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Evaluation of existing cost-benefit analysis tools in Disaster Risk Reduction

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Flussbau AG SAH
dipl. Ing. ETH/SIA flussbau.ch

Schwarztorstr. 7, CH-3007 Bern, Tel. 031 - 370 05 80

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Author	Flussbau AG SAH, Schwarztorstrasse 7, 3007 Bern, Phone 031 370 05 80 – Lukas Hunzinger, Dr. sc. techn., dipl. Kulturing. ETH
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Content

Appendix

1 Introduction

The benefit-cost ratio of projects becomes a more and more important decision making criteria in humanitarian and development activities. The comparison of benefits and costs allows choosing cost-efficient solutions, to justify investments and to lobby for development issues.
Swiss NGOs acting in the field of Disaster Risk Reduction (DRR) integrate cost-benefit analysis (CBA) at least in their flagship projects. They would like to add tools for cost-benefit analysis into their DRR-toolbox. The Swiss NGO DRR Platform decided therefore to compare selected cost-benefit analysis tools and to recommend preferred ones.

Swiss NGO DRR Platform mandated the author to evaluate a set of CBA-tools. The present report summarised the findings of this evaluation.

2 Procedure

The author followed four steps of the procedure:

1. *Review of the evaluation criteria proposed by the Core Group of the Swiss NGO DRR Platform.*

   The Core Group of the Swiss DRR NGO Platform had proposed evaluation criteria. The author reviewed these criteria and, in mutual consent with the representative of the core group, adjusted the set of criteria.

2. *Collect and evaluate CBA tools established in NGO circles.*

   The tools to be evaluated were selected by the Core Group. The tools were then evaluated according to the above-defined criteria. The following four tools were evaluated:

   1. EconoMe-Approach SRC [2]: an approach based on standard cost-benefit analysis for hazard mitigation projects in Switzerland.

   2. Caritas-Approach [4]: an approach based on standard cost-benefit analysis for hazard mitigation projects in Switzerland with a number of simplifications making it applicable in contexts with little basic information.

   3. Mi Resiliencia Bolivia [5]: an approach developed for the government of Bolivia, based on standard cost-benefit analysis for hazard mitigation projects in Switzerland and extended to consider the resilience of communities at risk.

   4. IFRC Prioritising Tool [6]: A community-based disaster risk reduction and adaptation planning tool for prioritising potential solutions.

3. *Present and discuss the evaluation results in a workshop.*

   The four approaches were presented and discussed during a learning workshop on the 4th of December 2018 with representatives of the Swiss NGO DRR platform. During the same workshop members were trained in the application of selected tools. For the workshop programme and the list of participants refer to Appendix A.

4. *Elaborate a technical report.*

   The findings of the evaluation process are outlined in the present report. Chapter 3 of the report gives a short introduction to cost-benefit analysis of DRR measures. In chapter 4 the four approaches are being presented and in chapter 5 the result of the evaluation is summarised.

3 Cost-benefit analysis in DRR in a nutshell

3.1 Definition

A cost-benefit analysis is a systematic approach to compare the overall gain (benefit) of an activity or project to its cost. Both, benefits and costs are expressed in monetary terms. In the context of disaster risk reduction, the benefit is the decrease in disaster risk achieved through targeted measures (cf. chapter 3.2 for details).

3.2 Risk reduction as a benefit of DRR measures

In the *conceptual framework of DRR*, disaster risk is expressed as a product of hazard and vulnerability divided by the capacities of the society to cope with natural hazards.

Disaster risk *in economic terms* is defined as the probable loss, an individual or a community is expected to suffer in a certain area and a certain laps of time. It is expressed in $/year or in †/year. The loss of lives can be monetized by the willingness of the society to pay for saving a human life. Standard values for that willingness to pay must be developed on national level before they can be considered in a cost-benefit analysis. In Switzerland for example, an amount of 5 Mio CHF per saved life has been established.

The benefit of disaster risk reduction is the difference in risk (expressed in $/year or †/year) in a situation with measures (residual risk) compared to the situation without measure (initial risk).

3.3 Reasons to perform a cost-benefit analysis

A cost-benefit analysis can be performed in order to meet one of the following goals:

- *The most effective and/or the most efficient alternative is identified.*
  In many cases, there is not only one measure to reduce existing disaster risks but risks can be reduced with a set of different and alternative measures. However, not all of the measures will have the same effect and most probably some measures are more costly than others. A cost-benefit analysis allows selecting the most effective measure (the one with the best risk reduction effect) or the most cost-efficient one.

- *Activities at programme or project level are prioritised*.
  Funding for development project or for humanitarian interventions is usually limited. The project team, the programme director or the donor should invest funds in activities that are effective and cost-efficient. The cost-efficiency may thus be a selection criterion. Nevertheless other criteria like political will or opportunities might justify an investment beyond its cost-efficiency.

- *An investment is justified*.
  A cost-benefit analysis can also be performed ex-post of a development or humanitarian activity in order to justify the investment and to advocate for future investments. If the analysis reveals that the intervention was cost-efficient, it is justified from an economic point of view. If the analysis reveals that it was not cost-efficient the analysis helps to identify gaps and improve the design of future measures.

3.4 System boundaries

Each cost-benefit analysis should clearly state the boundaries of the system; the cost-benefit analysis is performed in. There are several types of system boundaries:

- *The activities considered.*
  The range of activities extends from individual and specific mitigation measures (e.g. river bank protection, reforestation) to activities of a project and to an entire development programme.

- *The spatial boundaries.*
  According to the activities considered, benefits are analysed at community, municipality, department or country level. Spatial boundaries can also be defined by watersheds or by the outreach of a hazardous phenomenon (e.g. flood plain, flank of a volcano, etc.)

- *The timeframe.*
  Short-term effects can be considered as well as long-term effects.

- *The benefits considered.*
  In disaster risk reduction the overall benefit is the reduction of risks, particularly the reduction of risk of loss of human lives, the risk of loss of material assets (buildings, property) and the risk of loss of non-material assets. One may distinguish between direct losses and indirect losses. Direct losses are elementary damages (e.g. a destroyed houses, killed people). Indirect losses are losses in income or welfare (e.g. due to business interruption or interruption of access to health services). The benefit risk reduction is quantified in order to compare it to the costs of measures. Other benefits than risk reduction like social and ecological benefits can be considered in a cost-benefit analysis as long as they can be quantified.

- *The costs considered:*
  Most of the cost-benefit analysis tools consider investment costs, interests, maintenance costs and service costs. Other costs like social and ecological costs or costs for capacity development can be considered as long as they are quantified.

The reason to perform a cost-benefit analysis defines the system boundaries. The tools presented in this evaluation report are elaborated as tools that allow choosing the most efficient measures among several alternatives or allow justifying a specific investment. They consider risk reduction as the benefit of a specific mitigation measure and analyse its effect at community level. Only the IFRC-tool is less specific and incorporate social and ecological benefits and costs as well.

3.5 Calculation of risk and cost-efficiency

Given the risk definition in chapter 3.2, the risk of loss R_j for a given scenario j is quantified by the following equation:

$$R_j = p_j Loss_j \quad \left[\frac{\$}{year}\right] \qquad (1)$$

With p_j being the probability of occurrence of this scenario and $Loss_j$ the damage that is likely to be caused if the scenario strikes the given assets. The loss depends on the type of hazard, its intensity, the value of the asset and its vulnerability. Vulnerability in this case means physical vulnerability (susceptibility) and depends on the construction type and the physical impact of the governing hazardous process. Usually, a risk analysis considers several scenarios with different probabilities of occurrence. The total risk then sums up over all considered scenarios.

Costs of mitigation measures are expressed in $/year in order to compare them with the risk reduction. In order to convert one-time investment costs into annual costs they are divided by the lifespan of the investment. Interests, maintenance costs and service costs are added to quantify the annual costs of a measure.

Finally, the cost efficiency *CE* is calculated dividing the benefit (risk reduction) by the costs:

$$CE = \frac{R(0) - R(r)}{C(a)} \quad [-] \qquad (2)$$

With *R(0)* being the initial risk, *R(r)* the residual risk and *C(a)* the annual costs of the measures.

A measure is considered to be cost-efficient if *CE* is above 1 and not cost-efficient if *CE* is below 1. However one may consider that any entry value of a cost-benefit analysis is subject to uncertainties. The final result is therefore blurry. It's recommended to apply a certain range of uncertainty to the interpretation of the result.

For more details on risk calculation refer to Appendix A.

4 Cost-benefit analysis tools

4.1 Overview

The four approaches examined are:

1. EconoMe Approach SRC
2. Caritas Approach
3. Mi Resiliencia Bolivia
4. IFRC Prioritising tool

These approaches are those best known by the members of the Swiss NGO DRR platform. Approaches one through three are all based on the Swiss EconoMe tool [1], a tool mandatory to be used to evaluate the cost-efficiency of hazard mitigation measures in Switzerland. The tools use the basic equations of risk calculation and cost-benefit analysis presented in Appendix A and are hence classified as quantitative approaches (Fig. 1). However, the complexity of calculation and the quality of required input values differ from one approach to the other. Whereas the Caritas Approach works with simple hazard and risk parameters, Mi Resiliencia Bolivia and the EconoMe Approach SRC require detailed information on hazards and vulnerabilities.
The fourth approach is a qualitative to semi-quantitative approach. The core of the approach is a participatory evaluation of benefits and costs rather than a scientific one. Nevertheless, qualitative parameters like social and environmental benefits and costs are ranked in order to compare them with quantitative economic benefits and costs.

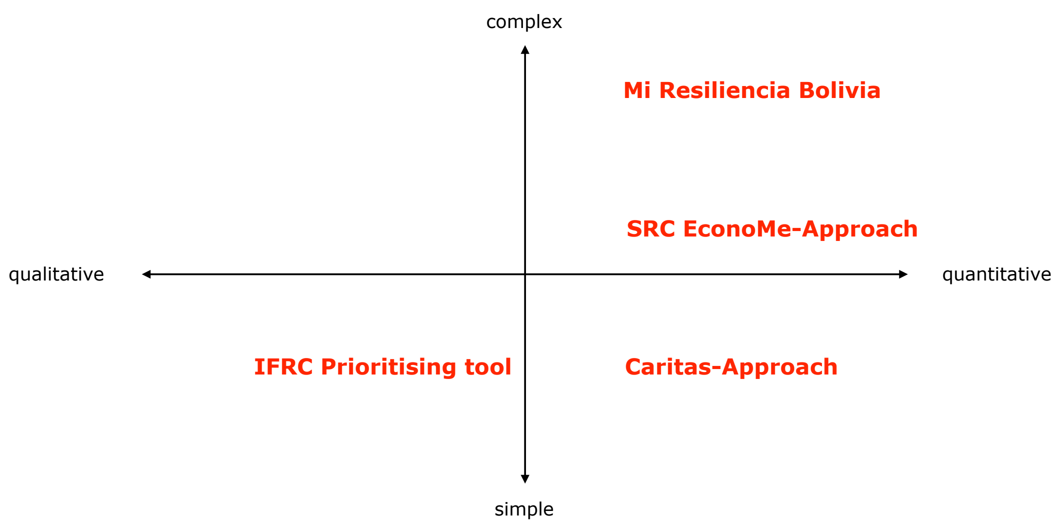


Fig. 1: Classification of the approaches in a qualitative-quantitative / simple-complex plane.

4.2 EconoMe-Approach SRC

4.2.1 Background

In the frame of the Swiss Red Cross DRR programme for Central America and the Caribbean a large number of mitigation measures – mainly on a very small scale – have been and are still being implemented. Swiss Red Cross wants to know, whether the implemented measures are cost-efficient. In the frame of a backstopper mandate, the author supported the project teams in El Salvador and Honduras in performing cost-benefit analysis of implemented mitigation measures. As a result of the process, a guideline for cost-benefit analysis was elaborated and an Excel-tool to calculate the cost-efficiency was developed.

Fig. 2: Slope stabilisation to protect the access road to the communities in Sonith, municipality of San Isidro, Choluteca, Honduras. A typical small-scale mitigation measure elaborated by the Swiss Red Cross in the frame of the DRR programme for Central America and the Caribbean [3].

4.2.2 Documentation and tools

The following documentation is available (Source: Swiss Red Cross):

- A step-by-step handbook to apply cost-benefit analysis according to the approach of EconoMe [2]. The handbook contains a list of required input parameters, the formulae for risk calculation and standard values for assets in Honduras and El Salvador and their vulnerabilities. The step-by-step method is illustrated with a case study.

- A report on the backstopping process to introduce cost-benefit analysis in the DRR projects in El Salvador and Honduras [3]. The report contains a list of lessons identified (main sources of error) and three examples of cost-benefit analysis. In one of the examples, the principle of cost-benefit analysis is applied to an infrastructure project that contains no DRR measures.

- An Excel-tool that allows calculating initial risks, residual risks, annual costs of measures and the cost-efficiency of the measures (Fig. 3). A set of standard values for assets and their vulnerabilities is implemented.

All documents are written in Spanish.

Riesgo inicial escenario 1	Nueva Esperanza	
Tiempo de retorno:	10	años
Resumen:		
pérdida en bienes materiales	262'350	Lps.
número de vícitimas	0.0000675	
pérdida en vidas humanas	67.5	Lps.

Elementos comunes, valores promedios				Exposición							Pérdida				
N°	Tipo	Valor básico estándar	Valor básico corregido	Número de objetos expuestos	Número de personas por objeto expuesto	Presencia promedia de personas [hora/día]	Proceso	Intensidad	p aparición espacial, valor estándar	p aparición espacial, valor corregido	Susceptibilidad del objeto	Mortalidad	Factor de construcción mejorada ε	Pérdida de bienes materiales	Víctimas
1	Casa y contenido (mejores condiciones, casa de ladrillo)	180'000		11	5	16.00	Inundación dinámica	muy baja	0.90		0.05	0		89'100	0
2	Casa y contenido (condiciones sencillas, casa de adobe o ma	145'000		5	5	16	Inundación dinámica	muy baja	0.90		0.1	0		65'250	0
3	Escuela estándar (edificio + contenido, muros de concreto)	750'000		1	40	6	Inundación dinámica	baja	0.90		0.15	0.0000075		101'250	0.0000675
4															
5															
6															
7															

Fig. 3: Screenshot of the excel tool: calculation of the initial risk.

4.2.3 Theory

The approach is based on cost-benefit analysis as commonly used in Switzerland [1]. It uses the standard equations of Appendix A. The approach considers the loss of material assets and the loss of human lives (direct losses). Indirect losses can be added, however no standard values are given and values for indirect losses must be defined case-by-case.
The approach defines standard values of vulnerability and lethality to the following hazardous processes: static flooding, dynamic flooding, spontaneous landslides and rock fall.

4.2.4 Steps of application

The handbook proposes ten steps to run through, in order to elaborate a cost-benefit analysis:

Steps for the initial situation (without measures)

1. Elaborate or collect basic documents (topographic maps, data on passed events, etc.)
2. Define the system boundaries
3. Define hazard scenarios and map hazards for initial state
4. Identify the damage potential
5. Calculate the initial risk (without measures)

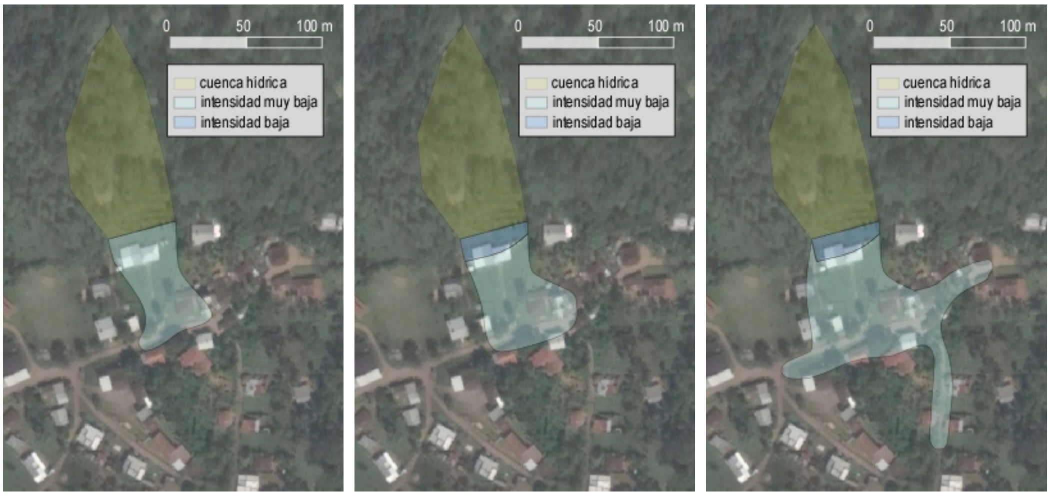
Steps for the situation with measures

6. Define and design the measure, calculate the costs
7. Map hazards for the state with measures
8. Calculate the residual risk (with measures)
9. Compare the benefit with the costs of the measure
10. Evaluate the result

The following steps are worth to be highlighted:

– Step 3: Define hazard scenarios and map hazards in the initial state.

  The method uses values for the vulnerability of assets that depend on the type of the asset (type of construction), on the type of hazardous process and on the intensity of the hazardous process (cf. formulae 3 and 4). The hazard mapping requires therefore intensity maps for each of the considered scenario (Fig. 4). This is true for the initial state and the state with measures.



T_j = 1 year T_j = 5 years T_j = 10 years

Fig. 4: Example of intensity maps for three different scenarios, initial state [1].

– Step 10: Evaluate the result.

The final result of the cost-benefit analysis, the value of the cost-efficiency *CE*, must be evaluated. The following scheme is proposed:

$CE < 1$:	the measure is not cost-efficient
$1 < CE < 2$:	the measure is poorly cost-efficient
$2 < CE < 5$:	the measure is cost-efficient
$CE > 5$:	the measure is highly cost-efficient

The entering values of the cost-benefit analysis are commonly based on suppositions with a certain range of uncertainty. The result is therefore fuzzy. It's recommended to vary the entering parameters like frequency of the scenario, the intensity of the hazardous process, the effect of the measure, the values of assets and their vulnerability, the lifespan of measures etc. in order to evaluate the sensitivity of the result on the values of the input parameters.

4.2.5 Required expertise and skills

In order to apply the EconoMe-approach the user must be able to perform a sound hazard analysis that includes the concept of hazard scenarios with different probabilities and the concept of the intensity of hazardous processes. The managing organisation must be able to define standard values of assets and their susceptibility to hazards.

4.2.6 Particularities of the approach

- The EconoMe approach by the Swiss Red Cross is a fully quantitative method.
- It proposes values to monetise the loss of human lives. However this is a first approach for Central American countries defined at project level and the values are not yet consolidated nor consented at national level.
- A sound hazard analysis is the basis of a reliable result.
- The approach comes with an easy to use Excel-tool.

4.3 Caritas-Approach

4.3.1 Background

Caritas Switzerland (CaCH) runs a long lasting DRR programme in Tajikistan. In the frame of this programme several flood protection measures have been implemented. In order to evaluate the cost-efficiency of the measures, NDR Consulting GmbH elaborated a methodology.

Fig. 5: Construction of a dike to control flooding and sediment deposition in Muminabad, Tajikistan [4].

4.3.2 Documentation and tools

The following documentation is available (Source: CaCH):

- A step-by-step handbook to apply cost-benefit analysis for flood protection measures [4]. The handbook contains a list of required input parameters, the formulae for risk calculation and standard values for assets in Tajikistan. The step-by-step method is illustrated with a case study.

The document is written in English. The Swiss Red Cross translated it to Spanish.

4.3.3 Theory

The approach is based on cost-benefit analysis as commonly used in Switzerland. However, risk is calculated in a simplified way. The vulnerability of assets to flooding is defined as a function of the return period of the event rather than as a function of the intensity of the hazardous process. The approach considers the loss of material assets (direct losses) in flood events only.

4.3.4 Steps of application

The handbook proposes five steps to run through, in order to elaborate a cost-benefit analysis:

Steps for the initial state (without measures)
1. Prepare basic requirements
2. Assess initial hazards and vulnerability, calculate the risks

Steps for the state with measures

3. Define measures, calculate the costs
4. Assess the effect of the measure (new flood hazard map) and calculate the residual risk
5. Determine the cost efficiency

The following steps are worth to be highlighted:

– Step 2: Assess initial hazards and vulnerability, calculation of risks.

  The method uses values for the vulnerability of assets that depend on the return period of the flooding (values for flooding with return period of 10, 30 and 100 years are given). Risk calculation is therefore quite simple and does not require detailed intensity maps.

Fig. 6: Risk calculation with the simplified method fits in a table of the size of one A4 sheet. Example issued from [4]

#	Type of infrastructure	Unit	Unit cost USD	Units in all hazard zones	Possible loss: 10 year event: affected units	dam-mage factor	loss USD	30 year event: affected units	dam-mage factor	loss USD	100 year event: affected units	dam-mage factor	loss USD
1	Living houses	Piece	11'000	45	9.00	0.10	9'900	32.00	0.50	176'000	45.00	0.75	371'250
2	School	Piece	80'000	1	1.00	0.10	8'000	1.00	0.50	40'000	1.00	0.75	60'000
3	Mosque	Piece	30'000	1	1.00	0.10	3'000	1.00	0.50	15'000	1.00	0.75	22'500
4	Canteen	Piece	15'000	1	1.00	0.10	1'500	1.00	0.50	7'500	1.00	0.75	11'250
5	Drinking water pipes	km	20'000	0	0.15	0.10	300	0.30	0.50	3'000	0.40	0.75	6'000
6	Asphalt road	km	21'000	1	0.20	0.10	420	0.40	0.50	4'200	0.60	0.75	9'450
7	Transformer	Piece	12'000	1	1.00	0.10	1'200	1.00	0.50	6'000	1.00	0.75	9'000
	Possible loss per event						24'320			251'700			489'450
	Possible annual loss						**2'432**			**8'390**			**4'895**
	Total possible annual loss												**15'717**

– Step 5: Determine the cost efficiency.

  Since the risk calculation is based on a very rough estimate of the expected damage in case of flooding, the evaluation of the cost-efficiency *CE* is consequently subject to stricter standards than the evaluation of cost-efficiency determined with the SRC approach (section 4.2.4). The approach proposes the following classification:

  $CE < 1$: the measure is not cost-efficient
  $1 < CE < 4$: the measure is poorly cost-efficient
  $4 < CE < 7$: the measure is cost-efficient
  $CE > 7$: the measure is highly cost-efficient

4.3.5 Required expertise and skills

In order to apply the Caritas-approach the user must be able to perform a community based flood hazard analysis that includes the concept of hazard scenarios with different probabilities. The managing organisation must be able to define standard values of assets.

4.3.6 Particularities of the approach

- The approach by Caritas is a fully quantitative method to evaluate the cost-efficiency of flood protection measures.
- It works with three scenarios with pre-defined return periods.
- A simplified (community based) hazard map is sufficient to describe the hazard situation.
- The simplified risk analysis gives a rough estimate of the cost-efficiency of measures.

4.4 Mi Resiliencia, Bolivia

4.4.1 Background

The Bolivian Government stipulates that DRR must be taken into account when planning public investments. In the frame of SDC's DRR programme for Bolivia a cost-benefit analysis tool based on the Swiss EconoMe approach was suggested and developed in 2018. The Bolivian government intends to additionally consider indirect losses based on the resilience level of the society.

4.4.2 Documentation and tools

The following publication will be publicly available after its presentation during the UN-ISDR Global Platform for Disaster Risk Reduction, which will be held in May 2019 in Geneva:

– A handbook [5] gives a brief overview over the hazard analysis, shows the formulae used for risk calculation and works as a user manual for the application of the Web-GIS interface.

4.4.3 Theory

The approach is based on cost-benefit analysis as commonly used in Switzerland [1]. It uses the standard equations of Appendix A. The approach considers the loss of material assets and the loss of human lives (direct losses) as well as indirect losses. The latter are defined as the loss of income of agricultural, commercial and industrial units. For that reason, the resilience of these units is quantified using a series of so called resilience factors like e.g. formal and informal community support, property insurance coverage, household savings etc.

The approach defines standard values of vulnerability and lethality to the following hazardous processes: static flooding, dynamic flooding, debris flow, drought, landslide and rock-fall.

4.4.4 Steps of application

The handbook proposes eight steps to run through, in order to elaborate a cost-benefit analysis:

Steps for the initial state (without measures)
1. Perform a hazard analysis (intensity maps)
2. Identify the damage potential
3. Evaluate the protection deficit
4. Calculate the existing risk for direct and indirect losses

Steps for the state with measures
5. Plan mitigation measures
6. Perform a hazard analysis (intensity maps) taking the effect of measures into account
7. Calculate the residual risk for direct and indirect losses
8. Calculate the cost-efficiency

The following steps are worth to be highlighted:

– Steps 4 and 7: Calculate the existing and the residual risk for direct and indirect losses

  Risk is calculated with the help of a Web-based GIS application. Intensity maps and the damage potential can be digitalised on the screen or uploaded as shape-files. The resilience is determined for those objects where income is generated (commercial/industrial unit or plot of agricultural land). For a set of eight factors (ten factors for drought) values between 0 (not existing) and 1 (working very well) are assigned by the user. The weight of each factor can be chosen in order to consider its relevance in comparison to the other factors. The resilience factors are then weight-averaged and applied to reduce the indirect losses in case of an event.

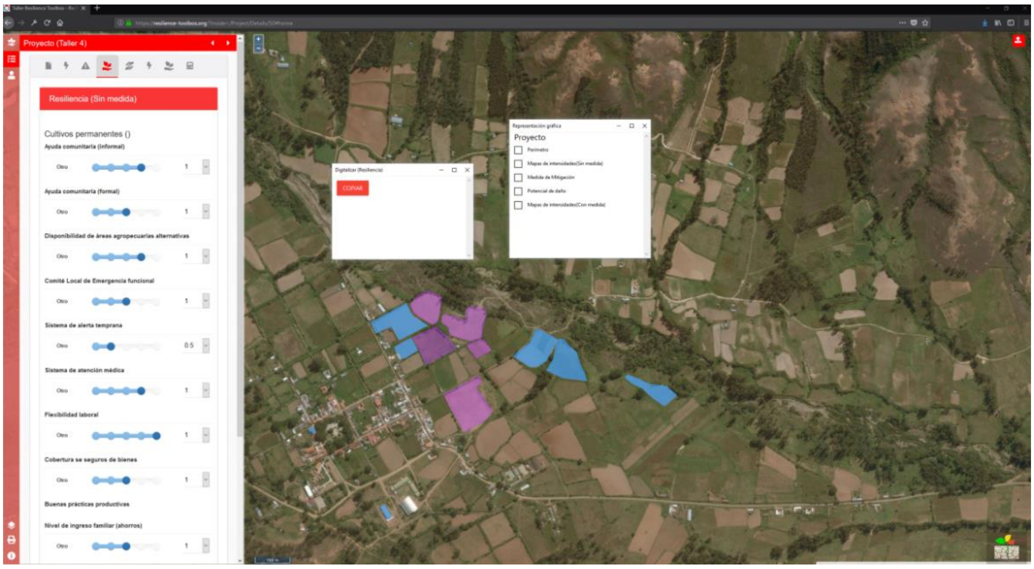


Fig. 7: Assigning values to the resilience factors of agricultural plots with the help of the Web-interface of Mi Resiliencia.

4.4.5 Required expertise and skills

In order to apply Mi Resiliencia the user must be able to perform a sound hazard analysis that includes the concept of hazard scenarios with different probabilities and the concept of the intensity of hazardous processes. He must be able to draw intensity maps. The managing organisation must be able to define standard values of assets and their susceptibility to hazards. Furthermore the user must be able to assess the effect of resilience factors on indirect losses.

4.4.6 Particularities of the approach

– The Bolivian Mi Resiliencia is a fully quantitative method.
– Direct and indirect (secondary) losses are quantified.
– The effect of activities to increase the resilience of the community is quantified.
– A sound analysis of hazards, of indirect losses and of the resilience factors is the basis of a reliable result. It must be elaborated carefully.
– The tool is based on an easy to use Web GIS application. The application requires hosting by an institution.

4.5 IFRC Prioritising tool

4.5.1 Background

The International Federation of Red Cross and Red Crescent (IFRC) developed and applies a participatory tool to assess vulnerabilities and capacities of communities (VCA). The tool has been intensively applied in humanitarian interventions and communities have been identifying possible solutions to reduce their disaster risks. However, the large number of potential solutions asks for prioritising them. That's where the prioritising tool begins to work. It has been developed by ISET in Pakistan and is being applied in various countries.

4.5.2 Documentation and tools

The following documentation is available (Source: IFRC):

- A description of the methodology with the general procedure and a step-by-step handbook for prioritising solutions [6]. The handbook describes the procedure and gives examples in tables.
- A step-by-step manual for the core element of the above-mentioned methodology, the community based cost-benefit analysis [7]. The manual gives additional recommendations to the facilitator of the participatory process.

The methodology is written in English, the step-by-step manual in Spanish.

4.5.3 Theory

In comparison to the above-presented approaches, the IFRC prioritising tool uses a broader definition of benefits and costs:

«The benefit is the increase in well-being of the individual and community, reflected in terms of what you earn from the activity as an individual, family or community.

The cost is the decrease in the well-being of the individual and community, reflected from the point of view of what is invested at individual, family and community level to carry out the activity.»

4.5.4 Steps of application

The general procedure consists of four main steps, marked in Fig. 8: Departing from an existing vulnerability and capacity assessment the number of solutions is being reduced to three to five options using the methodology of pairwise ranking[1]. Development and hazard scenarios are then established in order to assess the effectiveness of the options under different conditions. The options are thus modified for effectiveness or removed from the list. The participatory cost-benefit analysis (step 3) is the core element. In this step, economic, social and environmental returns on investment are calculated. Finally, a multi-criteria analysis is applied in order to make sure that additional criteria are being considered and that the benefits go to those who need them the most.

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1 For a detailed description of the pairwise ranking methodology refer to [6], page 6 ff.

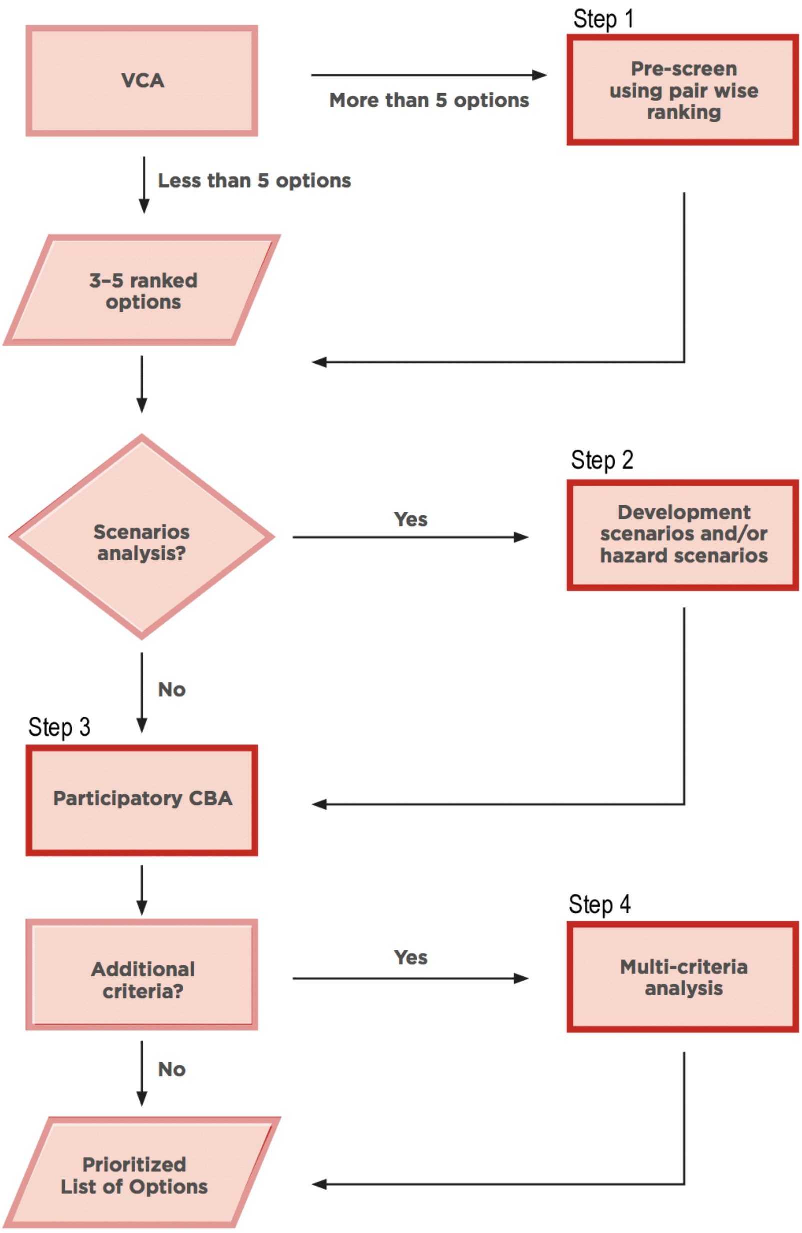

Fig. 8: Process flow chart for prioritizing actions [5]. Highlighting and numbering inserted by the author.

For the participatory cost-benefit analysis (#3) of the general flow chart, the methodology proposes six steps of application:

1. Select a strong facilitator
2. Organise the work in the community. It is suggested to work in groups organised on the basis of specific categories (gender, ethnicity, etc.).
3. Identify costs and benefits
4. Value the costs and the benefits, obtain the benefit/cost ratios
5. Identify distributional factors that show who benefits and who is harmed by an action.
6. Present and discuss findings with the community

The following steps are worth to be highlighted:

Step 3: Identify costs and benefits

Costs and benefits are categorised by economic, social and environmental capitals. Hence, not only risk reduction is regarded as a benefit of an intervention but also other benefits like social coherence or access to natural resources.

Step 4: Value the costs and the benefits, obtain the benefit/cost ratios

Costs and benefits may be of quantitative and of qualitative nature. In order to compare qualitative with quantitative costs and benefits the approach proposes a methodology of pairwise ranking. Community members value the importance of one benefit (or cost) compared to another one. This process leads to a ranking of quantitative and qualitative benefits and costs and allows comparing their relevance to the community.

4.5.5 Required expertise and skills

In order to apply the IFRC approach the user must be able to set up and to moderate participatory workshops in communities. The user must have a sound understanding of socio-economic issues of communities at risk.

4.5.6 Particularities of the approach

- The approach proposed by the IFRC is a fully participative approach.
- It considers quantitative and qualitative values of benefits and costs.
- It includes any kind of benefit (i.e. includes also co-benefits of DRR measures).
- However, the benefit of saving human lives is explicitly not quantified.
- The approach is applicable to any kind of development activity.

5 Evaluation of the approaches and tools

5.1 Evaluation criteria

Quality	Quantitative Approach Consideration of direct losses Consideration of indirect losses (secondary losses) Willingness to pay approach will be applied (consideration of fatalities) Transparent traceability of the results guaranteed Traceability of methodology and calculation procedure guaranteed Objective calculation of cost-effectiveness Documentation of assumptions Flexibility of analysing depth Potential to evaluate other benefits than risk reduction
Field of application	Suitable for use in urban areas Suitable for use in rural areas (considers losses in agricultural production) Cost effectiveness of structural AND non-structural measures calculable Possibility to adapt the tool to the local context
User-friendliness	Intuitional application (including a comprehensible step by step user manual / methodology) Users are always up to date with version changes of the tool. Little training effort for the application Low operating expenditure Independence from the Internet
Required expertise and skills of the applicant	Hazard analysis expertise Expertise in analysing the damage potential Mapping and GIS skills IT skills Facilitation expertise
Required expertise of the managing organisation	Expertise in defining standard values for the damage potential Expertise in developing IT-solutions

Table 1: Evaluation criteria.

5.2 Evaluation results

The detailed evaluation by the author is listed in Appendix B. To each criterion a rating scale of three grades is applied: fully true, partly true, not true. The required expertise and skills are attributed high, medium or low.

The evaluation can be summarised as follows:

The *EconoMe-approach* by the Swiss Red Cross is a practical method that combines detailed quantitative cost-benefit analysis with an easy to use Excel-tool. It is applicable to all kind of mitigation measures but is most suitable to analyse the cost-efficiency of small-scale measures that show their effect in a limited area. A sound hazard analysis with intensity maps is the basis of a reliable result and therefore needs to be carried out carefully.

The *Caritas-approach* is a very practical method for rough cost-benefit analysis of flood protection measures based on a simplified hazard and risk assessment. It is applicable in contexts where little information on the hazard processes is available or where hazard maps are community based. The tool could theoretically be adapted to other sudden onset hazards like rock-fall, debris flow etc. However, community based methods to map these types of hazards are limited and hazard mapping requires expertise. A more sophisticated approach for cost-benefit analysis might therefore be adequate.

Mi Resiliencia is a Web GIS-based application that allows for detailed quantitative cost-benefit analysis. It considers direct and indirect losses (income interruption) and proposes a methodology to take the resilience of the society into account. A series of so-called resilience factors are applied to estimate a reduction of indirect losses. The application is applicable to mitigation measures against flooding, debris flow, drought, landslide and rock-fall. A sound hazard analysis with intensity maps and a thorough evaluation of the resilience factors are the basis of a reliable result and therefore need to be carried out carefully.

The *Prioritising tool of the IFRC* is a method that combines quantitative cost-benefit analysis with the analysis of qualitative costs and benefits. It is not limited to the physical aspects of disaster risk reduction. The analysis is participatory and is applicable for all kind of intervention. The participatory process is time consuming and must be guided by an experienced facilitator.

5.3 Conclusion

Out of the evaluation of the approaches and tools by the author and the discussions held during the learning workshop one may draw the following conclusions:

– Selection of the appropriate tool:

  No general recommendation to use one or the other approach or tool is given. The suitable approach depends on the reasons for the cost-benefit analysis, the local context, the existing information on hazards and the damage potential and the expertise of the user. Tools should be used what they are made for and should not be stressed to answer questions they can‘t. Whatever kind of tool or approach is applied: it needs practice and experience to apply it correctly and in an efficient way.

– Quantitative vs. qualitative tools:

  Quantitative tools run the risk to pretend an exact and objective analysis. However, the calculations are based on assumptions on the probability of hazard scenarios, the extent and intensity of hazardous processes and the susceptibility of assets to damaging processes. Assumptions and calculations of each cost-benefit analysis must therefore be documented and the calculated cost-efficiency must be verified.
  The application of quantitative tools bears the risk that the cost-efficiency becomes the one and only selection criterion for DRR measures. Therefore it's crucial to communicate the results of a quantitative cost-benefit analysis in a way that they are read properly. Qualitative approaches on the other hand force the discussion on benefits and costs and can serve as an eye opener to identify the priority solution for a community beyond economic aspects.

– Quality issues

A sound hazard analysis is the basis of any quantitative cost-benefit analysis. The hazard analysis usually requires more time and expertise than the cost-benefit analysis itself. In many development countries the institutional and personal capacities to carry out such hazard analysis are lacking.
Taking indirect losses into consideration may lead to an over estimation of risks. The indirect loss of one community member, e.g. the business interruption of a service provider, can be the indirect gain of his not affected competitor who sells the same service twice as much. Nevertheless it is more important to consider indirect losses in less resilient communities than in resilient ones.

6 Bibliography

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7 List of abbreviations

CaCH	Caritas Switzerland
CBA	cost-benefit analysis
CE	cost-efficiency
CHF	Swiss francs
DRR	disaster risk reduction
GIS	geographic information system
IFRC	International Federation of Red Cross and Red Crescent societies
NGO	non-governmental organisation
SDC	Swiss Agency for development and co-operation
SRC	Swiss Red Cross
UN-ISDR	United Nations Office for Disaster Risk Reduction
VCA	vulnerability and capacities analysis

Appendix A Basic equations of cost-benefit analysis

Given the risk definition in chapter 3.2, the risk of loss R_j for a given scenario j is quantified by the following equation:

$$R_j = p_j Loss_j \quad \left[\frac{\$}{year}\right] \qquad (1)$$

With p_j being the probability of occurrence of this scenario and $Loss_j$ the damage that is likely to be caused if the scenario strikes the given assets.

Usually, a risk analysis considers several scenarios with different probability of occurrence[1]. The total risk then sums up over all considered scenarios:

$$R = \sum_j R_j \quad \left[\frac{\$}{year}\right] \qquad (2)$$

The loss depends on the type of hazard, its intensity, the value of the asset and its vulnerability. Vulnerability in this case means physical vulnerability (susceptibility).
The loss of material assets is calculated according to formula (3) multiplying the value $VA(ma)_i$ of the object *i* at risk with its vulnerability $V(ma)_{i,j}$, and the probability of the spatial occurrence $p(SpO)_j$ of the hazardous process. The (physical) vulnerability $V(ma)_{i,j}$ of the object at risk depends on the construction type and the physical impact (intensity) of the governing hazardous process The expected loss is lower, if the asset object is reinforced with protective measures. That is considered with the factor $1 - \varepsilon_i$.

$$Loss(ma)_{i,j} = p(SpO)_j \; V(ma)_{i,j} \; VA(ma)_i \; (1 - \varepsilon_i) \quad \left[\frac{\$}{scenario}\right] \qquad (3)$$

The loss of human lives is calculated in a similar way:

$$Loss(hl)_{i,j} = p(SpO)_j \; \lambda(p)_{i,j} \; N(p)_i \; p(pr)_i \; (1 - \varepsilon_i) \quad \left[\frac{\dagger}{scenario}\right] \qquad (4)$$

Instead of the value of the asset, the number of people $N(p)_i$ in a building *i* and the probability of presence $p(pr)_i$ of people in the building is considered. The vulnerability is replaced by the lethality $\lambda(p)_{i,j}$ of people inside the building.

The sum of values of material assets and the number of persons in an area at risk are named the damage potential in the area at risk.

Costs of mitigation measures are expressed in $/year in order to compare them with the risk reduction. In order to convert one-time investment costs into annual costs they are divided by the lifespan of the investment. Interests, maintenance costs and service costs are added to quantify the annual costs of a measure.

[1] In order to avoid cumulating risks, the probability of ocurrence rather than the exceeding probability of a scenario is considered.

Finally, the cost efficiency *CE* is calculated dividing the benefit (risk reduction) by the costs:

$$CE = \frac{R(0) - R(r)}{C(a)} \quad [-] \qquad (5)$$

With *R(0)* being the initial risk, *R(r)* the residual risk and *C(a)* the annual costs of the measures.

A measure is considered to be cost-efficient if CE is above 1 and not cost-efficient if CE is below 1. However one may consider that any entry value of a cost-benefit analysis is subject to uncertainties. The final result is therefore blurry. It's recommended to apply a certain range of uncertainty to the interpretation of the result.

Appendix B: CBA Toolbox Evaluation Frame

		EconoMe-Approach SRC (Lukas Hunzinger, 2018)		Caritas-Approach (Markus Zimmermann, 2009)		Mi Resiliencia (SDC, 2018)		Community-based Disaster Risk Reduction and Adaptation Planning - Tools for Prioritizing Potential solutions (IFRC, 2015)
Quality								
Quantitative Approach	Fully true	The benefit is quantified as risk reduction in $/a or +/a.	Fully true	The benefit is quantified as risk reduction in $/a.	Fully true	The benefit is quantified as risk reduction in $/a.	Partly true	Economic costs and benefits are quantified. Non-quantifiable costs and benefits (social and environmental ones) are ranked in order to compare them to the economic ones.
Consideration of direct losses	Fully true	Potential losses are calculated per scenario. The physical vulnerability of assets is defined as a function of type and intensity of the process.	Fully true	Potential losses are calculated per scenario. The physical vulnerability of assets is defined as a function of the recurrence interval of the flood event.	Fully true	Potential losses are calculated per scenario. The physical vulnerability of assets is defined as a function of type and intensity of the process.	Fully true	Avoided costs are part of the economic benefits considered.
Consideration of indirect losses (secondary losses)	Partly true	Default values are given for assets to calculate direct losses. The list of assets is open. Values for indirect losses could theoretically be added. It's up to the applicant to define the methodology to calculate indirect losses.	Partly true	Default values are given for assets to calculate direct losses. The list of assets is open. Values for indirect losses could theoretically be added. It's up to the applicant to define the methodology to calculate indirect losses.	Fully true	For objects that generate income, the indirect loss due to loss of production during a certain period of time can be quantified. If measures reduce the period of loss of production the risk of indirect losses decreases.	Partly true	There is no limitation in the type of benefit considered. Hence avoided indirect losses can be considered.
Willingness to pay approach will be applied (consideration of fatalities)	Fully true	Fatalities are monetised. The user enters the value attributed to human life or to the willingness to pay for saving lives.	Not true		Fully true	Fatalities are monetised. Standard values are predefined to quantify the willingness to pay for saving lives.	Not true	Monetizing lives is regarded as unethical.
Transparent traceability of the results guaranteed	Fully true	Input and output are listed in an Excel sheet. The use of non-standard values is highlighted. The user should documents the hazard scenario and the effects of the measures in the accompanying report.	Partly true	If the practitioner documents input and output the results are traceable.	Fully true	The risk parameters per object are visualized on a map. The use of non-standard values is highlighted. Results are listed in tables and errors are marked.	Partly true	If the facilitator documents the results of the workshops the results are traceable.
Traceability of methodology and calculation procedure guaranteed	Fully true	The methodology is specified in the guidelines. The formulae for calculation are underlying in the Excel-sheets.	Partly true	If the practitioner follows the methodology and documents the calculation steps, the calculation is traceable.	Fully true	The methodology is specified in the handbook.	Partly true	If the facilitator documents the results of the workshops the calculation is traceable.
Objective calculation of cost-effectiveness	Fully true	Standard formulae are used to quantify the risks and to evaluate the costs of measures.	Fully true	Simplified standard formulae are used to quantify the risks and to evaluate the costs of measures.	Partly true	Standard formulae are used to quantify the risks and to evaluate the costs of measures. However the result may be biased by the values and weight assigned to the resilience factors (no standard values exist).	Not true	Social and environmental costs and benefits are identified and valued in a participatory process.
Documentation of assumptions	Fully true	The use of other values than standard values is marked in the Excel sheets.	Partly true	No standard form for documentation is presented. It's up to the user to document assumptions.	Fully true	The use of other values than standard values is highlighted on the map.	Not true	No assumptions are made, but costs and benefits are valued in a participatory process.
Flexibility of analysing depth	Fully true	Elements at risk can be listed as groups (as long as they are affected with the same intensity) or as individual objects.	Fully true	Elements at risk can be listed as groups (as long as they are affected in the same hazard scenario) or as individual objects.	Partly true	Elements at risk are listed as individual objects. They can also be listed as groups as long as they are affected with the same intensity.	Fully true	There is no limitation in the definition of objects at risk or beneficiaries.
Potential to evaluate other benefits than risk reduction.	Not true		Not true		Not true		Fully true	There is no limitation in the type of benefit considered.
Field of application								
Suitable for use in urban areas	Fully true	However a large number of individual objects at risk will result in large and potentially confusing excel sheets.	Fully true	However a large number of individual objects at risk will result in a large and potentially confusing listing.	Fully true	No limits in number of objects at risk.	Fully true	There is no limitation in the type of benefit considered.
Suitable for use in rural areas (considers losses in agricultural production)	Fully true	Default values are given to calculate direct losses in agricultural production.	Fully true	Default values are given to calculate direct losses in agricultural production.	Fully true	Default values are given to calculate direct losses in agricultural production.	Fully true	There is no limitation in the type of benefit considered.
Cost effectiveness of structural AND non-structural measures calculable	Partly true	As far as the effect of non-structural measures on the exposure and the vulnerability of assets can be determined. The effect of an early warning system for example can be quantified by reducing the number of people present in a building at risk.	Partly true	As far as the effect of non-structural measures on the exposure of assets can be determined. Effects of non-structural measures on the vulnerability of assets cannot be considered.	Fully true	The effect of non-structural measures is considered by changing the value of the resilience factors.	Fully true	There is no limitation in the type of measures taken into account.
Possibility to adapt the tool to the local context.	Fully true	The list of assets, their basic values and values for the physical vulnerability can be adapted.	Fully true	The list of assets and their basic values can be adapted.	Partly true	The list of assets, their basic values and values for the physical vulnerability can be adapted. However, the source code of the application must be changed for the values of lethality and vulnerability.	Fully true	The method (not a tool) can be applied in any cultural context.

		EconoMe-Approach SRC (Lukas Hunzinger, 2018)		Caritas-Approach (Markus Zimmermann, 2009)		Mi Resiliencia (SDC, 2018)		Community-based Disaster Risk Reduction and Adaptation Planning - Tools for Prioritizing Potential solutions (IFRC, 2015)
User-friendliness								
Intuitional application (including a comprehensible step by step user manual / methodology)	Fully true	The methodology comes with a step by step application of the CBA. There is no manual for the Excel-sheet.	Fully true	The methodology comes with a step by step application of the CBA.	Fully true	The methodology comes with a step by step guideline and a user-manual.	Fully true	The methodology is described in detail.
Users are always up to date with version changes of the tool.	Not true	Each Excel-file stands alone. However, the method described in the user manual does not change.	n.a.	There are no changes of the methodology.	Fully true	The online application guarantees always the latest version.	n.a.	There are no changes of the methodology.
Little training effort for the application (cf. also the criteria on required expertise)	Partly true	Depending on the knowledge of the user on risk assessment.	Fully true	Depending on the knowledge of the user on risk assessment.	Partly true	Low training effort for the user of the front end. High training effort for the administrator. Most training effort is needed for the hazard assessment.	Fully true	With the help of a facilitator and of resource persons, the method can be applied in communities.
Low operating expenditure	Partly true	Most effort must be made to analyse the hazard in the state with and without measures (intensity maps required) and to identify the damage potential.	Partly true	Most effort must be made to analyse the hazard in the state with and without measures (flood maps required) and to identify the damage potential.	Partly true	Medium effort. Most effort must be made to analyse the hazard in the state with and without measures (intensity maps required) and to identify the damage potential.	Partly true	A participatory community workshop has to be held.
Independence from the Internet	Fully true	The Excel-file stands alone.	Fully true	Not an IT based method.	Not true	Web-based tool.	Fully true	Not an IT based method.
Required expertise and skills of the applicant								
Hazard analysis expertise	High	The user must be able to define hazard scenarios, analyse weak points and map the affected areas. He/she should master the concept of intensities and probability of spatial occurrence.	Medium	The user must be able to define hazard scenarios, analyse weak points and map the affected areas.	High	The user must be able to define hazard scenarios, analyse weak points and map the affected areas. He/she should master the concept of intensities and probability of spatial ocurrence.	Low	The user must be able to define hazard scenarios.
Expertise in analysing the damage potential	Medium	The user must be able to identify objects at risk. If non-standard values are being used, he/she must be able to value assets and to quantify their susceptibility to hazards.	Medium	The user must be able to identify objects at risk. If non-standard values are being used, he/she must be able to value assets.	High	The user must be able to identify objects at risk. If non-standard values are being used, he/she must be able to value assets and to quantify their susceptibility to hazards. Expertise in defining factors that influence in the resilience of objects at risk.	Low	The user must be able to evaluate the effect of hazards on the planned activity in a qualitative manner.
Mapping skills	Medium	Skills to map areas at risk with intensity maps are recommended.	Medium	Skills to map areas at flood risk required.	High	Skills to map areas at risk with intensity maps are mandatory.	Low	No mapping skills required.
IT skills	Medium	Working with Excel-sheets.	Medium	Working with Excel-sheets.	Medium	Application of a Web-GIS interface.	Low	No IT skills required.
Facilitation expertise	Low	Facilitation expertise required in order to including local knowledge in the hazard analysis.	Medium	Facilitation expertise for community based hazard mapping required.	Low	Facilitation expertise required in order to including local knowledge in the hazard analysis.	High	Experience in facilitation of participatory workshops required.
Required expertise of the managing organisation								
Expertise in defining standard values for the damage potential	High	Standard values for assets and their susceptibility to hazards must be defined.	Medium	Standard values for assets must be defined.	High	Standard values for assets and their susceptibility to hazards for direct an indirect losses must be defined.	n.a.	
Expertise in developing IT-solutions	Medium	Expertise in programming Excel-tools	n.a.		High	A web-GIS code for the back end and the front end must be developed.	n.a.	

Appendix C Programme of the learning workshop on the 4th of December 2018

Workshop Program

Time		Topic	Speaker	Location
09:00 - 09:15	15'	Welcome, Inscription	Mali Noor	Room Kambodscha
09:15 - 09:30	15'	Introduction	Georg Heim	Room Kambodscha
09:30 - 10:30	60'	Metodology and concept of Hazard and Risk Analysis	Georg Heim	Room Kambodscha
10:30 - 10:45	15'	Coffee break		Cafeteria
10:45 - 11:15	30'	Overview of evaluated CBA-Tools	Lukas Hunzinger	Room Kambodscha
11:15 - 12:45	90'	Detailed presentation and evaluation of selected tools for Risk and Cost-Benefit-Analysis	Lukas Hunzinger	Room Kambodscha
12:45 - 13:30	45'	Lunch		Cafeteria
13:30 - 15:00	90'	Practical exercice of Risk and CBA-Tools (working in groups), part 1	Lukas Hunzinger, Ali Neumann	Room Kambodscha, Room Libanon (4. floor)
15:00 - 15:15	15'	Coffee break		Cafeteria
15:15 - 16:45	90'	Practical exercice of Risk and CBA-Tools (working in groups), part 2	Lukas Hunzinger, Ali Neumann	Room Kambodscha, Room Libanon (4. floor)
16:45 - 17:30	45'	Discussion	Lukas Hunzinger	Room Kambodscha