A DECISION-THEORETIC APPROACH TO IDENTIFY OPTIMAL RISK MITIGATION STRATEGIES

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INTRODUCTION

The increase of human activities in floodplains lead to a reduction of natural water retention capacities and consequently a streamlining of the watercourses are observed. As a result of these land use changes an increase in the likelihood and adverse impacts of flood events is expected. Natural hazard risk in general, and flood risk in particular, need considerable public investments for the development of new management strategies. However, these investments and the underlying investment decisions provide a challenge to management options because of both the associated long-term societal capital commitments and the interdependencies induced with other economic activities in mountain regions (e.g. tourism and trading). A sound methodology derived from fundamental design principles and decision-theoretic approaches contributes to this challenge by increasing the acceptance of transparent and traceable solutions in hazard and risk management: Firstly, a system analysis procedure is used to define feasible concepts for appropriate mitigation concepts according to the outlined protection target. Secondly, a decision model that includes elements necessary for a decision making under uncertainty is set up to select the optimal mitigation concept. As a result of the application of such a decision model, an optimised and comprehensive mitigation alternative can be identified and implemented.

RISK MITIGATION STRATEGIES: GENERATION AND SELECTION

Natural hazard events have the potential to severely compromise economic activities and endanger human lives in all European Countries. Therefore, concentrated action is needed at the European level to decrease such impacts and thus the European Commission issued a Directive on the Assessment and Management of Flood Risks (Flood Directive, Commission of the European Communities, 2007). This Directive is one of the three components of the European Action Programme on Flood Risk Management (Commission of the European Communities, 2004) targeted at the development and implementation of flood risk maps and flood risk management plans. On an operational level the necessary planning procedures for flood risk management plans include conceptual design phases for risk mitigation; these have to be adjusted in order to approximate idealised standards of protection. Preventive mitigation measures – i.e., technical mitigation measures – are only appropriate if their functional efficiency is given and the maintainability of the entire protection system is cost-effective. Otherwise, if the system does not perform satisfyingly or the maintainability is not cost-efficient the mitigation measures have to be reconfigured. In this regard, Mazzorana & Fuchs (2010) proposed a structured approach to conceptually design highly-functional and reliable protection systems. They firstly determined analytic steps to progressively dissect the initial problem definition with the objective to re-formulate and define consistently the problem under consideration (critical system analysis). Secondly, they defined during a step of conceptual design the requirements to be met by future (protection) system entities (Ideal Final Result, IFR; according to Altschuller, 1984). Thirdly, they highlighted that, based on the Theory of Inventive Problem Solving (TRIZ-TIPS), the inherent contradictions originating from systemic or physical system constraints have to be overcome. As a

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result, the conceptual and functional, feasible and technically effective risk mitigation strategies can be formulated.

Following this approach of applied research, we adopted a decision-theoretic approach to structure and analyse the decision problem under uncertainty and to subsequently select the optimal strategy with respect to the defined target system. Concerning these issues the decision problem will be modelled following the basic assumptions of prescriptive decision theory (e.g. Eisenführ et al., 2010). Accordingly, the decision problem is decomposed into specific components, namely: (1) the risk mitigation options available to the decision maker, here refereed to as *alternatives*; (2) the natural hazard process scenarios, here referred to *states of nature* with the corresponding probabilities of occurrence; (3) the quantified *consequences* for each alternative and each state of nature with respect to the defined target system; and (4) the *target system* and the associated *preference structure* of the decision maker. The decision problem is thereby represented by a decision matrix. The selection procedure leading to the rational choice of an optimal alternative is then conducted according to the classical axiomatic theories of decision under uncertainty, culminating in Savage's theorem (e.g. Gilboa, 2009).

ADVANTAGES FOR RISK MANGAMENT STRATEGIES

A series of advantages can be derived from the adoption of such a structured procedure to generate and select effective risk mitigation strategies. If a decision maker or more generally a decision forum accepts a minimal set of well-defined design principles and decision-theoretic axioms the premises for making decisions consistent and rational from a procedural perspective are enhanced. Though, a sequence of transparent problem decomposition and synthesis steps, decision making is supported in terms of an increased problem solving competence which is inherently needed in flood risk mitigation. Aspects relevant for the decision problem can be clearly prioritised and consequently the solution spectrum can be tailored to the specific demands explicitly represented by a complete, concise and redundancy-free target system.

The optimality of a selected risk mitigation alternative is always related to a given preference structure of the decision maker, which implies that making this structure explicit contributes significantly to the quality of the decision problem as a whole. Through the elicitation of the utility functions for each domain of the different attributes of the target system the preference structure is analytically modelled. Considering the peculiarities of public investment decisions aiming at mitigating natural hazard risks, namely the associated long-term capital commitments and the induced interdependencies with important economic activities in mountain regions (e.g. tourism and trading), the required analytic effort is balanced. The proposed procedure is not free of limitations when abandoning the prescriptive point of view and aiming at describing the potentially intuitive behaviour of decision makers at various levels. However, from an anticipatory perspective, the main purpose is to stimulate the decision makers to rationalise their decision making process by removing obstacles to a complete adherence to the principles of a prescriptive decision theory.

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