Assessing the Economic Efficiency of Local Structural Protection Measures - Prevent-Building – A Tool for Building Insurances

Michael BRÜNDL[1*] and Linda Ettlin[1]

[1] WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland
*Corresponding author. E-mail: bruendl@slf.ch

In recent years cantonal building insurances in Switzerland have been confronted with increasing damage to buildings because of natural hazards. Due to their role as a public monopoly insurance, they are obliged to cover damage, which makes prevention a key issue for them. Local protection measures can be a very effective and efficient way to prevent damage to buildings. To support decision-making on the realization of local protection measures, the foundation for prevention of the cantonal building insurances has initiated the development of a method and a software tool to evaluate the economic efficiency of protection measures. We present this methodology and the software and illustrate the theory with an example. We conclude that the software Prevent-Building will support experts at building insurances in convincing building owners that prevention of damage is in their own interest and that mitigation measures pay off.

Key words: building damage, risk assessment, building insurance, local structural protection measures, benefit-cost-ratio

1. INTRODUCTION

Over the last years, avalanches, debris flows, floods, rock fall, and landslides have caused damage of several billion Euros in Switzerland [*Hilker et al.,* 2009] and in other Alpine countries. Next to prevention measures, intervention and recovery from a disaster, risk transfer to insurances plays an important part in the risk management of natural hazards. However, not in all countries insurance against damage caused by natural hazards is available at economic premiums [*Schwarze and Wagner,* 2009]. In Switzerland, in nineteen out of twenty-six cantons – having a certain degree of sovereignty and building the Swiss Confederation – it is mandatory to insure buildings with the cantonal building insurance (CBI) against damage caused by natural hazards. The CBI hold the monopoly in these cantons. In the other seven cantons, buildings have to be insured with private insurers. As a community of solidarity, prevention of damage plays an essential role for the CBI. In many cantons, the CBI is a key player in the risk management of natural hazards. In order to keep insurance premiums low, they contribute to prevention measures such as hazard mapping and information campaigns with the goal to convince building owners to take preventive measures.

Despite these efforts, building insurances in Switzerland have been confronted with increasing damage to buildings over the last years [*Imhof,* 2011]. Values at risk are continuously increasing in many areas and the consequences of climate change will likely change precipitation patterns, thus potentially increasing the probability of damage to buildings by floods [*Min et al.,* 2011*; Pall et al.,* 2011] and other hazards [IPCC, 2012]. Due to these facts the foundation for prevention of the cantonal building insurances has initiated the development of a method and a software tool for the evaluation of the effectiveness and the economic efficiency of local protection measures (LOP). Local protection measures are either permanent structural mitigation measures directly on buildings such as elevated light wells to prevent inundation (**Fig. 1**) or enforced walls which can resist the high pressures caused by snow avalanches. Alternatively, or in addition to these permanent measures, LOP can also be temporary, e.g. removable walls which prevent water entering a building. Investigations by *Holub* *and Hübl* [2008] have shown that LOP can be very effective in reducing damage.

In this paper, we will present the results of the project Prevent-Building. Firstly, we will introduce the methodology for assessing the effectiveness and the economic efficiency of LOP. Secondly, we will present the software tool, which was developed to enable architects, engineers and experts at cantonal building insurances to rapidly evaluate different protection measures. Finally, we end with some conclusions and an outlook.

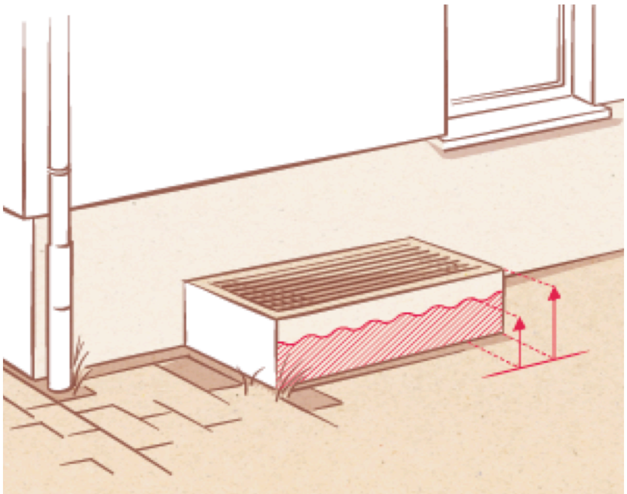

Fig. 1 Elevated light wells can prevent the entrance of water into a building. Source: PLANAT

2. A METHOD FOR THE ASSESSMENT OF EFFECTIVENESS AND ECONOMIC EFFICIENCY

The following method is based on the general risk concept, which has been suggested as the key concept for assessing natural hazard risks by several authors in the last decades and years [*e.g. Fell,* 1994*; Wilhelm,* 1997*; Merz,* 2006*; Bründl et al.,* 2009]. The risk concept is frequently used for the evaluation of mitigation measures regarding their effectiveness, which is the risk reducing effect of a measure, also denominated as its benefit. By setting the benefit in relation to the cost of a measure, the benefit-cost-ratio of a mitigation measure can be calculated [*e.g. Fuchs and McAlpin,* 2005].

2.1 Steps in the Prevent-Building Workflow

In order to express the contribution of the methodology and the software tool to the prevention of damage to buildings, the project was named "Prevent-Building". Following the typical workflow during an evaluation of LOP by experts of a cantonal building insurance, the following steps are distinguished (**Fig. 2**):

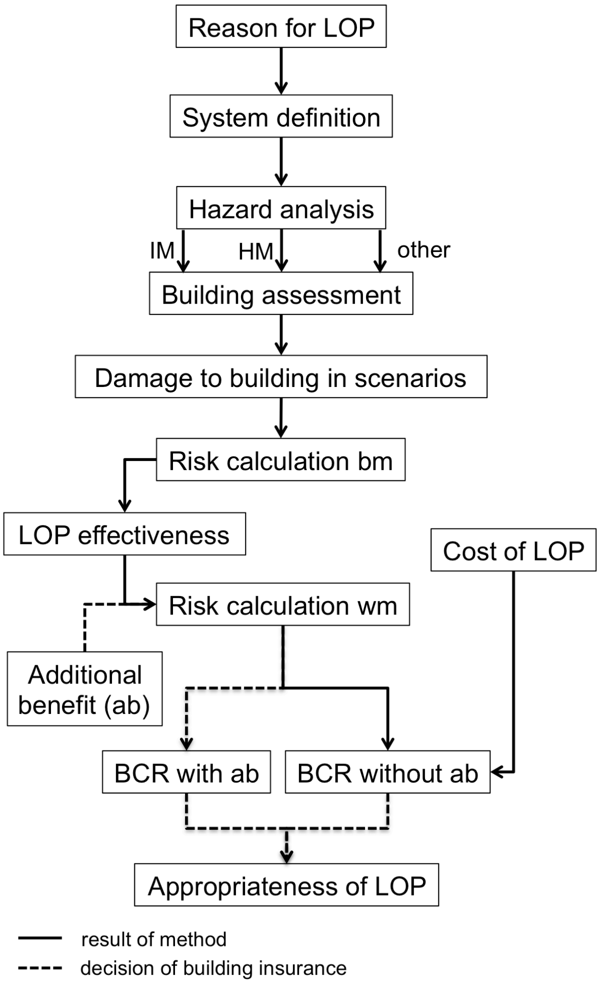

Fig. 2 Workflow for assessing the benefit-cost-ratio of a local structural protection measure. Abbreviations: LOP = local structural protection measure; IM = intensity map; HM = hazard map; bm = before measure; wm = with measure; ab = additional benefit.

(1) System definition: When an LOP is regarded as necessary by a CBI, e.g. because a certain building has been damaged several times, the system to be assessed must first be defined. This includes the identification of the building at risk as well as neighboring buildings, which could be affected by an averted hazard from the building under assessment. At this stage, the expert in charge for assessing the LOP has to check if any other measures protecting the whole area (e.g. dams) are planned. If this is the case, coordination with the involved authorities may be expedient to avoid unnecessary redundancies in protection.

(2) Hazard analysis: The prevailing process endangering the building has to be identified and characterized regarding its frequency and intensity. In the case of gravitational processes, intensity maps for several scenarios are used to consider the varying courses a natural hazard may take at different return periods. If no intensity maps are

available, hazard maps must serve as an alternative. However, according to the Swiss recommendations for hazard mapping [*BFF and SLF,* 1984*; Loat and Petrascheck,* 1997*; Lateltin et al.,* 1997] several intensity maps are summarized in one hazard map, thus the frequency and the intensity of the prevailing scenario can only be roughly estimated. This induces more uncertainties in the final result than when using intensity maps. In the case of hail and wind, regional maps for different intensities and return periods do exist. The hazard map for hail depicts the expected diameter of hailstones at certain return periods. For wind, a map describing the expected wind speed at different return periods is used to identify the correct scenarios at the location of a building. At the end of the hazard analysis, the scenarios must be known upon which the damage assessment is to be conducted.

(3) Building assessment: The type of building and its purpose must be identified and described, focusing on the impact of the natural hazard on the building. In the case of inundation for example, the assets and the use of the main floor and the basement are of importance. Besides the value of the building and the included assets, additional characteristics, functionalities and assets have to be identified, which might suffer damage or loss as a consequence of the hazard (e.g. loss of rent money).

(4) Damage assessment: For each scenario, the damage to building structure and to assets must be estimated. Since the vulnerability value for a certain intensity taken from a vulnerability function does not meet the specific situation for a single building in most cases [*Fuchs at al.,* 2007*; Eckert et al.,* 2012] the damage has to be estimated by a CBI expert. These specialists have the necessary experience to gauge potential damage, since their job consists of estimating damage after a destructive event. Their damage estimation is the basis for the refund of damage costs to building owners.

(5) Calculation of risk before measure: Based on the damage estimated for each scenario, the scenario risks and the overall risk can be calculated. The risks to the building structure and to the assets have to be calculated separately; they are expressed in monetary units (e.g. Euros) per year.

(6) LOP effectiveness: The effectiveness of the LOP has to be determined by the hazard expert in collaboration with a CBI damage expert. Most CBI require that buildings are protected against an event with a 100-, sometimes 300-year return period. Furthermore, it is necessary to judge whether the effectiveness of an LOP is 100% for its whole lifespan or whether declines (see example in section 4.2).

(7) Calculation of risk with measure: By taking the effectiveness of the measure into account, the risk with measure – i.e. the remaining risk after the measure has been realized – can be calculated. According to the protection goals of the CBI, the remaining risk has to be much lower than before the measure.

(8) Cost of measure: In this step, the annual cost of a measure is calculated. It consists of the investment costs, the lifespan of the measure, the annual maintenance costs, the residual value at the end of its lifespan and the interest rate. The annual costs are calculated with the annuity method.

(9) Benefit-Cost-Ratio: The difference between the risk before measure and the risk with measure yields the risk reduction, which is the benefit of the measure. If the annual benefit is divided by the annual cost of the measure, we obtain the benefit-cost-ratio (BCR), which is above one for economically viable measures. The BCR can be calculated separately for the benefit to the building structure alone and for the benefit to the building structure including the additional endangered assets (additional benefit of the measure). However, BCR around one should be interpreted with care due the uncertainties of the damage estimation.

(10) Appropriateness of measure: The BCR is only one criterion indicating whether an LOP should be realized. There are other criteria like aesthetics and financial capabilities of the building owner, which should also be considered by the CBI.

2.2 Calculation of annual risk

As described in steps 5 and 7 of section 2.1, the total risk before and with measure is expressed as an annual risk. In order to calculate the total risk, the risks of all scenarios are added together. As an example, assume that damage due to an inundation starts at a return period of T = 20 years and that three scenarios with return periods of T = 30, 100, and 300 years are taken into account. For the given example, the total risk is calculated with:

$$R_{j-1} = \left(P_{j-1} - P_j\right) \cdot \frac{A_j}{2} \quad (1)$$

$$R_j = \left(P_j - P_{j+1}\right) \cdot \frac{A_j + A_{j+1}}{2} \quad (2)$$

$$R_{j+1} = \left(P_{j+1} - P_{j+2}\right) \cdot \frac{A_{j+1} + A_{j+2}}{2} \quad (3)$$

…

$$R_{j+n} = P_{j+n} \cdot A_{j+n} \quad (4)$$

with R_{j-1} denoting the risk between the start of the damage (return period T = 20 years; P_{j-1} = 1/20) and the first scenario (T = 30 years; P_j = 1/30), R_j is the risk of the first scenario (T = 30 years), R_{j+1} is the risk of the second scenario (T = 100 years; P_{j+1} = 1/100) and so forth, and R_{j+n} is the risk of the last scenario (T = 300 years; P_{j+n} = 1/300); correspondingly, A_j denotes the expected damage for the first scenario, A_{j+1} the damage for the second scenario and so forth, and A_{j+n} for the last scenario.

This method is in line with algorithms implemented in other risk assessment tools used by Swiss authorities, like EconoMe [*FOEN,* 2014] or EconoMe-Railway [*Bründl et al.,* 2012]. However, the risk calculation method applied in Prevent-Building has been slightly adapted to better account for the transition of the damage between the scenarios as well as the contribution of the risk between the start of the damage (before the first scenario) and the damage of the first scenario to the overall risk.

2.3 Calculation of annual cost and benefit-cost-ratio

For the calculation of a measure's annual costs C the investment costs I_0, the lifespan of the measure n, the annual maintenance costs C_m, the measure's residual value L_n at the end of its lifespan and the interest rate r have to be known. According to the annuity method, the annual cost is calculated with:

$$C = \left(I_0 \cdot \frac{(1+r)^n \cdot r}{(1+r)^n - 1}\right) + C_m - \left(\frac{L_n \cdot r}{(1+r)^n - 1}\right) \quad (5)$$

where the first term in brackets denotes the investment costs I_0 times the annuity factor, the second term C_m represents the annual maintenance costs, and the third term shows the measure's residual value L_n at the end of its lifespan n, and r the interest rate.

The benefit-cost-ratio is calculated as the difference of risk before measure (R_{bm}) and risk with measure (R_{wm}) in relation to the annual cost C of the measure:

$$BCR = \frac{R_{bm} - R_{wm}}{C} \quad (6)$$

3. THE SOFTWARE TOOL 'PREVENT-BUILDING'

3.1 General setup

The software 'Prevent-Building' was developed as a password-protected Online-tool with SSL encrypted data transfer to enable the secure access for all CBI. A centralized Online-tool simplifies the maintenance of the software regarding updates and data backup. It is available in German and French, languages can easily be changed by the user. The software's methodology is described in a pdf-file, available in the documentation area. The login data is provided by CBI administrators upon the request from persons who are in charge of evaluating the LOP of buildings.

The workflow in the software follows the steps described in Fig. 2 and in section 2.1.

3.2 Example of an assessment

In the following a typical example of the assessment of the benefit-cost-ratio of an LOP is presented. For reasons of data protection this example is not a real example but shows a typical application of the tool.

The first step consists of initializing a new *assessment* and giving it a name. In the second step, *hazard analysis,* the prevailing natural hazard, the start of the damage and the scenarios are defined. In this example, we consider a situation where the building starts suffering damage from inundation at a return period of T = 20 years. The selected scenarios have return periods of T = 30 and T = 100 years (**Fig. 3**).

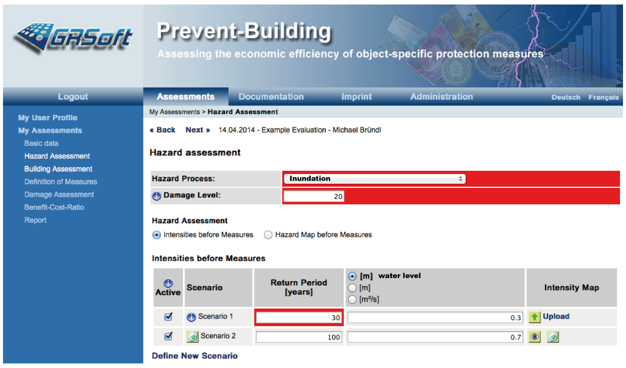

Fig. 3 Screenshot of the step hazard analysis.

In the step *building description*, information on the type of building, its purpose, value, and location etc. are recorded. Additional assets, which are endangered by the natural hazard but are not insured by a CBI can be described. In this example a one-family residential building with a value of

850’000 CHF and additional assets of 350’000 CHF including a flower garden is endangered.

In the following step *identification of measures*, the type of measure and its effect on the natural hazard are described and the annual costs are calculated. The user has access to a pdf-file containing the hazard specific chapters of the guideline for local protection measures against gravitational (e.g. snow avalanches, debris flows etc.) or meteorological driven processes (e.g. hail and storm). These guidelines illustrate various LOP and give instructions on how to implement them in practice [*Egli, 2005; 2007*]. For this example, elevated light wells (**Fig. 1**) are proposed as a measure to protect the building against an inundation with a return period of 100-years (**Fig. 4**).

The investment sum for this measure is 20’000 CHF, the lifespan is 50 years, the annual maintenance costs (for cleaning) is assumed to be 200 CHF per year, the residual value is 1’000 CHF and the interest rate is 1.5%. The annual costs amount to 757 CHF per year (**Fig. 4**).

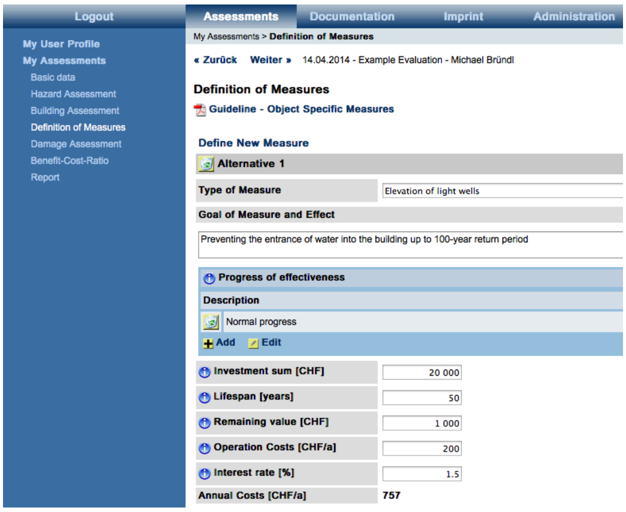

Fig. 4: Screenshot of the step *identification of measures*. In this example elevated light wells are proposed as a measure to prevent water entering the building.

The next step is *damage assessment*. In the example, damage for the 100-year scenario are listed in detail (**Fig. 5**) and can be separated in (1) damage to the structure and to the technical equipment of the building (indicated by ‘G’ in **Fig. 5**), which are insured by the CBI and (2), additional damages to assets which are not insured by the CBI (indicated by the letter ‘Z’). The protection of these assets represents an additional benefit of the LOP and can be a further argument for the building owner to realize the measure.

In **Fig. 5**, additional damage to assets is given by the damage to the wellness area, to the flower garden and to the furniture. The total risk for all scenarios is 3’321 CHF per year. By including the additional assets, the total risk amounts to 5’288 CHF per year.

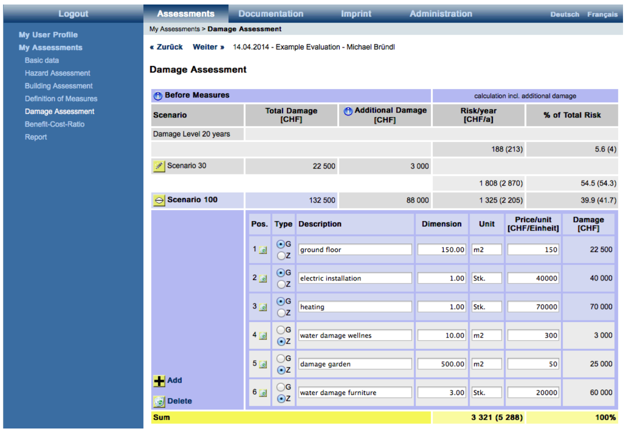

Fig. 5 Screenshot of the step *damage assessment*. The estimated damage can be entered for each scenario. Here, potential damage for the 100-year scenario before measures is listed in detail. The total risk for all scenarios amounts to 3’321 CHF. By including the additional assets, the total risk amounts to 5’288 CHF per year (in brackets).

The final results are depicted in the step *benefit-cost-ratio*. Here, the risk before measures without and with additional assets, the risk reduction, and the benefit-cost-ratio are calculated and displayed by the tool. All results are also summarized in pdf-files, which can be printed as a documentation of an assessment (**Fig. 6**).

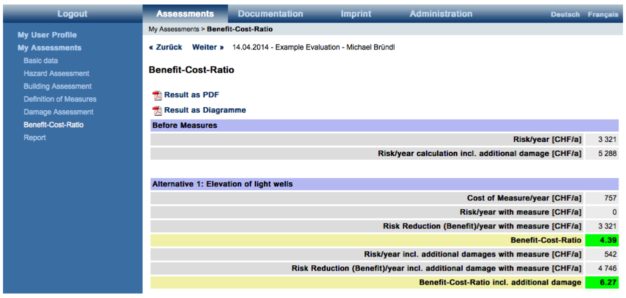

Fig. 6 Screenshot of the step *benefit-cost-ratio*. A benefit-cost-ratio greater one indicated that the measure is economically viable.

4. CONCLUSIONS

Analysis of insurance data reveals that damage caused by gravitational (e.g. snow avalanches, debris flows etc.) and meteorological driven natural hazards has increased in Switzerland [*Imhof,* 2011] and worldwide over the last years and decades. For cantonal building insurances (CBI), which have the monopoly for building insurances in nineteen out of twenty-six cantons in Switzerland and which are obliged to cover damage costs, the prevention of damages is of pivotal importance in order to keep premiums low. For a CBI it is important that they can convince building owners to take preventive measures. The economic benefit of LOP can be a key argument in this dialogue. The proposed method and the software tool will support CBI in this dialogue with building owners since it allows a quick presentation of the economic benefits of an LOP. The method is well documented and is in line with nationally and internationally accepted approaches for evaluating the economic benefit of mitigation measures against natural hazards. The economic evaluation of natural hazard mitigation measures (e.g. snow supporting structures or dams) using the software EconoMe has been a standard procedure at cantonal and federal authorities in Switzerland since 2008 [*FOEN,* 2014]. Since EconoMe and Prevent-Building are based on the same concept and are very similar in terms of calculation algorithms, the results can be compared to each other. This is important in cases where a choice must be made between local protection measures and protection measures for an entire area.

Prevent-Building has been available for professionals since mid-2014. First tests indicated that experts at CBI appreciate the tool, allowing them an easy and rapid evaluation of the economic benefit of measures. However, it also became clear that the economic efficiency is only one criterion - the realization of LOP has to be carefully analyzed in terms of other criteria as well, such as for example the consequences a measure may have on neighboring buildings (e.g. by channeling water in a certain direction), aesthetics, financial strength of the building owner, usability of a building (e.g. access for handicapped residents), and so on. We think that Prevent-Building can contribute to a well-balanced decision on the realization of local protection measures.

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