EconoMe-Develop – a software tool for assessing natural hazard risk and economic optimisation of mitigation measures

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ABSTRACT: In most countries, public money is used to finance the protection of human life, material assets and infrastructure against natural hazards. Limited financial resources need to be used in a way that they achieve the maximum possible effect by reducing as many risks as possible. Benefit-Cost-Analysis (BCA), based on risk assessment, is a recognized method for determining the economic efficiency of investments in mitigation measures.
In Switzerland, the software tool "EconoMe" was introduced to practice for assessing the economic efficiency of mitigation measures in 2008. Due to reasons of comparability of mitigation projects on the national level, the Federal Office for the Environment decided to fix most assumptions in the tool, so that they cannot be changed by the user. In order to overcome these limitations, EconoMe-Develop (www.econome-develop.admin.ch) was developed, allowing for risk assessment and benefit-cost-analysis of all prevailing natural hazard processes. We present the structure of the tool and conclude that easy-to-use calculation tools support risk-based decision making.

KEYWORDS: risk analysis, economic efficiency, risk-calculation tool, risk management

1. INTRODUCTION

In most cases worldwide, the protection of human life and material assets from natural hazards is financed by public money. The responsible authorities want to use this limited resource in a way that every investment in safety achieves a maximum possible risk reduction. Among other criteria, like technical feasibility and applicability, economic efficiency is a pivotal criteria. Benefit-Cost-Analysis (BCA) has become a recognized method for determining the economic efficiency of investments and mitigation measures for natural hazards.

Over the past ten years, the risk concept (Kaplan and Garrick, 1981) has developed as the prevailing concept for dealing with natural hazards in Switzerland (Planat, 2005), in addition to the Netherlands (Vrijling et al., 1995; Jonkman et al., 2010) and Germany (Merz, 2006). Decisions as to which mitigation strategy should be realised in a particular case are currently based on risk analysis, risk evaluation (both summarized as risk assessment) and evaluation of mitigation measures by various criteria, e.g. benefit-cost-analysis (Fig. 1).

The risk concept applied in Switzerland, is documented in the guideline 'RIKO' (Bründl, 2009). Following the approach suggested by Kaplan and Garrick (1981), in part A of RIKO, the methodological steps 'what can happen', 'what may happen', and 'what has to be done' are explained in general. In part B, the application of these steps are illustrated with examples for the processes avalanches, flood, rock fall, spontaneous and permanent landslides, earthquake, storm, hail and heat-waves. The guideline 'RIKO' is based on the earlier guideline 'Risk analysis for gravitational natural hazards' (in German: Risikoanalyse bei gravitativen Naturgefahren; Borter, 1999) and another guideline to calculate the cost-effectiveness of avalanche protection measures along traffic routes (Wilhelm, 1999). Determining the economic efficiency of mitigation measures plays a key role in these guidelines, and is an important decision criteria for communal, regional and national authorities from which mitigation measures can be prioritised.

In 2006, the Federal Office for the Environment in Switzerland FOEN initiated the

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development of the calculation tool "EconoMe", which has been in operational use since 2008 (FOEN, 2012). EconoMe follows the risk concept illustrated in RIKO (Bründl et al., 2009). Since EconoMe is a prioritisation tool for the national authorities. The number of scenarios and many of the calculation parameters in EconoMe are predefined and cannot be changed by the user. Furthermore, EconoMe can only deal with avalanches, flood, debris flow, rockfall, in addition to spontaneous and permanent landslides, while it cannot deal with earthquakes, storms, hail or heat waves. To overcome this gap, the National Platform Natural Hazards Planat and FOEN decided to develop the calculation tool 'EconoMe-Develop', which is able to meet individual needs of users.

2. OVERVIEW ECONOME-DEVELOP

EconoMe-Develop is an online tool (www.econome-develop.ch) requiring user registration. After approval, the user gains login access by FOEN (step 1). The workflow in EconoMe-Develop is similar to EconoMe also following the risk concept (Fig. 1). In contrast to EconoMe, the user can adapt a number of assumptions and calculation parameters according to the specific remit of a risk analysis, in particular:

- all processes like avalanches, floods, debris flows, rock fall and rock avalanches, spontaneous and permanent landslides, earthquake, storm, hail and heatwaves can be dealt with;
- the number and return period of scenarios are freely selectable; scenarios are not limited to the standard 30-, 100-, 300-year scenarios in Switzerland;
- the number of intensity classes are arbitrary and not fixed to three classes;
- users can weight low probability/high consequence events by a risk aversion function (results can be depicted with and without risk aversion);
- users can define risk exposition situations showing the influence of many people present for a limited time period vs. fewer people present for a longer time period;
- vulnerability factors (both for humans and material assets) can be adapted;

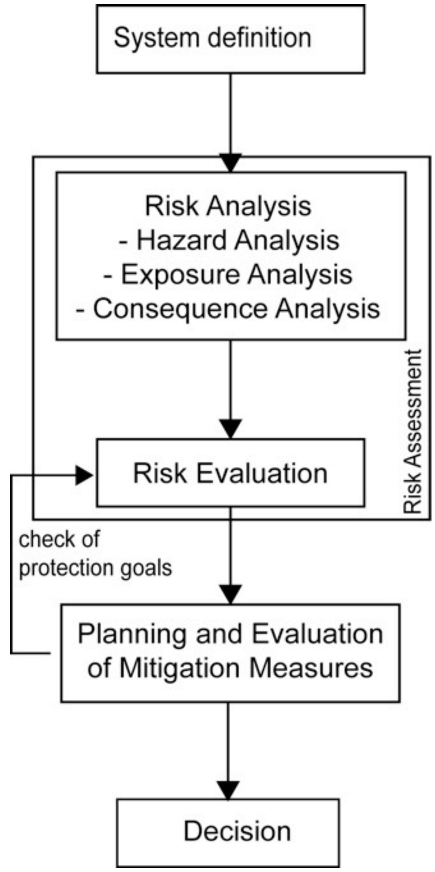

Figure 1: Schematic workflow of a risk-based decision process as it is implemented in EconoMe-Develop

- the spatial probability of processes can be adapted;
- indirect costs can be considered (e.g. costs due to closure of roads);
- organisational measures, like e.g. evacuations or closure can be considered by changing the number of people in the endangered zone with or without consideration of these measures;
- the effect of varying values of vulnerability and spatial probability of processes can be taken into account (Schaub and Bründl, 2010)..

In the following, the working steps are briefly described. For further explanations of the steps in a risk assessment and evaluation of mitigation measures, we refer to Bründl et al. (2009) and Rheinberger et al., (2009).

Step 1, opening a project, login access.
Step 2, system description: The location, the value of statistical life (e.g. Rheinberger, 2011), risk aversion factors, and protection goals for individual risks are defined.
Step 3, hazard analysis and scenario definition: the number and return period of scenarios, the number and probability of exposure situations, the value and vulnerability of exposed objects can be entered manually or imported as XML-File. Additionally, the uncertainty range of vulnerability in reference to a default value can be entered (e.g. ± 20%).
Step 4, damage potential in the investigation area: specific data of the damage potential, e.g. number of inhabitants in a building, frequency of trains etc. can be entered or imported as XML-File.
Step 5, exposure analysis: specific data of the damage potential during the selected exposure situations can be entered manually or imported as XML-File.
Step 6, consequence analysis: the objects can be attributed to intensity areas manually. A GIS-overlay of intensity maps and damage potential can be imported as XML-File. The damage in the scenarios is calculated according to defined vulnerability values for each object. The calculated risk is presented for each objects or as sum integrated over all scenarios (Fig. 2).
Step 7, calculation of individual risk: the individual risk to persons in exposed objects is calculated and compared to the protection goals defined in step 2.
Step 8, definition of mitigation measure: mitigation measures for risk reduction including the amount to be invested, annual maintenance cost, lifespan, and interest rate has to be entered. The annual cost of the measure is calculated.
Step 9, exposure analysis (with mitigation measure): as in step 5, data can be entered manually or imported as XML-File taking the risk reduction into account.
Step 10, consequence analysis (with mitigation measure): as in step 6, objects can be attributed to intensity areas manually or imported from an overlay in GIS.
Step 11, calculation of individual risk (with mitigation measure): the individual risk to persons in exposed objects is calculated taking the risk reducing effect of the mitigation measure into account. The calculated risk is compared to the protection goals defined in step 2.
Step 12, overview risks and benefits: the risk in all considered scenarios without and with measures is depicted. Risks can also be presented considering a defined uncertainty range.

All results, assumptions and calculation parameters can be exported as pdf-File or as XML-File.

CONCLUSION

The capabilities of EconoMe-Develop, such as adapting scenarios, intensity classes and calculation factors to specific requirements, enables engineers to conduct risk assessments and benefit-cost-analysis for all gravitational (e.g. snow avalanches), meteorological (e.g. storm) or seismic hazards (e.g. earthquake) within reasonable time. A useful feature is the ability to import data from GIS such as vulnerability data for specific objects which can be overlain onto intensity and damage potential maps. In addition to the flexibility of EconoMe-Develop, it includes default values for avalanches, floods, debris flows, rock falls and rock avalanches, sponteneous and permanent landslides to facilitate the rapid calculation of risk. These standard values are the same as in EconoMe, because they are linked to a common database.

Alongside EconoMe and EconoMe-Develop there are two additional applications which fit into the EconoMe framework. Econo–Me-Railway was specifically designed for risk assessment and benefit-cost-analyses along railways (Bründl et al., 2012). The second tool, based on the method developed by Utelli et al. (2012), is RoadRisk, designed for risk assessments along highways in Switzerland (FEDRO, 2012). RoadRisk is currently used by the Federal Office for Roads (FEDRO) to obtain an overview of natural hazard risks along Swiss highways.

In the last years significant progress in the development of tools for risk assessment has been achieved. However, we still experience that risk based decision making is in its infancy in many institutions. Along with further improvements to the precision of intensity maps and appropriate vulnerability functions, communicating the benefits of risk based decision making will be a key issue in future. Easy to use calculation tools with sophisticated visualisation may assist in this respect and might contribute to improved decision making.

— Rock fall, -

Activated scenarios

Action	Title	Probability of occurrence	prA	Intensity map	State
+	sc 1	1	0.005		✓
+	sc 30	30	0.01		✓
+	sc100	100	0.03		✓
+	sc300	300	0.05		✓

— Overview consequence analysis, -

— Exposition week days (71 %)

Summary damage exposition week days

Category	sc 1	sc 30	sc100	sc300
Buildings	0 CHF	0 CHF	0 CHF	0 CHF
Special objects	0 CHF	0 CHF	0 CHF	0 CHF
Road traffic	0 CHF	0 CHF	0 CHF	0 CHF
Conduits	0 CHF	0 CHF	0 CHF	0 CHF
Mechanical ropeway	0 CHF	0 CHF	0 CHF	0 CHF
Agriculture, forest and recreation area	0 CHF	0 CHF	0 CHF	0 CHF
Rail traffic	219 976 CHF	267 362 CHF	397 086 CHF	654 928 CHF
Special objects railway	0 CHF	0 CHF	0 CHF	0 CHF
People	2 680 958 CHF	2 738 160 CHF	2 868 473 CHF	3 209 700 CHF
Damage total without indirect damages	**2 900 930 CHF**	**3 005 520 CHF**	**3 265 560 CHF**	**3 864 630 CHF**
indirect damages	0 CHF	0 CHF	0 CHF	0 CHF
Damage total with indirect damages	**2 900 930 CHF**	**3 005 520 CHF**	**3 265 560 CHF**	**3 864 630 CHF**
Damage to people	**0.357461 Tf**	**0.365088 Tf**	**0.382463 Tf**	**0.42796 Tf**

Figure 2: Example of the result in step 6 of EconoMe-Develop.

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