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## Key elements to assess proposals for rockfall risk mitigation in the context of a technical and economic feasibility project – the experience of two alpine italian regions

**Claudia Strada**<sup>1</sup>, Davide Bertolo<sup>2</sup>, Volkmar Mair<sup>1</sup>, and Marco Paganone<sup>2</sup>

<sup>1</sup>Sudtiroler Landesverwaltung - 11.6. Amt für Geologie und Baustoffprüfung. BOZEN, Italy (c.strada@provincia.bz.it)

<sup>2</sup>Geological Survey - Regione Autonoma Valle d'Aosta, Difesa del Suolo, QUART, Italy (d.bertolo@regione.vda.it)

The Valle d'Aosta Region and the Autonomous Province of Bolzano territories include the highest mountain areas of Italy, where most of the communication infrastructures or strategic activities are totally or in part partially exposed to the rockfall hazards.

For this reason, the two administrations have established an operational cooperation in order to compare their procedures and to define the criteria and best practices to prioritize and project the mitigation the rockfall mitigation measures. The result achieved by the work group have inspired a new incoming version of the Italian technical standard UNI 11211 "Rockfall protective measures".

As a part of the rockfall risk assessment of the designing the mitigation measures, it is necessary to assess the actual effectiveness of the alternative mitigation options which have been identified.

The choice whether to mitigate the event intensity or the expected damage, with either structural or non-structural measures, will usually achieve a risk mitigation level, associated to a complimentary residual risk.

Therefore, the project management has to evaluate the degree of hazard and risk mitigation for any given solution. The acceptability of the residual risk and its possible mitigation through organizational measures are to be evaluated as well. A long-term cost/benefit analysis has to be performed, taking also into account the tolerability over time of the handling costs.

The first milestone in the decisional process the definition of the acceptable risk level. As a matter of fact, which is the key criterion supporting the decision to undertake cost-effective investments in mitigation works. For that reason, a preliminary analysis of the in-situ geological conditions should be as complete and detailed as possible. Project managers have to be aware that the zero-option has to be taken in to account as well, in the case the risk level would not be acceptable.

Moreover, it has to be taken into account that the risk evaluation is always site-specific, because the rockfall mitigation projects have to be based on a detailed geological reference

model. Local changes in geological, hydrogeological, morphological and structural conditions, vegetation, vulnerability and exposure of the objects at risk may lead to different hazard and risk conditions even at a local scale. Therefore, a risk assessment analysis is consistent to a single project and can't be directly upscaled to implement, for instance, a municipal land management plan.

Another key point in the decision-making process is the expected damage assessment, which has to include not only the direct damages (e.g.: loss of human lives) but also the indirect damages and their economic and social impacts. As a consequence, in assessing the acceptable risk both the probability of direct and indirect damage and the economic and social benefits derived from its acceptance have to be weighted.

The final result has led to guidelines based on QRA (Quantitative Risk Assessment) method and defining three risk levels: Acceptable, ALARP (As Low As Reasonably Practicable) and Unacceptable, providing to the project managers a rational and objective framework to manage rockfall hazards in Italy.