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Decision Framework for Seismic Risk Management

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ABSTRACT

Reflecting the evolution of attitudes toward seismic threats, seismic risk reduction initiatives have been launched in many countries. By gaining a better understanding of how the risk is managed by each sector, the engineer should be able to play a more effective role in the analysis of technical information [EERI 00].

In most situations, a range of different strategies are possible. Decision makers must therefore select the best-suited strategy. This paper describes a decision framework for selecting a strategy for seismic risk management. In a first phase, the risk is quantified and strategies are developed. In a second phase the impact of the strategies on the risk is quantified and a comparative evaluation is conducted. In a complex situation, this evaluation must account for multiple criteria and points of view. The comparative evaluation provides a rationale basis for the selection of a strategy. The proposed framework will be tested in the context of a pilot project studying the seismic risk management for the built environment of a small town in the Swiss alps.

KEYWORDS

Seismic risk, risk management, mitigation, multiple-criteria and multiple-actors analysis, decision support systems, outranking methods.

INTRODUCTION

Natural disaster mitigation efforts are increasingly evaluated in the context of integrated risk management. It is often useful to approach seismic engineering issues from a risk management stand point. For example, in a city with a seismically vulnerable building population, managing the consequences of an earthquake requires the selection of a risk management strategy (i.e. set of measures). Many strategies are possible, ranging from doing nothing (i.e. accepting the risk), to implementing an extensive building retrofit campaign. Another strategy could be to focus a limited retrofitting campaign on life-line buildings. Yet another strategy could be to use insurance to guarantee financial compensation for losses and ensure economic recovery. Decision makers must consider different, and often conflicting, interests in choosing a strategy. How should a strategy be selected? This paper deals with this question, proposing a decision framework for the selection of seismic risk management strategies.

The darker area of Figure 1. shows the position of the decision framework discussed in this paper in the risk management context. Even if the decision retains a strong subjective dimension, it is desirable for the selection to be founded on a rationale and quantitative basis, and to be obtained in a systematic and repeatable process. It is also desirable to use a process conducive to integrated natural risk management [Ammann 01], i.e. which make possible a comparative evaluation of risk management strategies for different natural hazards.

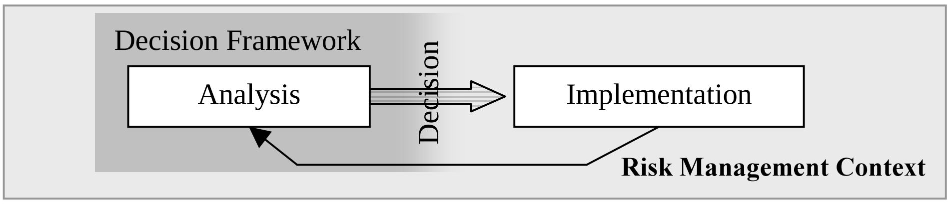

Figure 1: Risk Management Context

Pilot Project

The decision framework discussed in this paper is being developed and evaluated in the context of a pilot project. The goal of the pilot project is to quantify the seismic risk for the built environment of a small town. Aigle is located in the Swiss alps in a region of medium seismicty and includes a population of 1500 buildings of very different age and type. A companion paper [Brennet & al. 02] presents the vulnerability oriented seismic inventory of the town's building population. The creation of a seismic inventory was the first step made toward seismic risk management. The risk assessment for Aigle will serve as the starting point for the selection of a risk management strategy. Competing risk management strategies will be compared within the proposed decision framework. The pilot project will be used to illustrate the decision framework elements described below.

Decision Framework : Objectives Based Risk Management

The five phases of the decision making process leading to the selection of a risk management strategy are presented in Figure 2. They are:

- Risk Analysis,
- Objectives and Evaluation Criteria,
- Elaboration of Strategies,
- Comparative Evaluation of Strategies (in an Iterative Process),
- Selection of Strategy.

These phases are discussed in separate sections below.

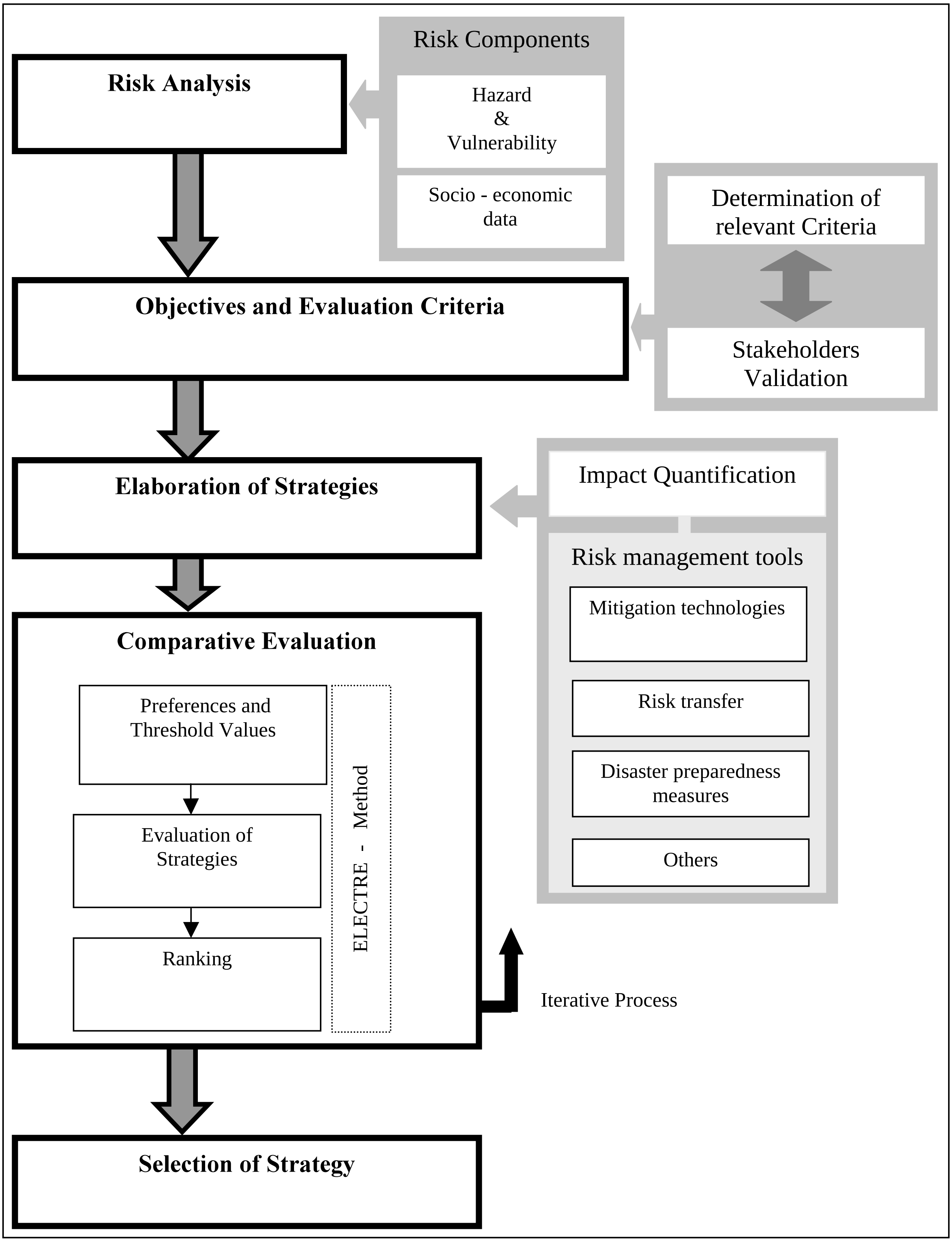

Figure 2: Decision framework for the selection of a risk management strategy

In a complex situation, the decision process will typically involve several types of participants. The Decision-makers have the responsibly of selecting the risk management strategy. The Experts provide the rationale data and analysis on which the decision is founded. They have an objective task of quantification of the risk components and definition of possible risk management strategies. The Stakeholder representatives, unlike the experts, their role has a subjective dimension. Their evaluation of the proposed strategies is oriented by the point of view of the groups they represent. The process might be organized by a facilitator.

RISK ANALYSIS

The object of this phase is to establish a risk profile for the system which is analysed. Experts play a dominant role in this phase. The goal of the risk analysis is to quantify the different types of losses. The classic risk quantification approach illustrated in Figure 3. can be used. It combines the three basic risk components: hazard, vulnerability and loss potential.

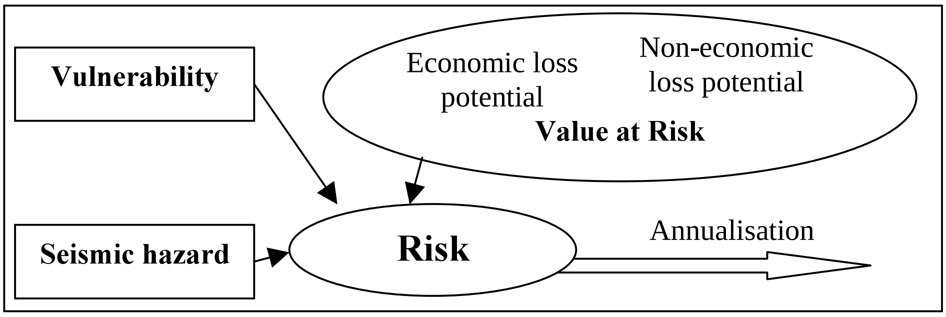

Figure 3: Risk Quantification

Seismic Hazard
The risk analysis requires a definition of the seismic hazard affecting the system at risk. This hazard must be quantifiable, i.e. a description of earthquake occurrences in space and time is required. In Aigle for example, stochastic hazard curves from [Rüttener 85] are being used.

Vulnerability
The vulnerability of the system at risk, or its elements, must be determined as well. In the case of the pilot study, a composite vulnerability curve has been developed for the building population (see companion paper [Brennet & al. 02]).

Loss Potential
The third component in risk quantification is the loss potential. Different types of losses can be considered following an earthquake. Besides loss of life and economic losses, other losses might be important in some situations, for example environmental losses (pollution of ecosystems), heritage losses, image losses (e.g. tourist industry), social losses (disruption of social fabric). For each type a scale and unit must be defined (e.g. $/yr, deaths/yr, …). Whenever reasonable, economic quantification is to be favoured.

For economic losses, direct and indirect losses are often distinguished. The potential for direct losses (material losses) is the simplest to quantify, because of availability of data, for example on the replacement value of a building population. Indirect losses are losses resulting from disruptions to industrial production capacity, service industry, infrastructures, networks, … In the absence of specific data and models, the corresponding loss potential is often estimated using a multiplier of direct loss potential (e.g. indirect losses are one and a half times the direct losses).

OBJECTIVES AND EVALUATION CRITERIA

The elaboration, evaluation and selection of a risk management strategy should be objectives based. Starting from the broad foundational objective of managing the risk over time and space in an "optimum" fashion, specific objectives can be defined: for example safety or economic objectives. The following comments apply to these objectives:

- Usually, they can be classified in the following four main categories: economic, social, technical and environmental [Haller 01].
- It is possible that they might have contradictory implications. The comparison method will need to be able to account for this.
- They might need to be reviewed in the decision process, i.e. there is a need for iteration opportunities and negotiation.
- The fulfilment of these objectives will be evaluated with criteria which must be defined accordingly.
- The objectives and their evaluation criteria must be validated by the main stakeholders affected by the risk. There will be differing points of view, on the relative importance of the objectives.

ELABORATION OF INTERVENTION STRATEGIES

In this step possible risk management strategies in a seismic risk context are developed. The risk mitigation tools and the preferences of the actors are both considered.

Risk management strategies

A strategy is a set of measures impacting the risk. In the Introduction, examples of risk management strategies for a building population are given. Other strategies will be considered for seismic risk management of an industrial complex, a transportation network or a historical object. It is the task of the risk manager to develop risk management strategies which are suited to the situation. This will be based on a) the risk profile developed under the Risk Quantification task and b) the range of Risk Management Tools which can be implemented in this situation. This task can be helped by different classical tools, such as:

- Logical trees for the establishment of possible potential loss scenario,
- Risk matrix (Probability vs. Consequences) to identify priorities for intervention.

This task produces possible strategies which are described in terms of cost, timing of implementation, and other pertinent characteristics such as interruption of business, technical specification, feasibility parameters, …

Impact of the strategies on the risk profile

In order to prepare a comparison of strategies, the impact of each strategy on the risk profile of the system must be evaluated. For example the changes in loss of life must be estimated. Figure 4. shows a qualitative example in which the impact of two strategies on four risk parameters (types of loss) is shown. The risk profile for each strategy can be determined with the models used in the risk analysis to establish the starting risk profile.

The “deltas” (changes) are typically positive, but could be negative (increase of risk) in some cases (figure 4.). These impacts can be calculated. They must be estimated for a reference period (e.g. 50 years) and can be annualised.

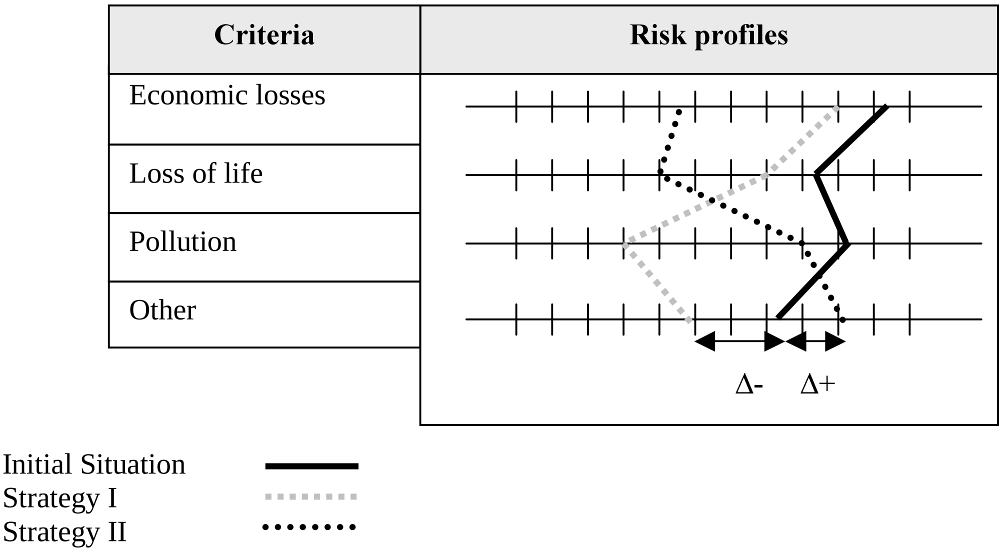

Figure 4: Qualitative Example of Risk Profiles

Risk Management Tools

There is a wide range of available measures for the seismic risk manager in each situation. For example the risk can be reduced by a number of technical schemes aimed at reducing the vulnerability of structures: retrofitting of the seismically inadequate piles of the bridges of a transportation network, or strengthening of vulnerable mutli-story traditional construction buildings of a region. Other tools include transferring (spreading) risk through insurance. For example, a building insurance can be introduced to create a pool of funds available to compensate for economic losses. Another classic tool is preparing for disasters, for example training of rescue workers and emergency personnel or implementing safety plans and systems for utilities (gas, water, …). Other risk management tools include measures such as enforcement of seismic code provisions for new structures.

COMPARATIVE EVALUATION OF STRATEGIES

The object of this phase of the decision process is to compare the different risks management strategies which have been developed. This phase requires the participation of the Stakeholder Representatives (e.g. political officials representing a constituency or a non-governmental organization defending the environment). This comparison process can be structured into the following three tasks.

Comparison Criteria

The comparison will be based on the criteria. In some cases a single criteria (e.g. economic) might suffice. Often however, several criteria must be considered. These criteria are closely related to the loss types described in the Loss Potential section above, but they are broader. For example the economic criteria considers, besides the direct and indirect economic losses, the investment costs for each strategy. As discussed above, these criteria are directly linked to the objectives which the risk management strategy must fulfil.

Comparison Methods

The strategy ranking problem is challenging because there is usually no single criteria that adequately captures the effect or impact of each strategy; in other words, it is a multiple criteria problem. It is also, because of the very different stakeholders typically affected by seismic risk management, a multiple points of view problem. Methods have been developed and are used in a number of fields for this type of situation. The following two main families of comparison methods are pertinent to the selection of risk management strategies.

Complete Aggregation Methods
The evaluation of each criteria are introduced into an aggregation function. This requires that the different evaluation criteria can be condensed to one parameter, for example a monetary unit in a cost-benefit analysis. In other words, these methods supposes the commensurability of the evaluation criteria. An example of such a method is described in [FEMA 97] and [FEMA 98]. These methods consider multiple criteria of different nature and solve the problem by the optimisation of an economic function. They are relatively simple and robust and are well adapted to a number of applications, for example risk quantification for insurance purposes.

Partial Aggregation Methods
These methods compare strategies by first ranking them criteria by criteria, thus respecting the incomparability of criteria. In the best case, the outcome is conclusive: if Strategy A is superior to Strategy B on a majority of criteria without being excessively inferior on the other, it can be concluded that A outranks B. Sometimes, however the results are unclear, leading to a “softer” ranking.
Partial aggregation methods are useful in complex situation with multiple criteria. One such method, an outranking method called ELECTRE III [Roy & al. 93] will be used for the pilot project. The following applies to the method:

- The fundamental concepts of the methods are “thresholds” and “outranking”, (see [Buchanan 99]).
- A feature of this method is that it is fundamentally non-compensative. This means that a very bad score in a criteria cannot be compensated by good scores in other criteria.
- The method can be a powerful decision aid [Roy 85]. Because it is transparent, experience shows that it can facilitate negotiations which might be required to develop a consensus around a selected strategy [Roy & al. 93].

SELECTION OF STRATEGY

In this phase the Decision Makers (government officials, or plant managers, or insurance industry representatives, or …) must select the strategy which will be implemented. Even if other considerations influence the decision. It can be based recommendations developed from the findings of the Comparative Evaluation phase described above. These recommendations are based on a comparison which is risk-oriented and which accounts for different criteria and point of views. The comparison distinguishes components which are objective (even if uncertain) such as economic losses or loss of life, and aspects which are subjective because dependent on the point of view of those affected.

SUMMARY & OUTLOOK

The decision framework presented above is aimed at providing a systematic and transparent approach to the selection of strategies for seismic risk managemement. The framework is based on classic risk analysis. The different tasks required to develop recommendations for the selection of a strategy are described. The process starts with the definition of objectives by the Experts. These must be validated by Stakeholder Representatives, whose point of view must also be used to weigh the criteria which will be used to compare the strategies and assess to what extent the objectives are fulfilled. The methodology used for evaluating the strategies, must allow for comparison in a multiple criteria and multiple point of view context. As such it will facilitate the negotiations which might be required to select a strategy with a broad support.

The framework is being used in the context of a pilot research project for seismic risk management for a small town. Focus of the research is:

- The quantification of “soft losses” such as environmental losses or heritage losses, and the estimation of expected indirect losses.
- Development of a typology for seismic risk management strategies.
- The application to seismic risk management of partial aggregation methods, considering multiple-criteria und multiple points of views

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