrigation systems (to prevents droughts) › Land-use planning › Economic incentives for pro-active risk management	› Early warning systems › Building codes › Contingency planning › Shelter facilities › Networks for emergency response › Information and education	› (Re-) insurance of public infrastructure and private goods › National and local reserve funds

[14] Instead of mitigation sometimes the term "prevention" is used, or both are used at the same time. Given that risks cannot fully be prevented, the term "mitigation" is instead used in this study.
[15] In recent years, also other specific strategies such as resilience building and anticipatory approaches have spread more widely

Of the 157 case studies reviewed in this paper, 101 case studies analyse preparedness measures, 45 analyse mitigation measures and only 2 pure risk transfer case studies. The remaining case studies assess a portfolio of different measures under different strategies. Whereas studies dating before the year 2008 primarily focussed on one single intervention, 56 case studies reviewed here include a portfolio of parallel measures that follow different strategies for flood, drought and storm risk – for example dredging a river as well as building dams.

The prevalence of preparedness case studies is partially explained by a lack of efficient mitigation measures to reduce exposure to certain hazard types. For example, for earthquake hazards, usually preparedness measures are most widespread. Mitigation measures in this case would require resettling outside the zone at risk.

The results of the analysis are presented in the Figure below.

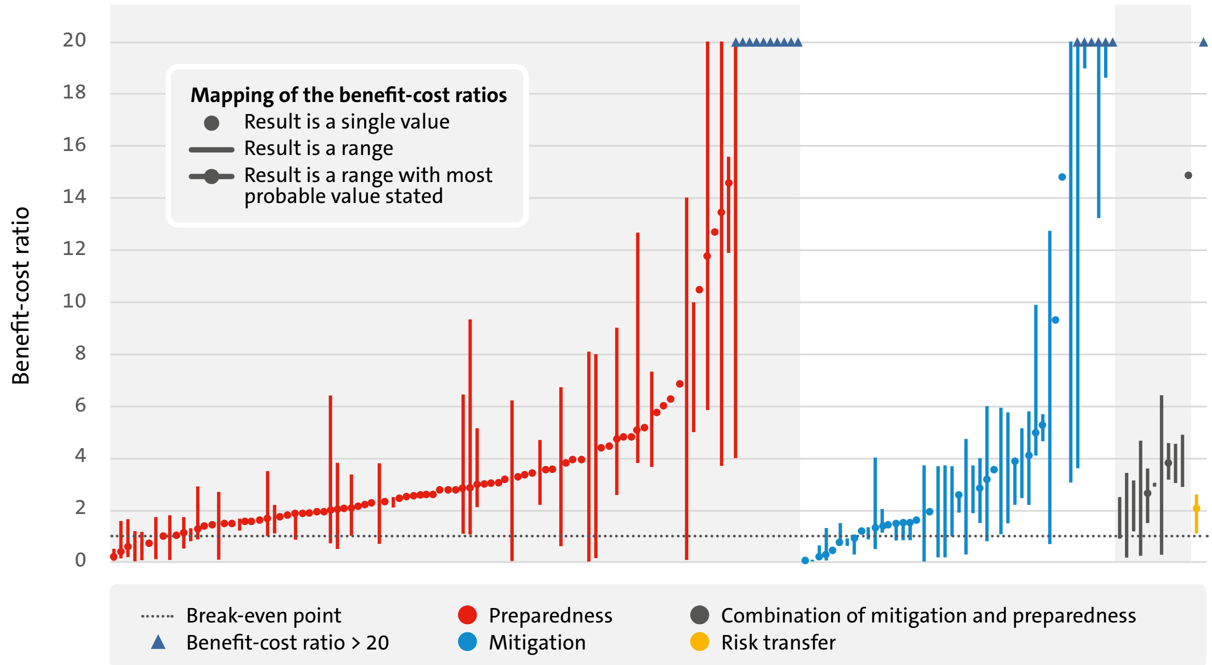


Figure 6: CBA results grouped by strategy

The analysis of case studies seems to suggest **that combined interventions reap higher benefit-cost-ratios than single interventions**. This is not surprising given that such interventions tend to have a more holistic view on disaster risk and seek to leverage the synergies of different components.

The analysis also suggests that **preparedness measures are on average more cost-effective than mitigation measures**.

Resilience plays in increasingly important role in DRR and subsequently in the more recent case studies. However, **only very few case studies could be identified that specifically focus on resilience building**; instead, resilience is more frequently mentioned as one aspect of the projects and the scope of the interventions seem to broaden, reflecting the resilience perspective. The lack of dedicated case studies for resilience might be linked to the challenges in measuring, quantifying and monetising the effects from resilience measures.

Likewise, for anticipatory action there is no large catalogue of CBA case studies available on its cost-effectiveness. A recent evidence review on this topic has found "that the evidence base is still relatively weak but evolving" (WEINGÄRTNER & WILKINSON 2019).

Throughout the case studies there was also only very little focus on cumulative risks and how the interventions address them. It is likely that this is partly due to methodological challenges, but also evident that the vast majority of projects focused on local single-hazard interventions.

Structural and non-structural

Measures can be structural or non-structural.

Structural measures are physical constructions that are targeted at reducing the direct adverse effects of hazards. This includes dikes or earthquake resistant buildings.

Non-structural measures include knowledge transfer, capacity building and codes/norms. Concrete examples are land use planning and knowledge building within local communities. Early warning systems are also non-structural measures

The majority of the case studies (84 out of 157) assess structural DRR projects, 60 case studies explore non-structural measures, and the remaining 13 case studies assess a combination of structural and non-structural measures.

Structural DRR is predominant for most hazard types. Notably, the case studies reviewed concerning coastal flooding and landslides exclusively considered structural measures. However, several studies emphasise the advantages of non-structural measures which usually require fewer resources than structural measures. In fact, **several case studies investigating riverine floods and storms consider early warning systems to be a very promising non-structural measure** (e.g. SUBBIAH, BILDAN & NARASIMHAN 2008, HOLLAND 2008).

Non-structural measures are predominantly implemented (and analysed) in more recent years, particularly following the release of the Hyogo Framework for Action (HFA 2005). With the exception of four case studies, all CBA of non-structural measures have been conducted after 2008. Particularly the investigation of non-structural measures against drought in the Global South gained momentum (a total of 24 non-structural CBA measures against drought in the years 2019 and 2020).

The results of the analysis are presented in the Figure below.

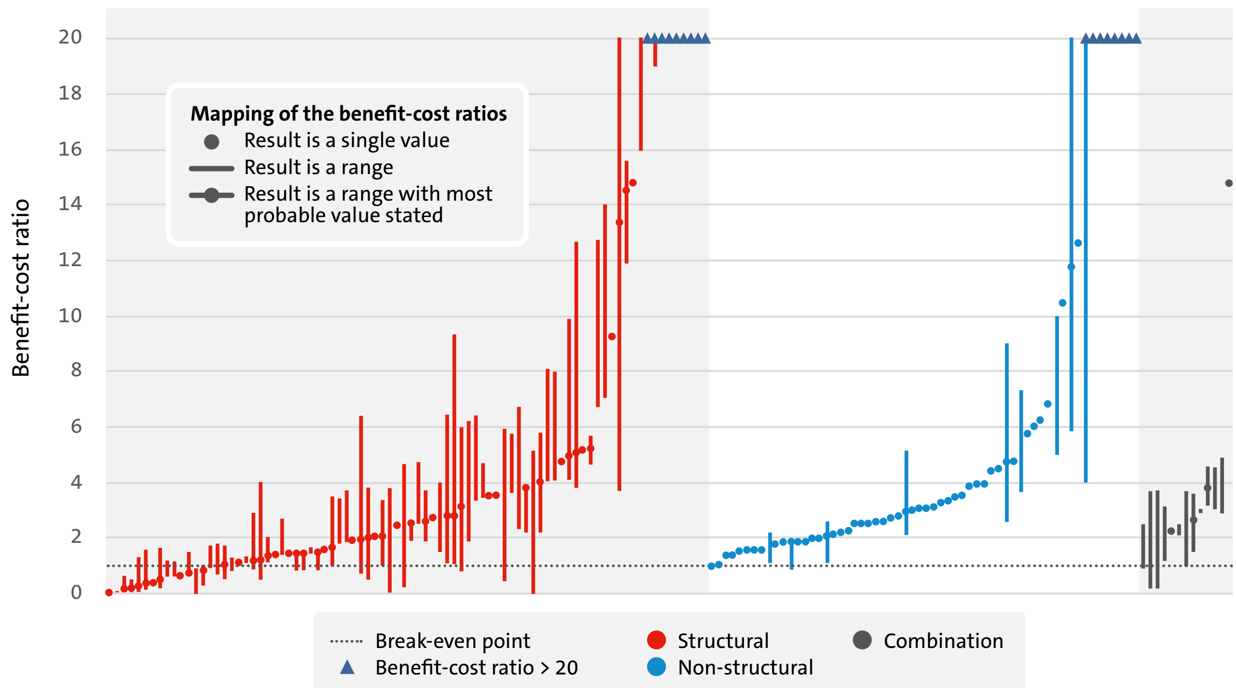


Figure 7: CBA results grouped by type of the DRR measure

The analysis suggests that non-structural measures are in general more cost-effective than structural measures. Half of all structural measures (40 out of a total of 84) are either within their lower uncertainty margin below the economic equilibrium or in general not economically advisable. This result was significantly lower for the non-structural measures (three out of a total of 60). Additionally, the share of non-structural case studies with exceptionally favourable results is higher than for structural case studies. **Particularly, ecosystem-based**

and community-based interventions as well as early warning measures performed outstandingly well.

Possibly, more case studies exist for structural measures than for non-structural measures because from a methodological viewpoint it is more challenging to assess benefits for the latter than for the former. Also, the line between non-structural DRR measures and general measures to enhance the livelihood or knowledge base of a community or society are often overlapping making it difficult to distinguish between the two goals.

This is in fact also a challenge for resilience building. As highlighted earlier, the concept of resilience is in some regards more complex than “classical DRR”. This also is mirrored in the additional complexity it brings when attempting to conduct a CBA for such projects since most of the effects will be indirect and intangible. Consequently, there are not many CBAs available on those projects. Indeed, already measuring resilience is a challenging undertaking and while there exist a number of approaches (for an overview see: SCHIPPER & LANGSTON 2015, BURTON 2015), no universally accepted methods exist.

5.3. The cornerstones of the CBA

Evaluation type

> CBAs for DRR measures are conducted ex-ante or ex-post. Ex-ante CBAs are conducted in preparation for a DRR measure (or ideally compare several options so that the most cost-effective can be selected) and predict impacts for the future. Ex-post CBAs assess the actual costs and benefits from the DRR measure after the project has been finalised.

By far most of the case studies are conducted ex-ante (116 case studies). Only 41 case studies are conducted ex-post. However, the vast majority of those ex-post studies are – de facto – interim assessments since they were conducted within the projects time horizon (see next chapter). This means that, while the ex-post assessments were conducted after the respective projects have been closed (e.g. a dam was constructed or a community received training), they were not conducted after the lifetime of the project benefits have fully accrued.

Time horizon

> The time horizon is the period over which costs and benefits are assessed in the CBA; this is either into the future for ex-ante analyses, into the past for ex-post analyses, or a mix of both for interim assessments.

The timeframe over which costs and benefits are analysed has a substantial impact on the overall result of the CBA. This has particularly important implications for the discount rate and the degree of uncertainty. Firstly, discounting over long timeframes can lower the economic value of a DRR measures. Secondly, the inherent uncertainties of the cost-benefit analysis increase alongside longer timeframes (KULL, MECHLER & HOCHRAINER-STIGLER 2013). Hence, selecting a reasonable time horizon is important.

However, there is no general consensus on how to define those time horizons. In most cases the analysis period is defined by the timeframe in which the DRR (or its longest living part) delivers benefits. For example, in the structural measures this could be defined by the productive lifespan of the structural elements. When referring to non-structural DRR timeframes, this could be determined by the decreasing impact e. g. of training sessions.

Another approach is to use the project length as a proxy for the analysis period. However, the benefits generated by DRR generally accrue for considerably longer periods than the project length.

Throughout the case studies, analysis periods range from 7 to 90 years, with most cases falling between 35-50 years. 14 case studies did not state an analysis period. There are substantial differences in the average expected DRR lifetime between countries with a low Human Development Index (HDI) and those with a high

HDI.[16] For the 23 case studies from seven countries[17] with a low HDI, the maximum lifetime is in one case 40 years while most case studies apply an analysis period clustering between ten and 15 years. In contrast, the 25 case studies from five countries[18] with a high HDI show lifetimes of the DRR measure of up to 90 years (in four cases) and generally cluster around 50 years.

One likely explanation is that in North America and Europe structural measures prevail, whereas in countries of the Global South as well as in countries with low HDI mostly non-structural measures are implemented.

The data also suggested that the analysis periods (project lifetimes) in ex-ante case studies is substantially longer than those used in ex-post case studies. This gives an indication that ex-ante assessments tend to overestimate the lifespan of a DRR measure.

Discounting

> Discounting refers to the process of assigning a lower weight to a unit of benefit or cost in the future than to that unit now. In discounting, we place a higher value on the present than the future.
>
> Typically, CBAs take account of this time preference by applying a discount rate over the costs and benefits over the analysis period. The further into the future the benefit or cost occurs, the lower the weight attached to it.

The choice of discount rate substantially influences the result of a CBA. This is particularly important for ex-ante analysis. Nevertheless, despite extensive research and scientific discourse there is to date no one agreed approach on the choice of discount rates. To illustrate the important choice to make we assume a discount rate of 1 % over 100 years. The present value of 100 million USD in 100 years later would be about 37 million USD. Whereas, using a discount rate of 7 % only 0.1 million USD of the 100 million USD would remain in 100 years.

Environmental economists have stressed the importance of using near-zero discount rates as an ethical and immediate responsibility towards future generations as well as to encourage more effective and progressive policy design (MARKANDAY, GALARRAGA & MARKANDYA 2019, CHAMBWERA ET AL. 2014). On the other hand, researchers argue that low discount rates favour investments in DRR measures but underestimate the high uncertainty regarding future disasters (LOMBARDI ET AL. 2019).

Surprisingly, only very few of the 157 case studies apply low discount rates. A total of 138 case studies apply a discount rate in the range of 1.3 % to 20 %. Only about 7 % of these case studies actually employ discount rates of 2 % and lower, whereas about 80 % of the case studies utilize discount rates of 5 % or higher, although without sound arguments for specific values.

In most cases, the discount rates applied in Europe and North America were considerably lower than those used in Latin America, South and South-East Asia, and Africa. The discount rate has more impact when the project sustains for a long time. CBA measures in Europe and North America are usually bigger infrastructure projects with long time spans.

Area of analysis

> A CBA needs a clearly defined area for the analysis.

Any CBA, weather within the context of DRR or not, needs to state the boundaries of the system it analyses. This includes a clear definition of the project itself (e.g. the project activities or the structural components) and a definition of the impact area, i.e. the geographic area which is impacted by the project. This needs to be defined based on a realistic assessment of those impacts on a case by case basis. The impact areas can be local, regional, national or even of larger scope.

[16] We use the countries' HDI of the year 2010 as a base, because this represent a mean value over the entire range of studies included here.
[17] Ethiopia, Malawi, Sudan, Tanzania (including Zanzibar as an autonomous region, assuming the same HDI as for Tanzania), Uganda and Madagascar
[18] USA, Finland, Germany, Austria and Switzerland

The case studies vary significantly regarding the extent of the area of investigation and the related level of details. They range from fishing pots that enable smallholder fishermen in the Philippines to catch fish even under extreme weather conditions (LOMBARDI ET AL. 2019) to 22 EU member states gaining from improved dykes (HINKEL ET AL. 2010). However, in the vast majority of cases the impact area (and spill over effects does not seem to be clearly defined in the assessments.

5.4. Assessment of costs and benefits

Assessment of costs

> The costs include all expenses which incur for the DRR measure, including investment costs (CAPEX) and operational costs (OPEX).

In general, the costs for CBAs are relatively easy to assess since those include the direct costs for implementing and maintaining the project throughout the project period.

Also, within the DRR case studies, no specific complications seem to have been encountered when assessing the costs.

In the case studies for structural DRR, the expenditures are predominantly defined by the construction costs. For non-structural measures, the costs that are most frequently assessed are staff expenses, material, and production costs.

Assessment of benefits

> For CBAs in a DRR context the benefits of measures are expressed in terms of avoided losses and avoided damage. These benefits are derived by comparing the business as usual scenario in the study area (i.e. without a DRR measure in place) with a scenario in which a DRR measure is in place.

It is by far more challenging to quantify the benefits of a DRR measure compared to its costs. While techniques exist for quantifying intangible and indirect benefits, measurement challenges are large and techniques for valuation are often controversial (MECHLER 2016). As a result, these avoided damages (i.e. the benefits) are often omitted from the analysis. **This gap in the ability to calculate costs and benefits suggests that the 'real' value of DRR measures is systematically underestimated resulting in imbalanced benefit-cost-ratios** (VORHIES 2012, WOODRUFF 2008). Some studies go one step further stating that prevented intangible and indirect benefits are considerably higher than benefits which can be easily quantified in monetary terms (UNISDR 2011, DEDEURWAERDERE 1998).

Due to the methodological difficulties, the reviewed studies focus mostly on the assessment of direct tangible benefits including e.g. avoided damages to buildings, agricultural areas, equipment, and infrastructure. The most commonly assessed indirect tangible damages include business interruptions and loss of income. The value of these indirect tangible damages can be significant. For example, a study by PADGETT, DENNEMANN & GOSH (2010) on an earthquake resistant bridge in Missouri (USA) concluded that, if the bridge was destroyed, the indirect tangible damages accrued through longer alternative driving routes could be 5 – 20 times higher than the direct tangible damages. Similar observations have been made by FLORIO ET AL. (2019) analysing the economic effect of a road closure due to flooding.

In most case studies, intangible damages remained unassessed. The category incorporated most frequently was human life (26 case studies). This is commonly assessed using the individual's foregone earning capacity (by estimating future income) and the willingness-to-pay approach. Values vary considerably between cases, ranging from 35.000 USD (HALLEGATTE 2012) to 6,000,000 USD (KUNREUTHER ET AL. 2012, HOCHRAINER-STIGLER ET AL. 2011). A significantly higher number of structural case studies (twice the number than those of non-structural studies) assigned a monetary value to human life. In some cases, study results only produced efficient DRR benefit-cost-ratios when human lives were factored in.

Box 2: Overview of types of damages

The Figure below gives an overview of the different types of possible damages from disasters.

Damages are tangible when they have a market value (e.g. construction material, equipment, services or farmland). Intangible damages, on the other hand, do not have a direct market value i.e. they cannot be bought. This includes social damages including fatalities, injuries, increased vulnerability, traumata, or feeling insecure. It also includes other damages such as loss of biodiversity and habitats. The process of assessing intangible damages and assigning monetary values to incorporate them into the CBA is usually complex.

Additionally, damages can be direct or indirect. Direct damages are an immediate consequence of the hazard such as fatalities or damage to buildings. Direct losses usually happen within the first few hours after the event and are usually assessed immediately after the event. Indirect damages, on the other hand, are highly elusive and result from the aftermath of the disaster, such as production downtimes or migration. The reduction in production might last for several years. Indirect damages should therefore be monitored over a long period.

The same is true for macroeconomic impacts. These are even more complicated to assess because economic activity is interlinked and tangible as well as intangible damages cause spillovers into the macroeconomy. For example, production decreases increase prices. Higher prices will result in increased interest rates. High interest rates will bring private investment down and reconstruction activity will stagnate for years or even decades (LAZAMANANA ET AL., 2015, KOUSKY 2012).

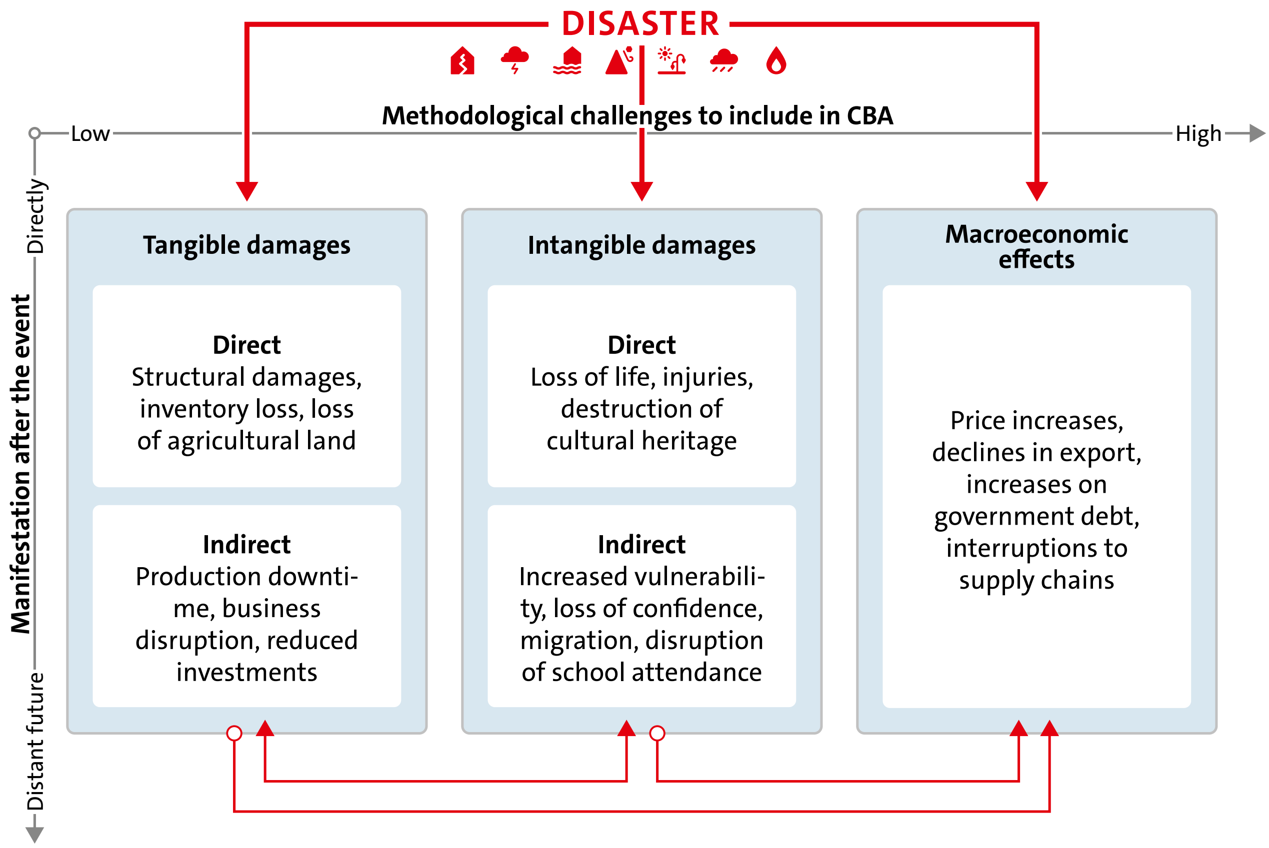


Figure 8: Schematic representation of damage categories

5.5. Handling uncertainty

Co-benefits

While there is no consensus on the definition on co-benefits, in general they are understood as benefits of DRR measures which manifest in addition to risk reduction.

In recent years, the “triple dividend” concept has gained traction as a way of assessing all benefits from DRR interventions in a more structured manner, including (i) the intended risk reduction, (ii) the stimulation of economic activity due to reduced disaster risk, and (iii) co-benefits

The analysis of the case study catalogue showed that recent case studies more consistently pick up the topic of co-benefits in their assessments of DRR measures. It is not fully clear if this is purely because in the design and implementation of more recent DRR measures co benefits actually play a more important role, or if this is also partly because case study authors are more aware of the concept and thus include it more consistently in the assessments.[19]

In any case, the focus on creating co-benefits through DRR measures seems to be the major driver in this trend which is also in line with the general trend towards boarder, resilience-focused interventions.

Besides the known positives of focusing on resilience, such broader measures can also reduce the danger that an intervention is eventually not cost-effective because the hazards did not manifest during the project lifetime or in another way than expected. In this sense, broader actions can be considered to be **no-regret options, which deliver benefits throughout the whole project lifetime even if hazards do not manifest**. One way to approach this in a CBA is e.g. presented by LOMBARDI ET AL. (2919). They suggest an approach which distinguishes between benefits of DRR measures in hazard versus non-hazard cases. Doing so enables the identification of no-regret options, where implementation makes good economic sense even if the hazard under consideration might not occur.

To achieve this, non-structural measures might be more relevant since they are more flexible and adaptable when compared with structural measures (KEATING ET AL. 2014, VAN NIEKERK ET AL. 2013). As a result, this calls for **the use of non-structural measures in cases where substantial uncertainty exists within the hazard analysis**.

Also, **nature-based solutions offer higher benefit-cost-ratios and higher overall benefits in terms of ecosystem-services compared to hard infrastructural** measures. For example, planting mangroves can be an effective measure to tackle coastal floods. At the same time, the mangroves can also increase and protect biodiversity, act as a carbon sink and help reduce erosion. For a flood protection project in Fiji, DAIGNEAULT ET AL. (2016) found that planting riparian buffer vegetation is the most cost-effective option since this offers important ecosystem co-benefits.

Sensitivity analysis

Sensitivity analysis enables the identification of the ‘critical’ variables and assumptions of the project. Such variables are those whose variations, be they positive or negative, have the largest impact on the project’s performance. The analysis is carried out by varying one variable at a time.

In the application of CBA for DRR there are several sources of uncertainty including oftentimes poor data condition, missing clarity on how climate change will play out locally, or methodological challenges for inclusion of benefits (especially for intangible and indirect values). Further, the result of a CBA can be greatly influenced by aspects such as the choice of discount rate, time horizon, and impact area (MARKANDAY, GALARRAGA & MARKANDYA 2019).

Thus, a sensitivity analysis should be an integral part of a CBA for DRR measures. 63 % of all case studies perform a sensitivity analysis. The majority (71 case studies) varied the discount rate followed by altering assumptions in the hazard analysis (40 case studies). Assumptions made for assessing costs and benefits varied in 40 case studies, as well. Some authors (22 case studies) varied the analy-

[19] This is also an important factor since the inclusion of those co-benefits in CBAs can provide additional arguments for investments in DRR and are also good practice in CBA for other sectors, e.g. transportation projects.

sis period. Looking at the case study catalogue, it seems like the number of studies undertaking a thorough sensitivity analysis is increasing over the last years.

5.6. Hazard specific findings

Earthquakes

> Earthquakes are caused by the movement of tectonic plates. Throughout the world, earthquakes are the hazard responsible for most fatalities – however, this number also includes fatalities from earthquake triggered tsunamis. This section only considers DRR measures to reduce impact of earthquake related ground shaking.

Earthquake interventions are usually costly and compared to other hazards, earthquakes ranked lowest in the CBA results of the case studies. Of the eleven case studies reviewed, nine perform at a level that is either close to the economic equilibrium or – at least partially – below a benefit-cost-ratio of one. Additionally, there was minimal improvement in the economic performance even where avoided fatalities were monetarized and included as a benefit.

Storms

> Storms are meteorological events. They are responsible for the highest economic damage globally.

Case studies addressing storm-related DRR (21 in total) generally performed well, only one study reported a benefit-cost-ratio below the economic equilibrium and a limited number (5 case studies) reported a range close to one. Three case studies reported an excellent performance of the analysed DRR measures (benefit-cost-ratios of 40 and even 559). Albeit, such high benefit-cost-ratios should be treated with caution, the results of storm CBA are promising and point towards cost-effectiveness of these DRR.

Floods

> Riverine floods (floods along rivers) and flash floods are usually caused by extreme rainfall or melting of snow. They are the hazard which trigger disasters most frequently.

Coastal floods on the other hand are triggered by strong onshore winds. Either extra-tropical storms or tropical cyclones push water in the direction of the coastline potentially leading to coastal inundation.

Case study literature availability was highest for this hazard type. It can be differentiated between river/flash floods (48 in total) and coastal floods (13 in total).

Of the 48 river/flash flood case studies reviewed, nine had ratios which were below the economic equilibrium. Of those case studies performing below the economic equilibrium, 8 had a structural focus whilst only one non-structural measure was not economically efficient. This points to the assumption that soft measures are more successful for flood (particularly river and flash flood) hazards.

Structural measures can include large infrastructural projects such as construction and strengthening of dikes and polders, redirection of river channels, the raising of buildings, and the construction of highly resistant buildings. Most non-structural measures can be summarised under the header of early-warning systems. Usually, non-structural measures are applicable for protecting against a wide range of threats. They are also usable in situations not directly linked to DRR, as a result, non-structural measures are often more robust and can usually be realised with lower costs compared to their structural counterparts.

Many of the coastal floods case studies show favourable benefit-cost-ratios. Five case studies report ratios significantly above the economic equilibrium (a benefit-cost-ratio of three and higher), and only two case studies reported benefit-cost-ratios (either individual measurement points or a value range) below one. All case studies covered structural measures and focused on mitigation strategies.

Landslides

The landslide hazard type includes hazards such as avalanches, rockfall, mudflow and debris flow, all of which are downhill shifts of surface material being moved by gravitational force.

Only a few case studies covering landslides were identified (six in total), thus generalisations of the results should be treated with caution. All case studies except one reveal a ratio of benefits and costs above the economic equilibrium. The highest benefit-cost ratio is 2.3. Albeit this is a very favourable ratio the ratios are relatively low compared to the results for hazards. However, it should be mentioned that all case studies concerning this hazard focus on regions in the Swiss and Austrian Alps. These locations already benefit from a high degree of protection. Additional protection measures are increasingly costly and raising the protection status is often associated with a low overall gain.

It is surprising that no additional case studies on landslides in other mountainous regions around the world were identified.

Droughts

Droughts are a creeping hazard. They are usually defined as a lack of rain over a defined time or the absence of rain over specific, location-depended, periods.

Drought interventions usually take place in countries with low HDI located in the Global South. All case studies calculated favourable results. Five case studies in this group report results which are among the economically most advantageous across all hazard categories. Even though such case studies reporting very high economic efficiency should be treated with caution, the results of the drought case studies point overall in the direction of high economic efficiency. This case study research suggests that drought DRR has proven to be cost-effective over numerous measures and therefore offers a promising outlook.

It can be observed that drought hazards became a focus of DRR CBA only in recent years with more and more studies emerging in East and South Africa as well as in Southeast Asia. Usually, non-structural DRR interventions such as training and education, diversification of agriculture (distribution of new seeds or new plant varieties) as well as foundation of disaster management committees performed very well. Structural interventions such as the construction of wells, pumps and dams did not perform as well.

Hydro-meteorological hazards

The group of hydro-meteorological hazards has been introduced to summarize case studies that consider meteorological services. These services provide predictions for meteorological and hydrological extreme events and can also be used to extrapolate climatological trends. This group comprises measures addressing all three hazards (hydrological, meteorological and climatological).

All hydro-meteorological hazard case studies (twelve in total) focused on the set-up and enhancement of hydro-meteorological services report benefit-cost-ratios of above one. Indeed, in most cases, the value is far above the economic equilibrium with most results ranging between three and six as well as some very high values (benefit-cost-ratio of 12, 20 and 37). Moreover, results show that the improvement of hydro-meteorological services is particularly worthwhile in countries with a high HDI, such as the USA, Australia, and Finland. This contrasts with the general observation that the efficiency of DRR in countries with high HDI scores is on average lower than in countries with a low HDI.

Despite these case studies with high benefit-cost-ratios, none of the studies reviewed included a consideration of present or future climate change threats. Since climate change is expected to alter hydro-meteorological patterns and increase the frequency of extreme events (extreme rainfall or no rainfall over long periods of time) the incorporation of these threats into benefit-cost-ratios would likely yield even higher results.

Multi-hazards

Multi-hazard case studies address DRR measures against spatially overlapping or interrelated hazards.

Although the literature stresses the obvious values of DRR measures which are applicable across a range of potential hazards, the analysed case studies do not reflect this statement. Only a limited number of case studies address multi-hazards (twelve in total) and of those cases, half had value ranges that stretched below the economic equilibrium. This may be linked to the increase in uncertainties which occur when multiple hazards are considered in combination. For an analysis of these measures, each individual hazard plus the interconnectedness of the hazards must be assessed. Further, such interventions are complex and difficult to design.

5.7. Relations between the case study authors and results

Most of the case studies are published by international organizations (65 case studies). The most active ones are the FAO[20], the World Bank and various UN development programs. A total of 23 case studies are published by NGOs, 17 of those by the Red Cross[21]. Another 24 case studies are published by independent research institutions or think tanks. Usually, the latter two groups of organizations evaluate their own projects or initiatives. Universities published 17 case studies, in nine cases it was not possible to identify the leading authority behind the case study and in three cases the CBA has been conducted by a private company.

Most of the case studies are from grey literature. Only about 20 % of the sources are scientific articles. Further, virtually all CBA are donor driven and are conducted by the same entity which implemented the project. This can lead to bias resulting in high benefit cost-ratios.

For example, one case study (HENDRIKSEN ET AL. 2015) analysed the cost efficiency of a surface water drainage component in Zanzibar to reduce flood risk. An earlier World Bank study has also done an economic analysis of this drainage project with significantly different results (see MEHTA & KHATIB 2011). Another example is described in MECHLER (2016). Two case studies assessed the value of wind proofing of buildings in St. Lucia. One study concluded that such wind proofing is not advisable from an economic perspective. Whereas a World Bank study from the same year reached the conclusion that such a general assumption is misleading. On the contrary, their spatially more detailed analysis shows that in specific locations wind retrofitting makes good economic sense.

This comparison between case studies from different authors and authorities show that methodological differences can limit the robustness of a CBA and different studies can reach very different conclusion – even as far as rejecting the measure in one case versus promoting it in the other.

5.8. Relations between case study locations and results

The majority of the case studies cover locations in South Asia (India, Bangladesh, Nepal, Pakistan, Sri Lanka and Maldives) as well as South-East Asia (Indonesia, Philippines, Thailand, Taiwan, Laos and Vietnam). Particularly India (ten case studies) and Vietnam (ten case studies) are prominent in the literature. There are also a few case studies in Europe (particularly Germany, Austria and Switzerland) (eleven case studies) and North America (14 case studies in the USA) as well as some case studies in other European and Asian countries as well as South and Middle America and Australia/ Oceania. Within the last years also the number of CBA case studies on the African continent increased. For example, the countries Uganda and (to a lesser extend) Sudan receive high attention. In the case of Uganda all studies are FAO field projects and in the case of Sudan projects from the Red Cross.

From all 157 case studies more than 40 % (65 case studies) stem out of only seven countries (USA, Uganda, Bangladesh, Pakistan, India, Vietnam and the Philippines). Some regions receive very little attention in the literature on DRR in CBA (see e.g. also (MARKANDAY, GALARRAGA & MARKANDYA 2019). Many countries

[20] Food and Agriculture Organization of the United Nations
[21] International Federation of Red Cross and Red Crescent Societies

(particularly in Africa, Europe and South America) are completely missing. Probably, to some extend this may be attributed to language barriers as only English and German sources were assessed.

None of the case studies in the Global South has been conducted by local authorities or the country itself. All studies are commissioned by other organizations or institutions under the overarching objective of humanitarian aid.

The analysis of the case studies suggests that DRR is more cost-effective in countries with a low HDI.[22] We use a value the benefit-cost-ratio of two as a reference value. This is to say, it is likely that the benefits of the measure will two times or more outweigh the costs. 23 case studies stem from seven countries[23] with the lowest 2010 HDI of all case studies' focus areas. Out of these case studies only 7 (i.e. 30 %) report a benefit-cost-ratio below two of the lowest calculated value (e. g. the lowest part of the uncertainty margin). On the contrary, the 25 case studies from five countries[24] with a high HDI are in 14 cases (i.e. 56 %) below a benefit-cost-ratio of two. **This suggests that DRR is, on average, more beneficial in countries with a lower HDI.**

This imbalance may be due to highly concentrated populations in countries with a low HDI (LOMBARDI ET AL. 2019, GANDERTON 2005). Additionally, it may be linked to the greater macroeconomic damage caused by natural hazards relative to the gross domestic product in countries with low HDI scores. In highly developed, industrialised countries, macroeconomic damage relative to the gross domestic product is generally low (KEATING ET AL. 2014).

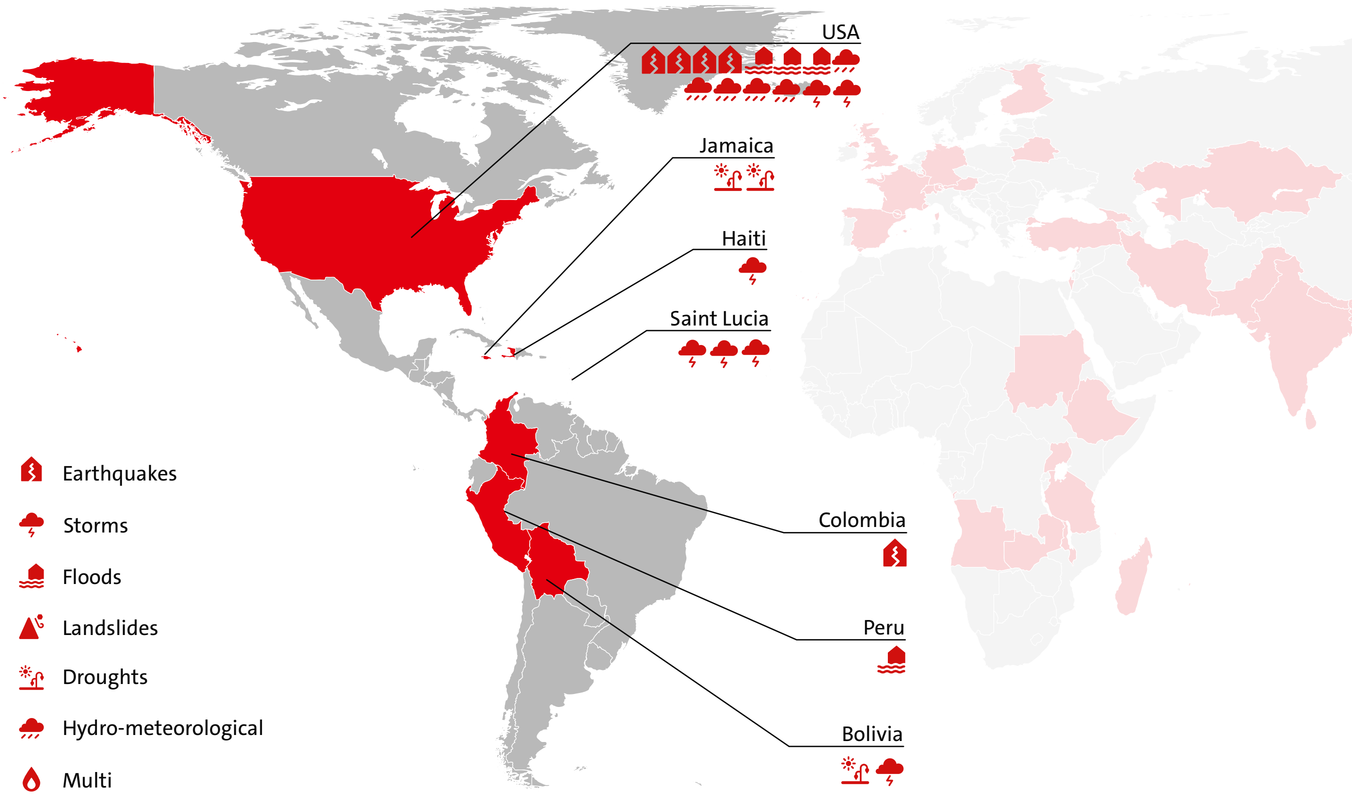


Figure 9: Overview of case studies in the Americas

[22] We use the countries' HDI of the year 2010 as a base, because this represent a mean value over the entire range of studies included here.
[23] Ethopia, Malawi, Sudan, Tanzania (including Zanzibar as an autonomous region, assuming the same HDI as for Tanzania), Uganda and Madagascar
[24] The USA, Finland, Germany, Austria and Switzerland

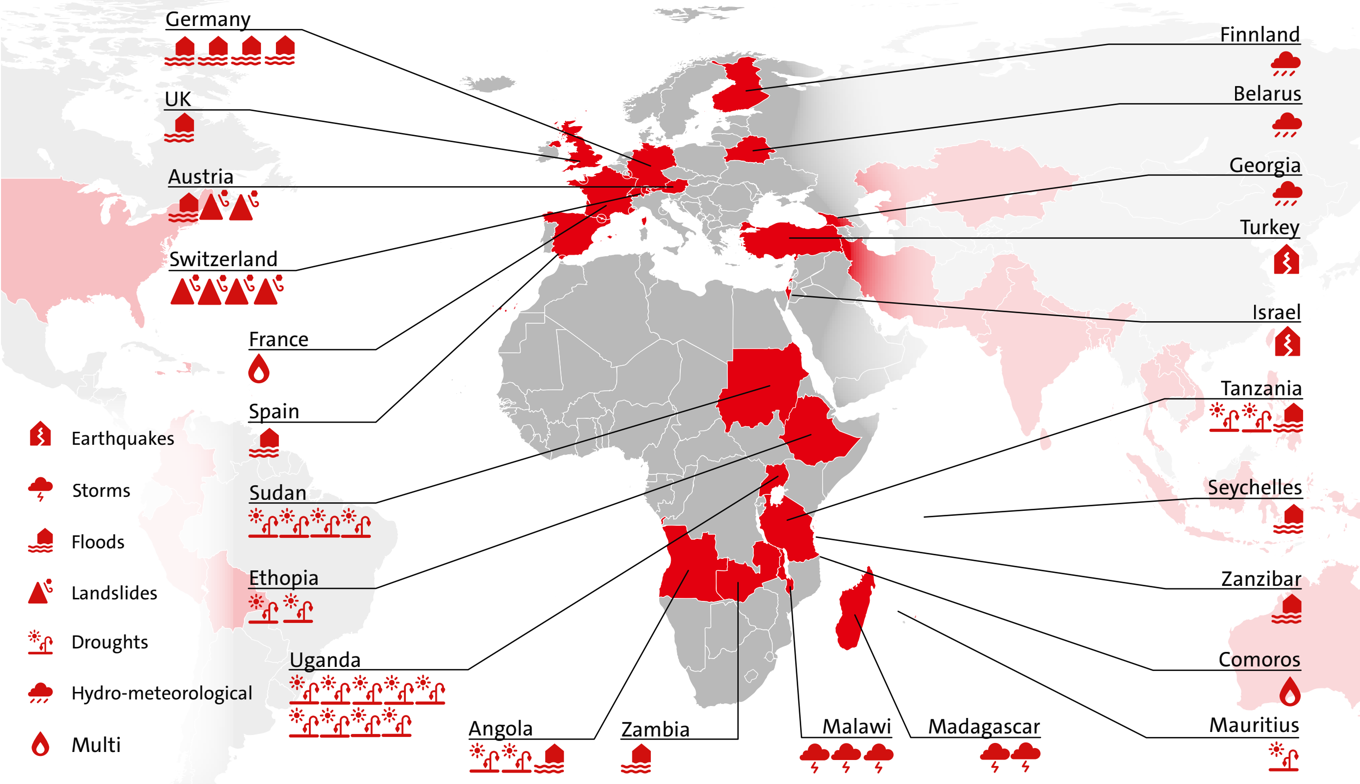


Figure 10: Overview of case studies in Europe & Africa

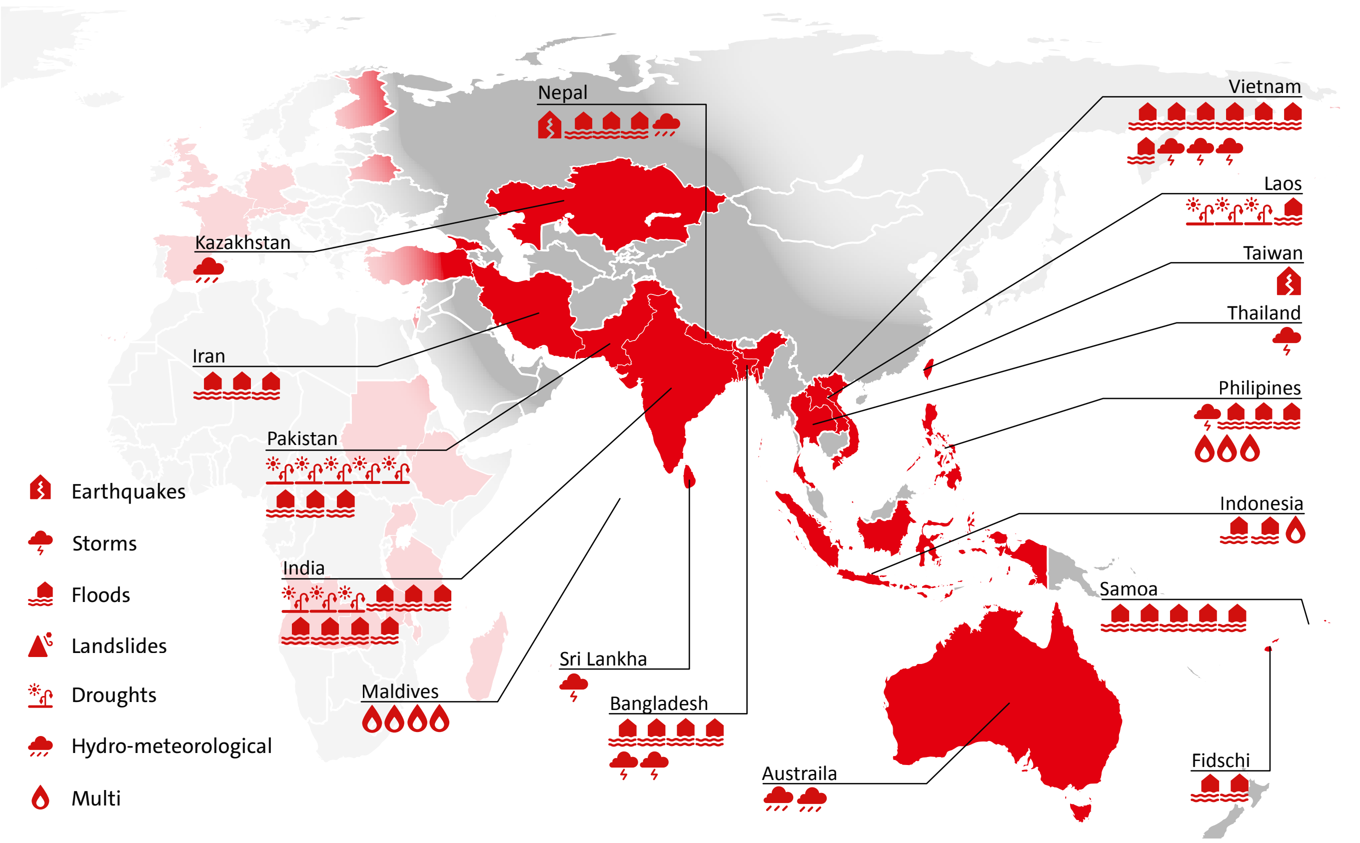


Figure 11: Overview of case studies in Asia & Australia & Oceania

5.9. Recent priorities in CBA

Even though no major changes have been observed in the overall CBA methodology, a number of new approaches and trends appear which are summarised below.

- It can be observed that **CBA moves away from classic impact driven assessments towards resilience and iterative climate risk management**. The incorporation of future climate change plays an increasingly important role in CBA. Integrating CCA elements can improve the economic feasibility of a DRR measure. Climate-resilient DRR yields additional benefits by incorporating community- and ecosystem-based measures. In addition, the design of such combined climate-resilient DRR measures does not only pay off in case a disaster strikes. Such measures can have an important added-value for the economy as well as ample co-benefits for the population. We can conclude that the classical impact-driven DRR measures can learn and prosper a lot from CCA elements. The question of climate-resilience will be of utmost importance for the design of (long lasting and sustainable) DRR measures and so far, questions of iterative climate risk management have been widely neglected in the debate.

- **Resilience plays in increasingly important role in DRR and subsequently in more recent case studies.** While earlier case studies often analyse structural measures, this has shifted more towards non-structural measures in recent years. Even though most of those case studies do not specifically refer to resilience as main objective it can be observed that interventions often have changed towards a broader scope which often encompasses resilience building features.

- **Early-warning – early action plays an increasingly important role in CBA on DRR.** The first study which addresses the economic benefits of forecasts and prediction of (hydrological, meteorological and climatological) hazards dates back to the year 1996. Over the years many studies in different – particularly industrialized – countries emphasis the high value of such services. Nonetheless, only in recent years[25] some studies [26] start to translate such forecasts and predictions into early action – with promising results.

- **CBA studies are becoming more realistic.** Some case studies highlight that DRR interventions are not always cost-effective (18 case studies in total[27]) depending on design and context. Particularly, over the last few years case studies report lower ratios of benefits and costs. At the same time these studies base their findings on a considerably more nuanced analysis and intensive handling of uncertainties. This suggest that CBA case studies are becoming more realistic. After 2013 no case study was found that reports an average benefit cost-ratio higher than seven.

[25] since about 2015
[26] see e. g. the FAO country reports on early warning – early action, for example Madagascar: http://www.fao.org/3/ca3933en/ca3933en.pdf
[27] with their mean or most likely value below the economic equilibrium

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

- **DRR pays off.** From a total of 157 case studies, 139 report benefit-cost-ratios above the economic equilibrium. This suggests that in the vast majority of cases, beyond the obvious DRR benefits of avoiding casualties, suffering and economic loss, there are strong indications that DRR is a cost-effective way of managing disaster risk. This is substantiated by the fact that often a large range of benefits is not included in the calculations due to methodological challenges while costs are usually fully accounted for.

- **Climate change is not considered as a factor in most case studies.** Only 33 out of the 157 case studies factor in climate change as part of the calculations when projecting disaster risk over the analysis period of the interventions.

- **Combining several measures and strategies might be beneficial.** Interventions combining several measures, including combining preparedness and mitigation measures, seem to reap higher benefit-cost-ratios than single interventions.

- **Preparedness measures are on average more cost-effective than mitigation measures.** While the results need to be interpreted with care, the data suggests that preparedness measures are on average more cost-effective than mitigation measures.

- **The evidence base for resilience and anticipatory action measures is still in its infancy**. Only very few case studies could be identified which specifically assesses interventions under those strategies.

- **Non-structural measures are on average more cost-effective than their structural counterparts.** A larger proportion of non-structural measures reports values above the economic equilibrium compared to hard structural measures. Non-structural measures are more flexible and robust in addressing future DRR uncertainties. Particularly, ecosystem-based and community-based interventions as well as early warning measures performed outstandingly well.

- **The estimated DRR lifetime is on average considerably lower in countries with a low HDI than in countries with a high HDI.** There are substantial differences in the average expected DRR lifetime between countries with a low HDI and those with a high HDI. The DRR lifetime is likely influenced by the type of the implemented measure. Particularly, in the Global South as well as countries with a low HDI non-structural measures prevail which are often characterized by shorter lifetimes.

- **Cost-effectiveness differs per hazard.** For example, for earthquakes a relatively high share of the case studies came to the conclusion that the measures were not cost-effective. For others, like droughts, interventions seem to be in general more cost-effective.

- **CBA for interventions against many types of hazard do not exist.** The focus on conducting CBA on flood hazard interventions is striking. Nearly 40 % of all analysed case studies refer to flood hazards. At the same time, there are some hazards which seem to be missing in the reviewed CBA literature (under the caveat that the number of assessed case studies, although comparably high, might have led to the exclusion of some other hazard case studies).

- **In countries with a lower HDI the cost-effectiveness of DRR measures is higher.** On average DRR measures in countries with a low HDI compared to highly developed nations are more cost-effective. This is a powerful argument for the expansion of DRR measures in the world's poorest countries. At the same time, investment in DRR in those countries is very low. The significance of this result is enhanced if considering that in the past, case studies utilised high discounting and assumed low durations of effect in these countries.

- **There is a lack of independent evaluations of DRR projects.** Most case studies were conducted by the same entity which implemented the project. This could lead to bias resulting in high benefit cost-ratios.

6.2. Recommendations

Based on the findings of the study the following recommendations are distilled:

- **Invest more into DRR.** The analysis has clearly shown that DRR in the vast majority of is cost-effective and "pays off". This should provide a strong mandate for decision makers and donors to push for increased efforts in this field. The following points should be kept in mind in this regard:

  a. Interventions should ideally account for **cumulative risks** and be part of a larger risk governance system. COVID-19 has been a powerful proof that the current predominant thinking in "risk-silos" has major limitations in an increasingly complex and interconnected world. Increasing **resilience** is a relevant approach for addressing this challenge since it aims at giving stakeholders the tools to face a wide array of risks, including unknown ones.

  b. Interventions should actively create **co-benefits** to increase the likelihood that the intervention is cost-effective even if no hazard events occur during the lifetime of the intervention. This leads to "no-regret options" which can be implemented even if there is large uncertainty about the hazards.

  c. Interventions should consider including a **portfolio of different measures** which seem to lead to higher overall cost-effectiveness.

  d. When designing interventions, it should be kept in mind that in average **non-structural and preparedness** measures seem to be the most cost-effective ones while also being more robust in the face of uncertainties.

- **Increase investments in DRR in poorest countries.** The evidence shows that DRR measures are most cost-effective in countries with a low HDI. At the same time, those are the countries with the lowest investment in DRR. To avoid loss and suffering, and to save future costs for disaster relief, investments should be increased in those countries. For climate change adaptation measures this is also integral part of the Paris Agreement[28] which stipulates that wealthier countries should provide financial resources to assist poorer countries and prioritise those which are particularly vulnerable to the adverse effects of climate change and have significant capacity constraints. Under the UNFCCC agreements, the international community committed to jointly mobilise 50 billion USD annually by 2020 for climate change adaptation.

[28] See: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

- **Increase evidence base:**

  a. **For all hazards.** Usually only a limited number of CBA seem to be available for the various types of hazard. A larger evidence pool could improve insights.

  b. **For resilience and anticipatory action.** While in practice those strategies have gained traction over the last years there is only limited evidence available on the cost-effectiveness of such measures – which is an important argument for decision makers and donors to support those strategies.

  c. **For micro insurance and risk transfer.** Although the results are promising, micro insurance and risk transfer to date receive very little attention in the CBA literature. As we cannot fully eliminate risk, risk transfer and insurances can be an adequate measure to buffer the shock during and after a disaster and ultimately enable fast recovery. Hence, such measures can be a potential alternative to costly large-scale hard infrastructural protection.

  d. **Through independent evaluations.** Most of the studies on DRR measures stem from the organisation which implements or plans to implement the measure. Hence, the organisation usually evaluates its own project. Organisations may be tempted to conduct analysis in a way which emphasises the economic benefits of their own projects.

- **Increase methodological rigour of CBA in DRR:**

  a. This study presents a **methodological framework** which permits to “dissect” existing CBA case studies. It can also be a guideline for CBA practitioners when conducting an analysis to ensure that all steps are included in an assessment and, importantly, to identify steps and methods that are not incorporated in an assessment due to methodological difficulties or poor data conditions. Those limitations should be clearly lined out in the analysis to contextualise it and provide best-possible transparency to decision makers.

  b. **Climate-proof DRR interventions.** It Is striking that only a few case studies seem to consider climate change in their future risk projections. Climate change should always be an integral part of those projections to ensure that risks are, to the extent possible, understood and accounted for in the planning and the CBA.

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9. GLOSSARY

This paper follows the UNDRR terminology. Terms used in this paper are:

Anticipatory action: A set of actions taken to prevent or mitigate potential disaster impacts before a shock or before acute impacts are felt. The actions are carried out in anticipation of a hazard impact and based on a prediction of how the event will unfold. Anticipatory actions should not be a substitute for longer-term investment in risk reduction and should aim to strengthen people's capacity to manage risks.[29]

Disaster risk reduction: Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Disaster Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Disaster: A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Exposure: The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Hazard: A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Mitigation: The lessening or minimizing of the adverse impacts of a hazardous event.

Preparedness: The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Risk transfer: The process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.

Structural and non-structural measures: Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non-structural measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Vulnerability: The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

[29] This definition is not part of the UNDRR terminology.