MITIGATION OF HYDROGEOLOGICAL RISK: RANKING OF AREAS PRONE TO WATER-RELATED HAZARDS BY PRIORITY OF INTERVENTION

ABSTRACT

The mitigation of hydrogeological risk has assured to be one of the most striving challenges that governments and societies are facing today. In this context, the enormous complexity of public decision processes aimed at mitigating hydrogeological risk makes it emerge the need for policymakers and planners of robust and transparent decision models to support and inform the design of risk mitigation strategies and rank top priority areas of intervention. In this paper, we propose an operational framework to address hydrogeological risk and uncertainty through an integrated approach based on the AHP, which can be applied to different areas exposed to water-related hazards.

Keywords: hydrogeological risk, risk mitigation, AHP absolute model.

1. Introduction

Climate change is causing an increase in both sea level rise and the occurrence of heavy rainfalls and storms, which in turn are increasing the frequency and intensity of flooding. In a business-as-usual scenario, the estimated costs of hydrogeological events will amount to 46 billion Euros per year by the 2050s (ECA, 2018). Directive 2007/60/EC (Floods Directive) focuses on effective flood prevention and mitigation and requires, *de facto*, that flood risk management plans include interventions to prevent and reduce damage to human health, the environment, cultural heritage, and economic activities (D'Alpaos and Bottacin, 2021). Multiple criteria approaches can provide a sound theoretical and methodological framework to address the wealth of environmental, economic, physical, social, and cultural factors, which make the design and implementation of hydrogeological-risk mitigation strategies of utmost complexity.

2. Literature Review

Within academic literature, the ability of multiple stakeholders and actors to share information and learn from best practices in achieving common goals is deemed as a proper approach to managing complex systems and their impact on society, the economy, and the environment (Bodin, 2017). Nonetheless, the results of a systematic literature review reveal the lack of operative approaches that inform the assessment of hydrogeological risk and support policymakers in coping with hydrogeological risk mitigation in real-world situations.

3. Hypotheses/Objectives

The paper aims to provide policymakers with specific tools to inform the design of hydrogeological risk mitigation strategies and rank top priority areas of intervention. In detail, we propose an operational framework to address hydrogeological risk and uncertainty through an integrated approach, which can be easily understood by third parties and applied to different urban and rural areas exposed to water-related hazards.

4. Research Design/Methodology

We developed an absolute AHP model for the prioritization of interventions to mitigate hydrogeological risk. The model provides a dashboard of weights and guarantees policymakers and public decision-makers to adopt a dynamic perspective, which accounts for changes in the valuation of alternatives on a single criterion due to changes in the boundary conditions of the decision environment. To structure the decision problem and define the hierarchy, we conducted an extensive literature review and interviewed nine experts via a Delphi survey process. We finally organized focus groups for brainstorming and validating the hierarchy and the priorities through dynamic discussion (Saaty and Peniwati, 2000).

5. Data/Model Analysis

We considered the following hierarchical levels: goal, criteria, sub-criteria, and ratings. In detail we considered environmental, social, and economic criteria. Environmental sub-criteria include: water quality deterioration, soil erosion, pollution due to contamination, and loss of biodiversity. Social sub-criteria include: loss of confidence among population, change in expectations, perceived unsafety, and loss of sense of community. Economic sub-criteria include: repair/reconstruction costs of real estate assets, repair/reconstruction costs of infrastructures, and indirect costs such as loss in regional GDP, costs for temporary relocation of local population, and health and sanitary costs. We considered five ratings for each sub-criterion: null/very low, low, moderate, high, and extreme. Figure 1 in the appendix displays the hierarchy and the (local) priority vectors.

6. Limitations

This is a preliminary study, starting from which a further focus can be implemented. Additional hierarchical levels can be added to better disaggregate sub-criteria and a more sophisticated definition of ratings and relative measurement scales can be introduced.

7. Conclusions

The methodological framework here proposed addresses a preliminary and fundamental step in the design of cost-effective hydrogeological risk mitigation strategies and can be applied to solve decision-making problems involving the resilience of territories.

8. Key References

Bodin, Ö. (2017). *Collaborative environmental governance: achieving collective action in socialecological systems*. Science 357(6352), eaan11.

D'Alpaos, C., & Bottacin, G. (2021). *Social Choices and Public Decision-Making in Mitigation of Hydrogeological Risk*. 12956 LNCS, pp. 289-300.

European Court of Auditors - ECA (2018).*Floods Directive: Progress in Assessing Risks, While Planning and Implementation Need to Improve* (2018). https://www.eca.europa.eu/Lists/ECADocuments/SR18_25/SR_FLOODS_EN.pdf. (Last Accessed 4 November 2022).

Saaty, T.L., & Peniwati, K. (2007). *Group decision-making: Drawing out and reconciling differences*. Pittsburgh, PA: RWS Publications.

9. Appendix

Goal	Environmental criteria	water quality deterioration	null/very low	0.088
	0.450	0.284	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		soil erosion	null/very low	0.088
		0.329	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		pollution due to contamination	null/very low	0.088
		0.190	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		loss of biodiversity	null/very low	0.088
		0.197	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
	Social criteria	loss of confidence among population	null/very low	0.088
	0.129	0.269	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		change in expectations	null/very low	0.088
		0.510	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		loss of sense of community	null/very low	0.088
		0.221	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
	Economic criteria	repair/reconstruction costs of real estate assets	null/very low	0.088
	0.420	0.203	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		repair/reconstruction costs of infrastructures	null/very low	0.088
		0.375	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		loss in regional GDP	null/very low	0.088
		0.171	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		costs for temporary relocation of local population	null/very low	0.088
		0.085	low	0.201
			moderate	0.359
			high	0.393
			extreme	1
		health and sanitary costs	null/very low	0.088
		0.166	low	0.201
			moderate	0.359
			high	0.393
			extreme	1

Figure 1 - Hierarchy