

Evaluation of early warning systems for natural hazards: a generic framework

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INTRODUCTION

During the last decade, early warning systems (EWS) have been increasingly applied as flexible risk mitigation measures for natural hazards. They are especially useful to prevent damages from hazardous processes that exceed the capabilities of structural measures, such as strong earthquakes or high-magnitude rockfalls. EWS can reduce the consequences of hazardous events, when timely information leads to preventive measures; e.g. an evacuation. In an integrated risk management approach, EWS should be compared to alternative mitigation measures in cost-effectiveness analysis. Since there is no method for a quantitative assessment of the reliability and effectiveness of EWS available, we present a framework approach for addressing this issue (Sättele, 2015; Sättele und Bründl, 2015; Sättele et al., 2015a,b).

METHODS

The proposed framework approach is developed in three steps. In a first step, a classification for EWS is developed, to provide a basis for a structured evaluation of EWS. The classification is applied to a selection of state of the art EWS technologies. In a second step, active EWS of two different EWS classes are evaluated in comprehensive case studies to identify factors that influence the performance of EWS in each class and to develop tailored evaluation methods. Based on the classification and on major findings of the case studies, the generic framework is developed in the third step.

RESULTS

The framework for the evaluation of EWS comprises three main parts, as illustrated in Figure 1. In part 1, the reliability of automated sections of EWS is assessed, and in part 2, the reliability of non-automated sections of EWS is assessed. In the last part, the effectiveness is calculated as a function of the reliability.

The classification distinguishes EWS according to their degree of automation in alarm, warning and forecasting systems, which provides the basis for the selection of the necessary reliability analysis methods. For fully automated alarm systems, the first reliability analysis is sufficient, for partly automated warning and forecasting systems the second reliability analysis should be included. In both analyses, the reliability is expressed in terms of probability that events are detected (POD) and the probability that false alarms are issued (PFA). POD and PFA are a function of both the inherent and the technical reliability of an EWS. The technical reliability of EWS is a result of the failure probabilities of individual components and their configuration in the system. The inherent reliability of EWS is their ability to detect dangerous events and avoid false alarms. For automated EWS, this ability depends on the monitoring strategy, including the type, number and positioning of sensors, and on the decision instance, such as predefined thresholds. The inherent reliability of non-automated system parts depends chiefly on human decision-making and on the accuracy of applied models.

The effectiveness is quantified in the third part of the framework as the risk reduction achieved with the EWS. To account for both positive and negative effects associated with EWS, the effectiveness is calculated as a function of the POD and the probability that persons comply to the warning (POC). The POC is calculated from a basic compliance rate and reduction factors due to the false alarms (PFA) and insufficient lead time.

CONCLUSION

A comprehensive framework for quantitatively assessing EWS is presented. The framework comprises three parts and has a flexible design to cover future developments of EWS. It enables decision-makers to evaluate EWS following a structured

approach to compare EWS to alternative mitigation measures and select optimal risk mitigation strategies.

ACKNOWLEDGMENTS

This framework is one main achievement of a PhD thesis, which is financially supported by the Swiss Federal Office for Civil Protection (FOCP).

REFERENCES

- Sättele M. (2015). Quantifying the Reliability and Effectiveness of Early Warning Systems for Natural Hazards, PhD Ing., Technische Universität München TUM, Munich.

- Sättele M., Bründl M. (2015). Praxishilfe für den Einsatz von Frühwarnsystemen für gravitative Naturgefahren, WSL-Institut für Schnee-und Lawinenforschung SLF, Bundesamt für Bevölkerungsschutz.

- Sättele M., Bründl M., Straub D. (2015a). Reliability and effectiveness of warning systems for natural hazards: concept and application to debris flow warning. Reliability Engineering and System Safety, 142, 192-202, 2015.

- Sättele M., Krautblatter M., Bründl M., Straub D. (2015b). Forecasting rock slope failure: How reliable and effective are warning systems? Landslides, 605, doi: 10.1007/s10346-015-0605-2.

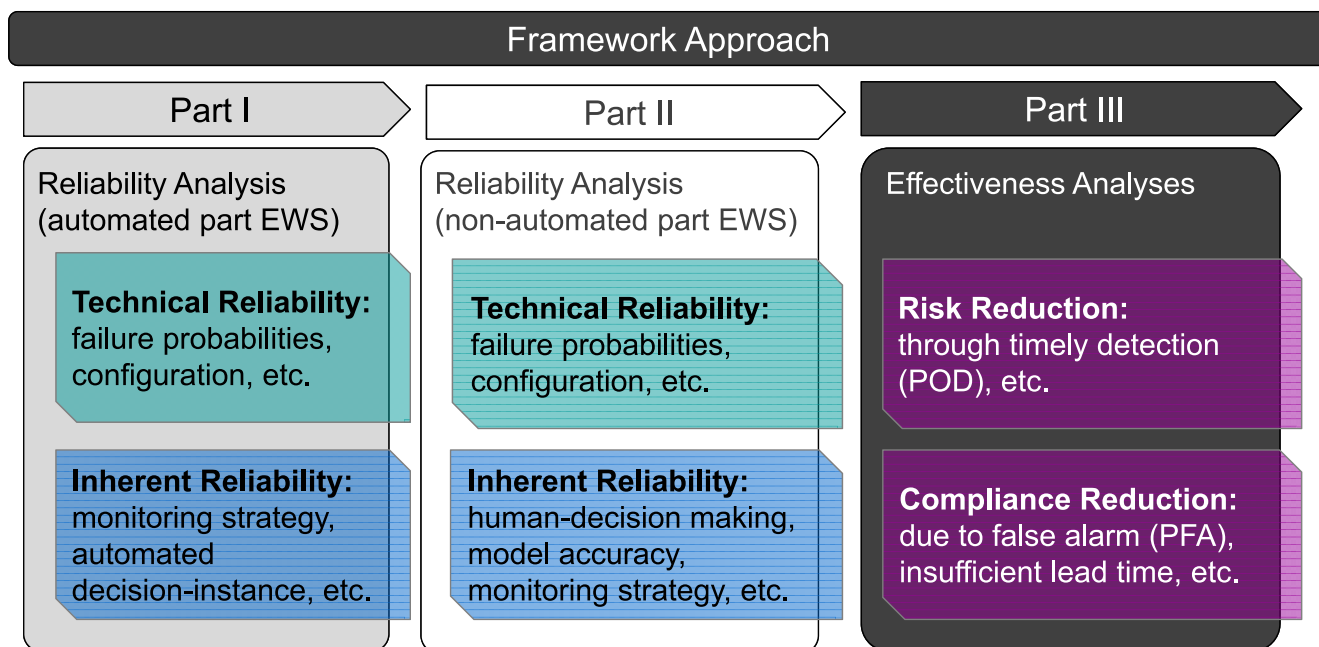


Figure 1. Framework for the evaluation of EWS comprises three main parts: the effectiveness (part 3) is quantified as a function of the technical and the inherent reliability, which are evaluated separately for the automated and the non-automated EWS in part 1 and 2.

KEYWORDS

early warning systems; framework approach; effectiveness; reliability

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