Good practice

Cost-benefit analysis for flood and landslide safety in the Romagna rivers basin (Italy)

During the 10th MiSRaR seminar the basin authority of the Romagna Rivers in corporation with the province of Forlì-Cesena presented the experiences with cost-benefit analysis (CBA) for safety measures. In 2001 a CBA was made for the looming flood risk in Ravenna. At current an experimental CBA is developed for the slow flow landslide risk in Santa Sofia.

Flood risk Ravenna

In the Romagna city of Ravenna an area of circa 300 hectares is threatened by the flooding risk of the Montone river. The flooding according to current estimations has a probability of once every 300 to 400 years. Within this area some 50.000 people are living. A flood would mean loss of electricity and/or water services for 80.000 people and affect 20.000 commuters. Furthermore various buildings with cultural heritage could be damaged. In order to assess the advantages of specific risk mitigation measures a cost-benefit analysis was made in 2001.

Risk mitigation measures

The identified best solution to prevent a flood was a combination of two main structural measures. Firstly the acquisition of extra space for the river channel over a stretch of 4 kilometers downstream of the threatened area. This required the shifting of the existing embankment by demolition and complete rebuilding. By this means the capacity of the river would be increased in order to prevent high waters upstream. The second measure was to place waterproof screens in the actual threatened area.

Cost-benefit analysis

The total costs for the realization of the proposed measures were estimated at 12 million Euros. The structural maintenance was estimated at 100.000 Euros every 10 years. On the other hand the total costs of flood damage were calculated at 405 million Euros. Calculating with a probability of a flood once every 300 years and taking into account an estimated discount rate

			discount rate =	0,005	
	cost and benefit plan		*Discounting*		
Years	*Cost*	*Benefit*	*Cost*	*Benefit*	*net benefit*
1	€ 12.000.000,00	€ 0,00	-€ 11.940.298,51	€ 0,00	-€ 11.940.298,51
10	€ 100.000,00	€ 0,00	-€ 95.134,79	€ 0,00	-€ 95.134,79
20	€ 100.000,00	€ 0,00	-€ 90.506,29	€ 0,00	-€ 90.506,29
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
270	€ 100.000,00	€ 0,00	-€ 26.011,38	€ 0,00	-€ 26.011,38
280	€ 100.000,00	€ 0,00	-€ 24.745,87	€ 0,00	-€ 24.745,87
290	€ 100.000,00	€ 0,00	-€ 23.541,93	€ 0,00	-€ 23.541,93
300	€ 100.000,00	€ 405.000.000,00	-€ 22.396,57	€ 90.706.100,39	€ 90.683.703,82
				total net benefit	€ 77.248.335,48

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the total net benefit was calculated at 77 million Euros (see table).

Landslide risk Santa Sofia

Within the province of Forlì-Cesena the land slide risk in the Apennine mountains area is substantial. Different kinds of landslides can occur:

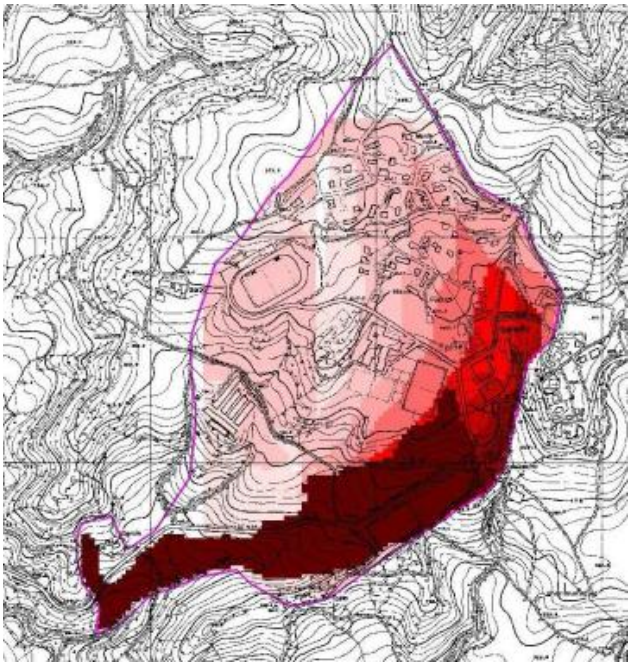
- shallow landslide
- rockslide
- rockfall
- slow flow earth
- complex l andslide

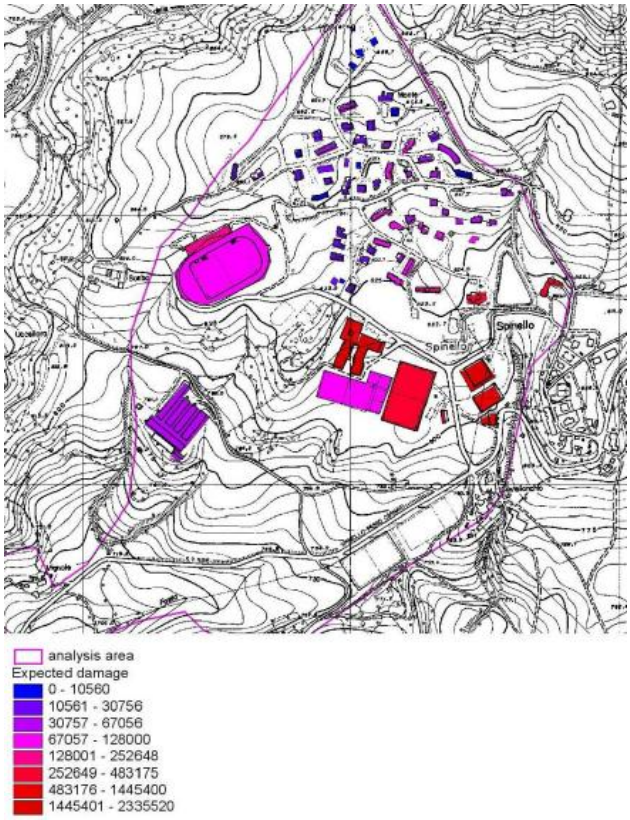
Every year, especially in periods with heavy rainfall and/or melting snow, dozens of landslides occur, from small ones to very big ones. In 2010 for example at Corniolo a massive slow flow landslide occurred of more than one kilometer in length and 220 meter in width. The main road and power supply to the village were destroyed and a couple buildings were flooded because the landslide blocked the mountain stream in the valley. Several buildings narrowly escaped complete destruction by the landslide itself.

To be able to make informed policy decisions on the prevention of landslides and/or to minimize the impact of landslides the basin authority is experimenting with methods for risk assessment and cost-benefit analysis.

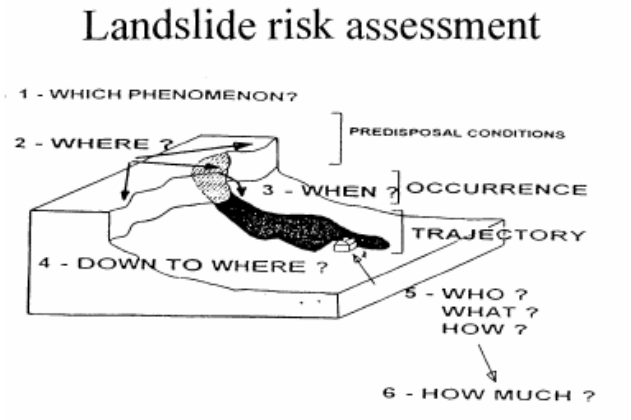
Following the a methodology on risk assessment developed by mr. Uzielli the basin authority is collecting data on the shift of the earth surface in the 'Spinello' area in the municipality of Santa Sofia. The data is collected by permanent scatters (about 20 years) and Synthetic Aperture Radar (SAR) interferometry (about five years). SAR combines signalprocessing techniques with satellite orbit information to produce a high-resolution radar image. Both amplitude and phase information are stored from the returning echoes. Interferogram is a phase difference image of two SAR-images acquired at slightly different positions. When the two images are not taken simultaneously the technique is called repeat-pass interferometry. Interferogram can be converted to a digital elevation model (DEM) with meter accuracy.

The collected monitoring data at Spinello indicate that the land slide slowly is moving towards the nearby sports centre and the village itself. Data indicate a regressive movement of the slow flow earth. The evolution of this landslide could affect houses, buildings and economic activity.
Main question is what the authorities and inhabitants could and should do best.



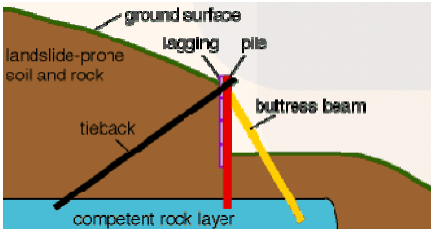


The first step in the specific risk assessment for this location was to determine the spatial differentiation in the probability of the landslide. The probability of increasing slides is after all not the same at every location within the Spinello site. The spatial differentiation is presented in a specific risk map (see figure). The second step in the risk assessment was to analyze the 'elements at risk' and their vulnerability to the landslide, resulting in a forecast of the expected damage in Euros (see figure). The combination of probability and potential damage to the elements at risk lead to a predicted total of 12.7 million Euros within the next 200 years. This outcome of this risk assessment was a direct input for a cost-benefit analysis on the potential mitigation measures.



A possible hypothesis to defend the elements at risk is to implement structural prevention works. In a preliminary project plan the CBA of a bulkhead piling foundation are analyzed. This foundation would constitute of:

- about 130 piles with an average depth of 15 meters;
- about 130 tieback anchors with an average length of 30 meters;
- about 130 sub-horizontal drainages with an average length of 30 linear meters;
- a concrete beam linking the piles.



The total estimated costs of for the realization of this structure were calculated at 1.4 million Euros. The structural maintenance was estimated at 50.000 Euros every 10 years.

The basin authority used the following fundamental economic formula for the CBA:

$\Sigma t(Bt-Ct\pm Et)*(1+r)^{-t}>0$

Legend
Bt = Benefit as a function of time
Ct = Cost as a function of time
Et = Environmental cost or benefit as a function of time
t = Time
r = Rate discount

The outcome of this CBA was negative: there was an expected net cost of 0.7 million Euros. Based upon this CBA the decision was made not to implement structural works. Instead the basin authority decided to issue a mandatory rule for territory management by the municipalities and province. This rule prohibits new buildings in high risk land slide areas and requires new buildings in medium risk areas to be built on piles, with a maximum of 20% more buildings than the current situation.

Lessons learnt
With these CBA's the basin authority learned some valuable lessons:

- The performing of a CBA to make informed decisions requires different kinds of expertise. In these two cases besides the expertise on (hydraulic) engineering, geology and geostatistics, which are traditionally available within the basin authority, in addition also specific economical expertise was needed to perform the actual CBA and discounting.
- The probability of a risk has a very high influence on the outcome of a CBA. It makes quite a difference whether a structural investment into mitigation measures has to be valued against a scenario with a probability of for example once every 10, 100 or 1000 years. The problem is that the probabilistic estimation of risks is in most cases very uncertain. The macro-factors which govern the probability of a risk are significantly uncertain. When this uncertainty cannot be reduced the outcome of a CBA in many cases could go either way: positive or negative.
- A specific problem is the spatio-temporal variability of risks, meaning the probability and impact of risks can be very different over time and for different places. This means a CBA in many cases is only valid for a specific location and timeframe and has to be repeated over and over to be able to make informed decisions for a larger area.
- For the calculation of vulnerability and actual potential damage in Euros in many cases extensive research is needed.
- The probability of events related to the climate is difficult to calculate for a longer period of time, because of global warming. For example floods as well as rain and snow induced landslides are likely to occur more often in future. This means with the ongoing discoveries and insights in global warming the outcome of CBA's on mitigation measures for those related disasters will have to be reevaluated continuously.

The MiSRaR project

The MiSRaR project is about Mitigation of Spatial Relevant Risks in European Regions and Towns. The project is a cooperation between seven partners in six EU member states:

- *the Safety Region South-Holland South, The Netherlands (lead partner)*
- *the city of Tallinn, Estonia*
- *the region of Epirus, Greece*
- *the province of Forlì-Cesena, Italy*
- *the municipality of Aveiro, Portugal*
- *the municipality of Mirandela, Portugal*
- *the Euro Perspectives Foundation (EPF), Bulgaria.*

The goal of the project is to exchange knowledge and experiences on risk mitigation in spatial policies. The project will result in a handbook in which the lessons on the mitigation process are described and the good practices from the partners are presented. The Risk Assessment and Mapping Guidelines for Disaster Management of the European Commission will be implemented in the handbook.

The MiSRaR project is cofinanced by the European Regional Development Fund and made possible by the INTERREG IVC programme.

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