Evaluating the Effectiveness and the Efficiency of Mitigation Measures against Natural Hazards

Michael Bründl[1]; Reto Baumann[2]; André Burkard[3]; Fabian Dolf[4]; André Gauderon[4]; Eva Gertsch[2]; Peter Gutwein[5]; Bernhard Krummenacher[4]; Bernard Loup[2]; Adrian Schertenleib[2]; Nicole Oggier[3]; Linda Zaugg-Ettlin[6]

ABSTRACT

The Federal Office for the Environment in Switzerland (FOEN) introduced EconoMe in 2008 to compare and prioritize mitigation projects against natural hazards. Mitigation projects have to be assessed regarding their effectiveness and economic efficiency with EconoMe in order to apply for financial subsidies. Experiences and user comments from practitioners have led to continuous improvement and the introduction of additional modules. As such, EconoMe-Light was introduced in 2015 for assessing projects with low investment costs and for a first, rapid estimation of the benefit-cost-ratio of a mitigation project. Analyses of 104 projects show that annual risk reduction of most projects exceeds the annual mitigation cost of mitigation measures by a factor two. The optimization of the effectiveness and the efficiency of mitigation measures is illustrated by the case study Rubi-/Chienbach in the Canton of Lucerne. In the next years, the performance and the data basis for risk calculations such as vulnerability and lethality curves will be improved and further tests on the robustness of the system for decision-making will be conducted.

KEYWORDS

risk assessment; Risk concept; Cost-Benefit-Analysis; Optimization; Decision-Making

INTRODUCTION

In 2008, the Federal Office for the Environment (FOEN) introduced the Online-Tool EconoMe (hereafter EconoMe) for a comparable evaluation of the effectiveness and the economic efficiency of mitigation measures against gravitational natural hazards. The legal background was a change of the subsidization practice, which requires that mitigation projects submitted to FOEN have to be assessed with comparable criteria of economic efficiency all over Switzerland. EconoMe is based on the general risk concept for natural hazards (Bründl, 2009; Bründl et al., 2009; Tobler and Krummenacher, 2013) and the up-to-date version 4.0 (release in April 2016) is available as Online and Offline-Version. It guides the user step-by-step through a complete risk assessment to compare the calculated risk with protection goals in order to check whether protection measures are needed (Dolf et

1 WSL-Institute for Snow and Avalanche Research SLF, Davos Dorf, SWITZERLAND, bruendl@slf.ch
2 Federal Office for the Environment
3 wasser/schnee/lawinen. Ingenieurbüro Burkard AG
4 GEOTEST AG
5 Gutwein IT-Service
6 WSL Institute for Snow and Avalanche Research SLF

al., 2014) and finally through the evaluation of an analyzed mitigation project by its benefit-cost-ratio (Fig. 1; Bründl, 2009). EconoMe is well established with cantonal authorities and private engineering companies and additional tools with specific purposes were integrated in the EconoMe software platform during the last years (Bründl et al., 2012; Bründl, 2012). Recently, the overall framework of EconoMe served as a basis for the development of Prevent-Building, a tool to evaluate the efficiency of local structural protection measures (Bründl and Ettlin, 2014). In the following sections, we present recent developments of EconoMe by the example of EconoMe-Light before we show experiences gained with EconoMe in the last years and benefits of this tool with a case study. We conclude with an outlook on future developments.

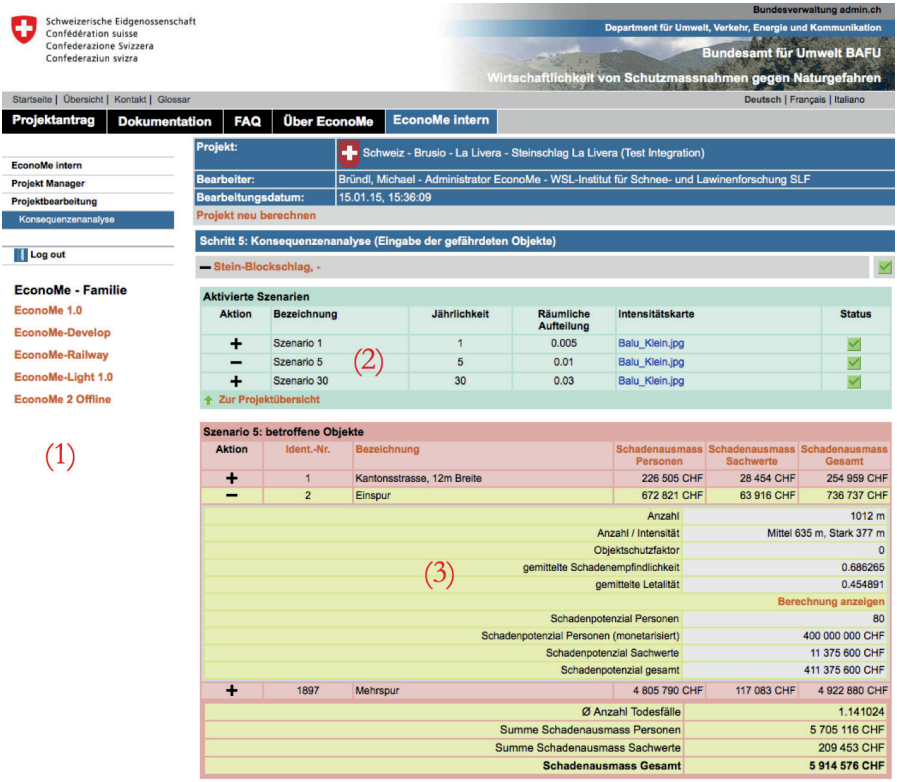

Figure 1: Screenshot EconoMe 3.0 (release version 4.0 in April 2016) showing the working step "consequence analysis". On the left side, links to other tools of the "EconoMe-Family" are shown (1); in this step, the results of considered scenarios could be analyzed in detail (2), showing all parameters of a calculation (3). Source: www.econome.admin.ch.

ECONOME-LIGHT – EXAMPLE OF RECENT DEVELOPMENTS IN ECONOME

The application of EconoMe requires a sound analysis of the local hazard situation using intensity maps for all selected scenarios and an assessment of objects at risk regarding location, type and value. Damage susceptibility values for all categories of objects at risk are integrated as average values in the software (Bründl, 2009; Bründl et al., 2009). Comments of practitioners indicate that the effort for a full benefit-cost-analysis with EconoMe is not always appropriate for situations with a low damage potential and low mitigation costs; thus, practitioners asked for a simple tool for a quick assessment. In response to this, the tool EconoMe-Light was developed; it allows a rapid, simplified risk analysis and a simplified benefit-cost-estimation for a given risk situation following the steps (Fig. 2):

- selecting the hazard process (e.g. debris flow); denoting the mitigation measure and its annual costs;
- selecting one or several hazard scenarios with return periods of 30-, 100-, 300-years and/or two scenarios with adjustable return periods;
- selecting categories (e.g. building) and types (e.g. residential house) for objects at risk;
- attributing the number of objects at risk to an intensity class in all selected scenarios without and with consideration of mitigation measures;
- interpretation of results: collective (societal) and individual risk to persons is calculated automatically; a benefit-cost-ratio greater than one indicates that the selected mitigation measure might provide an economically efficient solution; results can be either exported as XML-File or printed as pdf-document.

EconoMe-Light was developed as a tool for a first, rough estimation and not for proofing the validity of subsidy payments. Basics like standard values of objects adapted for Switzerland (e.g. 650'000 CHF for a one-family residential building) or damage susceptibility values are identical to those in EconoMe. First experiences of practitioners indicate that EconoMe-Light is applied either for small projects with low damage potential and low costs of mitigation measure or as a first hint whether a detailed benefit-cost-analysis with EconoMe is justified. EconoMe-Light is available as Online- (with Internet access) or Offline-Tool (no Internet access). Registered EconoMe users have access to the tool since April 2015 via the EconoMe-Platform (www.econome.admin.ch).

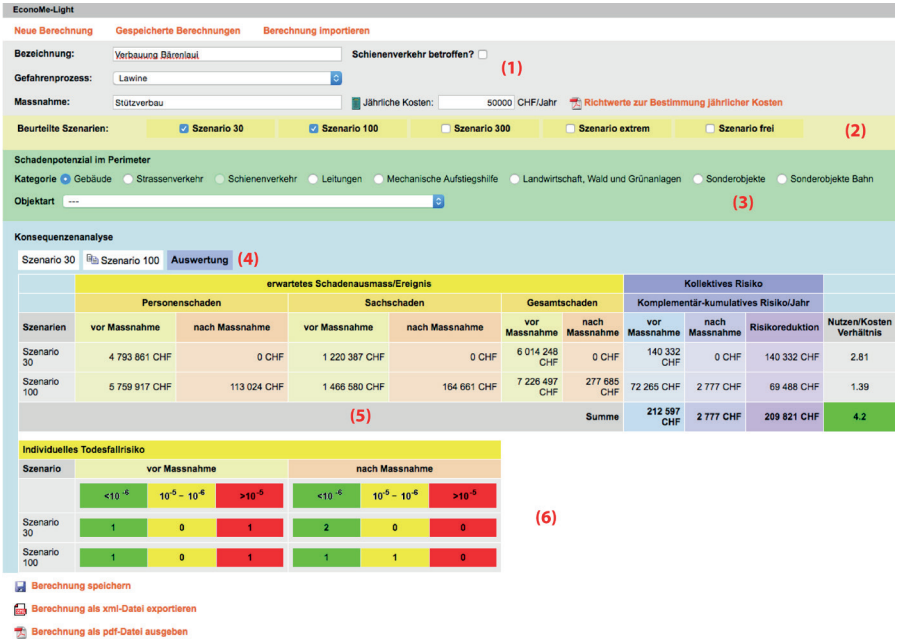

Figure 2: Screenshot of an assessment with EconoMe-Light. (1) input of description, process type, mitigation measure and annual costs; (2) definition of scenarios; (3) definition of objects at risk; (4) selection of scenarios for consequence analysis; (5) results; (6) individual risk to persons. Source: www.econome-admin.ch.

EXPERIENCES AND BENEFIT OF ECONOME-TOOLS

For FOEN, EconoMe has become an indispensable tool in everyday operations concerning project steering and financing. Additionally to judging a project's general cost-effectiveness, various alternatives of protection measures can be compared to each other, which improves decision-making. Moreover, EconoMe allows calculating separately the risks and benefits for each stakeholder in a project and each process area and thereby cost-splitting among these stakeholders. Finally, EconoMe supports the FOEN in an efficient, transparent use of subsidies in context of technical protection measures against natural hazards.

Communities and cantons which apply for subsidies for mitigation projects from the federal state (i.e. the FOEN as responsible authority) are required to analyze the effectiveness and the economic efficiency of measures using EconoMe. In a recent study, FOEN analyzed projects, which received financial support according to Swiss legal regulations (i.e. they were decreed), as is the Forestry Act (in German Waldgesetz, FA hereafter) and the Hydraulic Engineering Act (in German Wasserbaugesetz, HEA hereafter) for the years 2011-2013. Projects subsidized by FA include measures against avalanches, rock fall, and landslides; measures against hydrological driven processes like floods and debris flow are subsidized according to the HEA. In total, 104 projects were decreed and analysed with EconoMe, as of which 65 projects according to the HEA and 39 projects according to the FA.

Table 1 shows, that 75% of the federal subsidies are invested in projects with a benefit-cost-factor higher than 1.3 and 50% in projects with a benefit-cost-factor of at least 2.1. The mean value of the benefit-cost-factors is 3.6. The benefit-cost-factors of FA-projects are slightly higher, because these projects reduce more risks to persons, which are monetized with 5 million CHF (app. 4.6 million Euro) per averted fatality (Rheinberger, 2011; Leiter et al., 2013).

Table 1: Benefit-Cost-Factors of mitigation projects decreed by FOEN in the years 2011-2013.

benefit-cost-ratio	Projects decreed according to Hydraulic Engineering Act (HEA)	Projects decreed according to Forestry Act (FA)	Projects decreed according to HEA and FA
mean	3.3	4.1	3.6
25% quantile	1.3	1.4	1.3
median	1.9	2.4	2.1
75% quantile	3.3	4.0	3.7

Figure 3 shows the distribution of classified benefit-cost-ratios and the sum of investment costs. It can be seen that:

- investment costs for projects subsidized according to HEA are in average higher than those subsidized by FA;
- investment costs are highest for projects with a benefit-cost-factor between 1 and 2; this distribution of investment costs also correlates to the number of projects (not shown in the figure);
- the range of benefit-cost-factors is high (minimum class 0.5 – 1, maximum class > 15);
- projects with benefit-cost-factors lower than one were also decreed, as a result of a weighting of the social, political or ecological interests of the public.

CASE STUDY RUBI-/CHIENBACH

With EconoMe it is possible, to optimize a protection project during the planning process in order to achieve a better cost-effectiveness of a protection project, which can be illustrated with the flood protection project Rubi-/Chienbach in the community of Weggis, Canton Lucerne. After the flood in 2005, a set of different technical protection measures including a retention basin, dikes, a flood bypass channel as well as additional technical measures for managing the over load case was planned. During the participatory planning process with the community of Weggis, the Canton of Lucerne and FOEN, a detailed cost-effectiveness study for each part of the protection concept was conducted with EconoMe. It showed that the combination of a retention basin, dikes and a flood bypass channel with investment costs of CHF 6'000'000 would reduce risk by 96%, resulting in a benefit-cost factor of 4.9. The study also showed impressively that the additionally planned measures to manage over load case with costs of CHF 4'500'000 would reduce the risk by only additional 1%, resulting in a total

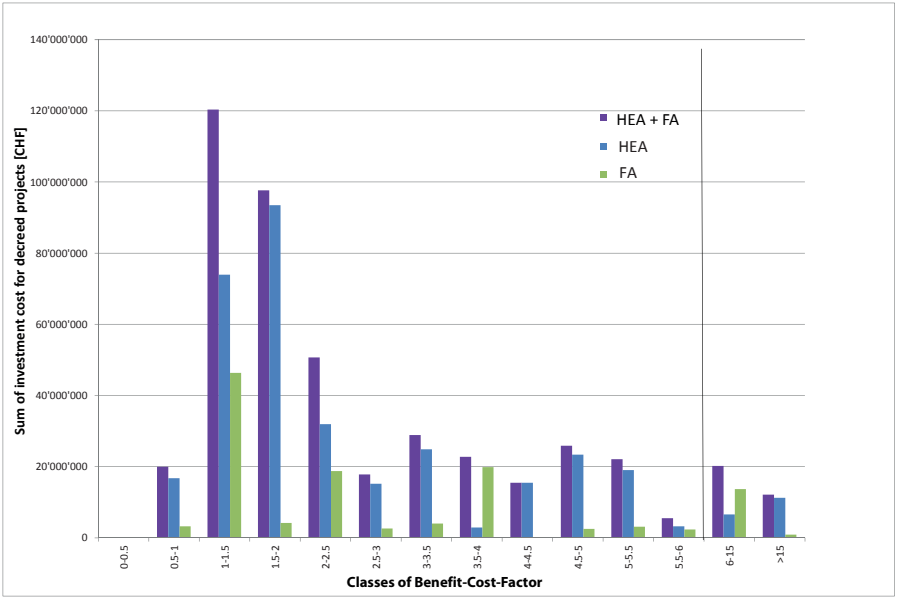

Figure 3: Distribution of sum of investment costs for decreed projects in 2011-2013 in classes of benefit-cost-factors. Projects with a benefit-cost-factor between 1 and 2 show the highest sum of investment costs. The range of benefit-cost-factors lies between 0.5 and larger than 15. The vertical line marks a change of the class range.

risk reduction of 97%. Consequently, the community of Weggis decided to renounce these additional, non cost-effective technical measures. Instead, remaining risks were planned to be reduced with an early warning system and a professional emergency planning. In summary, this case study shows that EconoMe can assist planners in financially optimizing a whole project in the sense of cost-effectiveness, for the community, the Canton Lucerne and FOEN. However, cost-effectiveness is not the only element in the assessment of appropriate, sustainable and effective mitigation projects. Other criteria, like incidental costs, ecological worth, other superior interests and the acceptance by the involved population and authorities in charge are also decisive for the realization of mitigation projects. Therefore, every project has to be assessed individually by considering all influencing factors.

CONCLUSIONS AND OUTLOOK

Since its introduction in 2008, EconoMe served as a tool for prioritizing mitigation projects against gravitational natural hazards by benefit-cost criteria. An analysis of 104 projects decreed in 2011-2013 revealed that reduced annual risks overpass annual mitigation costs. The largest investments are made with projects with a benefit-cost-factor ranging between 1 and 2; overall, the benefit-cost-factor varies from 0.5 to larger than 15 with at least 50% of the projects exceeding 2.1.

In spring 2015, EconoMe 3.0 was released and introduced to practitioners in a workshop. In this workshop, EconoMe-Light was introduced for a simplified analysis of mitigation measures. Experiences over the last years have shown that regular knowledge exchange with practitioners in workshops generates valuable feedback helping to streamline the tool to users' needs and thereby strengthens the commitment of users. We recommend to take the continuous maintenance of a tool and the education and exchange with users into account before the development of such a tool is considered.
In 2016, version 4.0 was introduced, with enhancements in the performance and the user interface. However, a key issue in the next years will remain the improvement of the data basis for risk calculations such as vulnerability and lethality curves and further tests on the robustness of the system for decision-making.

REFERENCES

- Bründl M. (Ed.) (2009). Risikokonzept für Naturgefahren. Einzelprojekt A1.1: Leitfaden. Nationale Plattform Naturgefahren PLANAT, Bern: 420 p.
- Bründl M., Romang H.E., Bischof N., Rheinberger C.M. (2009). The risk concept and its application in natural hazard risk management in Switzerland. Nat. Hazards Earth Syst. Sci., 9(3): 801-813.
- Bründl M., Winkler C., Baumann R. (2012). "EconoMe-Railway". A new calculation method and tool for comparing the effectiveness and the cost-efficiency of protective measures along railways. In: G. Koboltschnig J., Hübl J., Braun (eds), 12th Congress INTERPRAEVENT. International Research Society INTERPRAEVENT, Grenoble: 933-943.
- Bründl M. (2012). EconoMe-Develop – a software tool for assessing natural hazard risk and economic optimisation of mitigation measures, Proceedings International Snow Science Workshop "a merging of theory and practice". ISSW, Anchorage, Alaska: 639-643.
- Bründl M., Ettlin L. (2014). Assessing the Economic Efficiency of Local Structural Protection Measures – Prevent-Building – A Tool for Building Insurances. In: M. Fujita et al. (Editors), Interpraevent 2014. International Research Society Interpraevent, Nara, Japan.
- Dolf F., Krummenacher B., Aller D., Kuhn B., Gauderon A., Schwab S. (2014). Risiko-analyse für ein Sihl-Hochwasser in der Stadt Zürich. Wasser Energie Luft 105(4): 23-27.
- Leiter A. M., Rheinberger C., Bründl, M. (2013). Zur Bewertung von Personenschäden - Grundsätze, Methoden und Anwendungen. Zeitschrift für Wildbach-, Lawinen-, Erosions- und Steinschlagschutz 77(172): 136-144.
- Rheinberger C. M. (2011). A Mixed Logit Approach to Study Preferences for Safety on Alpine Roads. Environmental Resource Economics 49(1): 121-146.
- Tobler D., Krummenacher B. (2013). Risk concept Switzerland hazard analysis, risk evaluation and protection measures. In: C. Margottini et al. (eds), The second world landslide forum, Rome 2011 (WLFF2-2011-0287), Landslide Science and Practice, Vol.7, DOI 10 1007/978-3-642-31313-4_2, Springer-Verlag, Berlin, Heidelberg.