Nat. Hazards Earth Syst. Sci. Discuss.,
doi:10.5194/nhess-2016-265-AC1, 2016

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "An approach for evaluating the role of protection measures in rock fall hazard zoning based on the Swiss experience" *by* Erika Prina Howald et al.

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Received and published: 13 December 2016

Thank you for your valuable comments to our paper. Please find here below our answers to your comments and suggestions.

1) The idea of an example illustrating the application of the methodology is surely valuable and relevant; we definitely agree it would in principle provide a better insight on the application, step by step. However, an example could not be included in this paper for the following reasons. As specified in the paper (Page 2, lines 25-27), the methodology derived from a rather "specific" study we carried out for one region (Canton of Vaud) in one country (Switzerland). Its main goal was primarily to present a methodological framework, within which many aspects and issues characterising the evaluation of haz-

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ard in presence of protection measures could be structured into steps to be followed by professionals and firms (Page 13, lines 6-16), in order to have a clearer view of the problem and on how to possibly solve it. The approach proved itself interesting to be potentially extended in a broader sense, i.e. at the international level, rather than regional or national, and involving both the practitioners and the research community. Therefore, efforts were focused primarily on extending the methodological framework, at first. At the same time, we are indeed very much interested in going deeper into this work and give more operational and quantitative solutions to solve the most technical aspects of the methodology within this framework we proposed. The application/testing phase of the methodology has actually been started, but its developments are still in the very beginning, including an appropriate calibration of the penalty factors (which has still to be done, see Page 13, lines 19-26), a sufficient number of test sites to be defined for validating the methodology, as well as a suitable method for using the reduced capacity of the protection to estimate a residual hazard (energy-return period couple on the intensity-frequency diagram). This is why it was chosen to focus mainly on the general framework of the methodology at this stage, rather than showing an example which would not have not been fully relevant and meaningful, due to too uncertain values assigned to the penalty coefficients, as well as too rough estimates of the residual hazard as a function of the reduced capacity. The straightforward applicability of the methodology mentioned in the paper referred for the moment to the application of the methodology based on an intensity-frequency matrix different than the Swiss, which is indeed possible without any modification of the approach. In other words, the computations to be done to estimate residual hazard are not based on the intensity-frequency diagram used (the diagram is used only to check which new hazard level is obtained after these computations).

2) For already existing protections: the use of Scenario 0 is justified by the fact that environmental conditions and/or even norms and directives concerning the design of protection measures can change in time, even within the life span of a protection. If this is the case, when the state of the measure is evaluated after a certain time it was in-

stalled, the potential influence of the factors considered in Scenario 0 should be taken into account (e.g.: some recommendations/norms might have partially changed after, for instance, a specific event, and because of this some technical specifications of the measure might require to be adjusted; damages due to animals might have occurred even when not expected; after a few minor events occurred since the measure was installed, its possibility of plastic deformations has been reduced, etc.) For the design of new measures: the observation that all factors related to Scenario 1) should already be accounted for in the designing codes and respected by the chief designer is absolutely correct, we do agree (and we do agree that this is valid for existing measures as well). Scenario 0, basically, simply allows to evaluate the effects of those factors which are/should be existing in the designing codes (and does not aim at "substituting" designing codes), for possibly mitigating them and ensuring that the protection can work according to its nominal capacity (as it should, since it is newly designed). Capacity and position of a protection are often determined based on rock fall simulations, and most of the factors in Scenario 0 cannot be simulated; thus, the methodology aims at recollecting these factors and establishing how they affect the nominal capacity determined from simulations results. This evaluation is relevant, as engineering solutions to mitigate the potential influence of the factors belonging to Scenario 0 should be based on the specific protection chosen; Scenario 0 helps in detecting whether the reduction of capacity for the chosen protection is significant or, despite some environmental factors might play a role, negligible (i.e. the protection chosen can still work perfectly and no adjustment/new design is needed). Based on these considerations, therefore, the methodology does not aim at designing the measures independently from the site conditions, but rather the contrary, and this is the reason why environmental factors and factors somehow linked to the interaction between the site and the protection are taken into account.

3) Thank you very much for another very constructive comment: again, we fully agree with these considerations. Indeed, the situation in which a given hazard level is solely due to a "natural" scenario is different from the situation in which the same level of

hazard is the result of a mitigation obtained relying on the performance of a protection. In fact, in the methodology proposed, the reclassification is planned to be done by representing the new hazard level with a hatched zone in all the area(s) concerned of the hazard zoning map. This hatched zone will feature both the colour corresponding to the hazard level associated to the event ("natural" scenario), and the colour corresponding to the new hazard level obtained in presence of protections ("final" scenario). The aim of this representation is exactly to inform users that the new (lower) hazard level at the area(s) concerned is the one resulting from the final scenario, because a protection actually is working to reduce the hazard (which would otherwise be higher, i.e. other colour in the hatched zone). We reckon this should have been included in the paper. We propose to include these details in Section 3.2.4.

Minor comments:

Page 2. Lines 4-6. Thank you very much for the comment, we will make corrections accordingly.

Page 3. Lines 10-14. We propose to modify the following definitions, according to your suggestion: Page 3. Lines 10-14 : "residual hazard" (Switzerland): "An additional hazard level qualified as "residual" is defined for return periods higher than 300 years; this definition is based only on the probability of occurrence and identifies the possible occurrence of extreme rare events (but no further specification or well defined classes are given in terms of return period and energy to classify this hazard). In the paper, the concept of residual hazard is used with the same meaning, as it always used in relation to the corresponding hazard zone defined in the Swiss Codes. We could precise though that, even according to the Swiss Codes, if residual hazard is the result of the performance of a protection measures, the event should not only be considered as "rare" in the area concerned (very low probability of occurrence), but the definition somehow implies also a very low intensity (as most measures work on the energy of the event too) – on the contrary, if no measure is in place, residual hazard is associated to events which have a very low probability of occurrence also because of their

extremely high and rare magnitude.

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