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Risk and resilience-informed decision-making for strategic territorial risk management : from methodologies to practical implementation for infrastructures exposed to mountain natural hazards

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1 Context

People, assets and infrastructures located in mountain territories are highly exposed to natural phenomena that induce both direct consequences (damage) on objects but also indirect, remote consequences. In these areas, critical infrastructures such as transport, energy, communication, water networks disruption due to either rockfalls, floods, snow avalanches or landslides can have severe long-term, remote, economic, social consequences which somehow characterize the territory resilience including therefore a temporal dimension. To reduce risk, local authorities, state, infrastructures managers often build structural protection measures. For instance, torrent check dams control material volume and flow through stabilization of bed scouring and banks. More than 21,000 old protection works, including 14,000 check dams, are registered in French public forests. Those works are highly exposed to phenomena effects, to severe climatic conditions and are often located in non-easily accessible areas: they are therefore submitted to deterioration with consequences on their efficacy and the risk level on areas where protected assets are located downstream. Assessing their actual effectiveness is a key issue in maintenance decision-making (Carlados et al., 2016a, b). In this context, being able to assess the status of the protection works, their maintainability and to choose the best maintenance strategy remain challenging decision-making issues for stakeholders.

Several scientific and methodological developments have been proposed to both characterize the efficacy of protection works, to support related decisions processes such as identifying the best maintenance strategies and also finally to analyse the effects of deterioration on risk levels. This presentation presents a global picture of the natural risk management context and the interest of proposing integrated, pluridisciplinary and complementary methodologies. It recalls recent findings but also connect them to decisions contexts and stakeholders' needs for research to implementation and real-life decision contexts.

2 Some pluridisciplinary methodological developments

2.1 Analysing the efficacy of protection works

The efficacy of a system may be an ambiguous concept. For a (risk) protection work, it can be defined as the level of objective achievement according three features: structural, functional, and economic. Its assessment is based on the comparison of its capacity with the chosen objectives. Nevertheless, due to ageing and deterioration the nominal capacity of a structure may be reduced. When analysing structural pathology, field practitioners focus on structural and functional features. A first essential step is to define and assess

degradation criteria that can affect structural stability and the functional service of each structure or cluster of structures. This analysis based on inspection done by experts is the basis to propose maintenance strategies. A pluridisciplinary, integrated process is proposed to assess this efficacy using multicriteria, multi-feature (structural, functional, and economic) and multiscale (check dam, device, and watershed) analysis. Those developments combine functional analysis and multi-criteria decision methods (MCDMs) in a context of imperfect information (Carladous et al., 2016a, b).

2.2 Analysing the deterioration process and prioritizing maintenance strategies

Protection structures that reduce the risk caused by natural hazards protect infrastructures and are there part of critical systems. Their deterioration over time influences their level of performance and can lead to dramatic consequences. In the context of natural hazards, identifying and analysing dependencies between the structure and the environment, and supporting decision-making for choosing the best maintenance strategy with limited budgetary resources remain challenging. New approaches are proposed to go beyond traditional methods used in safety and reliability analysis and to develop a comprehensive approach that permits incorporating possible interactions when modelling system's deterioration and provides information for analysing cascading effects prioritizing maintenance actions. Recent developments couple (1) numerical models that account for the dynamic deterioration of check dams and retention dams (Chahrour et al., 2021, 2022b) based on civil and hydraulic engineering expertise, and (2) a decision-aiding model, based on surrogate stochastic models built with e.g. stochastic Petri nets, that compares the evolution of the system deterioration and the associated incurred costs when subjected to maintenance operations.

2.3 Developing practical tools and frameworks for operational risk management decision-aiding

Practitioners need operational risk management frameworks. To help local authorities to manage multiple risks in mountain areas and choose the best strategy, the French ministry for Ecological Transition has designed and promotes the new French framework called Mountain Risk Management and Prevention Strategy (STePRiM). It consists in a new innovative framework to help local authorities choosing and funding their risk management strategies in mountain areas. A first step of risk diagnosis and protection works' status analysis is first carried out over a large area and is then followed by a step of prioritization between possible options in collaboration with local stakeholders. Risk analysis is here directly linked to risk evaluation and finally decisions related to the choice, the location and the scheduling of risk reduction strategies and actions (Carladous and Tacnet, 2022; Tacnet et al., 2022).

3 Perspectives and challenges

The objective of merging science, engineering and decision-aiding open new research perspectives dedicated to critical infrastructures risk and resilience assessment. Combining disciplines, approaches developed for industrial, technological assets and infrastructures for application to natural and NATECH risks is a promising challenge. Improving knowledge about cascading effects between natural and technological risks, including the evolution of vulnerability are important issues. Linking the level of protection works or systems with the downstream risk and resilience levels is one of the next on-going challenges (Chahrour et al., 2022a). Merging technical analysis and decision-making processes is key for effective territorial risk and resilience management. New spatial group decision-aiding methods are required to associate all stakeholders.

4 References⁺

- Carladous S, Tacnet J-M. Stratégie Territoriale de Prévention des Risques en Montagne (STePRiM) - Guide méthodologique pour la mise en œuvre - version de travail. Ministère de la Transition Ecologique et Solidaire (MTES), Direction Générale de la Prévention des Risques (DGPR), Service des Risques Naturels et Hydrauliques (SRNH), Bureau des Risques Naturels Terrestres (BRNT); 2022.
- Carladous, Simon and Tacnet, Jean-Marc and Batton-Hubert, Mireille and Dezert, Jean and Marco, Olivier, 2019. Managing protection in torrential mountain watersheds: A new conceptual integrated decision-aiding framework. *Land Use Policy*, Elsevier, Vol. 80, 464-479, 10.1016/j.landusepol.2017.10.040
- Carladous,S., Piton,G., Tacnet,J.-M., Philippe,F., Nepote-Vesino,R. et al.(2016a). From the restoration of French mountainous areas to their global management: historical overview of the Water and Forestry Administration actions in public forests. 13th INTERPRAEVENT Conference, May 2016, Lucerne, Switzerland.
- Carladous,S.,Tacnet,J.-M.,Batton-Hubert, M., 2016b. Protection structures against natural hazards: from failure analysis to effectiveness assessment. 13th Congress INTERPRAEVENT 2016, May 2016, Lucerne, France.
- Chahrour, N., Bérenguer, C., & Tacnet, J.-M. (2023 – accepted,under press). Incorporating Cascading Effects Analysis in the Management Process of Torrent Check Dams Against Natural Hazards. *Reliability Engineering & System Safety*.
- Chahrour, N., Piton, G., Tacnet, J.-M., & Bérenguer, C. (2024). A Surrogate Deterioration Model of Debris Retention Systems Towards Cost-Effective Maintenance Strategies and Increased Protection Efficacy. *Engineering Structures*, Volume 300, 2024, 117202, ISSN 0141-0296, <https://doi.org/10.1016/j.engstruct.2023.117202>.
- Chahrour, N., Piton, G., Tacnet, J.-M. and Bérenguer, C. (2022b). Decision-Aiding Towards Improved Resilience of a Deteriorating Debris Retention System Subject to Maintenance Strategies. 60th ESReDA Seminar On Advances in Modelling to Improve Network Resilience, Grenoble, France.
- Chahrour, N., Tacnet, J.-M. and Berenguer, C. 2022a. Economic Efficacy Assessment of Deteriorating Protection Structures Subjected to Natural Phenomena in Mountains. ICASP14 - 14th International Conference on Applications of Statistics and Probability in Civil Engineering. https://hal.science/hal-04245183/file/ChahrourEtAl_ICASP14_2023.pdf
- Chahrour,C., Tacnet,J.-M., Bérenguer,C. (2021b). Deterioration Modelling and Preventive Maintenance of Critical Torrential Protection Structures towards Improved Resilience – A Petri Net based Approach. R. Remenyte-Prescott; V. Kopustinskas. *Modelling the Resilience of Infrastructure Networks - An ESReDA Project Group Report*, Det Norske Veritas, pp.166-181, 2021, 978-2-930928-11-1. (hal-03408080)
- Chahrour, N., Nasr, M., Tacnet, J.M. and Bérenguer, C. (2021a). Deterioration modeling and maintenance assessment using physics-informed stochastic petri nets: Application to torrent protection structures. *Reliability Engineering System Safety* 210, 107524.
- Curt,C., Tacnet, J.-M., 2018. Resilience of critical infrastructures: review and analysis of current approaches. *Risk Analysis*, 2018, pp.18. (hal-02607701)
- ESREDA. Modelling the Resilience of Infrastructure Networks: an ESREDA (European Safety, Reliability & Data Association) project group report. Remenyte-Prescott R, Kopustinkas V, editors. Norway: Det Norske Veritas AS; 2021.
- Tacnet, J.-M., Carladous S., Sassus, Ripert, E., Lagleize, P., Stephan, A., Calmet, C., Gili, 2022. Risk, resilience in Mountain Risk Management and Prevention Strategy (STePRiM). Proc. 60th ESReDA Seminar (ESReDA 2022) - Advances in Modelling to Improve Network Resilience, Grenoble, France
- Tacnet,J.-M., Dezert,J., Curt, C., Batton-Hubert, M., Chojnacki, E., 2014. How to manage natural risks in mountain areas in a context of imperfect information? New frameworks and paradigms for expert assessments and decision-making. *Environment Systems and Decisions*, 2014, Volume 34 (Issue 2), pp 288-311, 10.1007/s10669-014-9501-x, <https://hal-emse.ccsd.cnrs.fr/emse-00995011/file/P033.pdf>
- Tacnet J-M, Mermet E, Zadonina K, Deschatres M, Humbert P, Dissart J-C, et al. Road network management in the context of natural hazards: a decision-aiding process based on multi-criteria decision making methods and network structural properties analysis. *Proceedings of the International Snow Science Workshop (ISSW 2013)*, 7-11 october 2013, Grenoble, France. Grenoble, France; 2013. p. 95-106.
- Tacnet J-M (coord. . Decision Support Guidelines - Methods, procedures and tools developed in PARAMount (WP7 report) - hal-03639896. European Regional Development Fund - Alpine Space Program - Intereg IV - PARAMount projet : imProved Accessibility: Reliability and safety of Alpine transport infrastructure related to mountainous hazards in a changing climate. <http://www.paramount-project.eu/>; 2012.

⁺ see also <https://cv.hal.science/nour-chahrour> ; <https://cv.hal.science/christophe-berenguer> ; <https://cv.hal.science/jean-marc-tacnet>