Development of a multi-hazard and multi-users risk scenario methodology and application to a study case

Author : Silvia De Angeli | Supervisors : Eng. S.Traverso, Dr, R.Rudari, Prof. M. Kervyn, Prof. G. Boni

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Introduction

Recent statistics on natural disasters explain the necessity to develop always **new methodologies** helpful to face better the risk and to apply correctly measures of mitigation and reduction. The risk management is nowadays a priority in a lot of heterogeneous fields. The need of a multi-user approach starts exactly from this awareness. Furthermore, the modelling of the multi-hazard dimension is a new challenge that allows the stakeholder to face with the chain effects between hazards.

The main goal of this master thesis has been to point out how to develop **multi-hazard** and **multi-user** risk analysis in the field of the natural risk management. From the practical point of view this work can be considered as a **proof of concepts**: it has been an attempt to lay the theoretical basis necessary for the development of a unique methodology able to generate **diversified multi-hazard risk scenarios**. The multi-hazard and the multi-user dimensions have been modelled separately and merged together in a unique approach.

Vector representation

The global characterization of the territory can be imagined as a **vector representation**. According to this representation, the real world is scanned: each single object on the territory is seen not only composed by its physical structure but as an infinite series of informative layers, that are able to describe its features and its behaviours at three hundred and sixty degrees.

This "stratified" description of the environment allow us to live in a sort of **"hyper reality"**, an amplified reality that contains all the possible levels of knowledge of the elements.

This type of description is particularly useful when an object could be described differently considering different dimensions; these dimensions could be spatial, temporal or generically related to the final purpose of the user that is looking for a description of the territory.

Multi-users

The main focus has been on the diversification of scenarios according to different users' needs. In particular the following parameters able to cover these needs have been identified:

- **geographic scale**: the territory can be studied at the scale of the single element for local studies till the global scale, in which the vulnerability is aggregated at big areal elements;
- **temporal scale**: the risk can be assess in different phases of the territory management such as in emergency, in planning or in restoration activities ;
- **diversity of impacts**: a certain element can be characterized in economic, environmental and social (human lives and civil protection) terms.
- **functionality**: the elements can be studied individually or considering their role inside the infrastructural network; in this way systemic studies can be chosen instead of studies at point element or vice versa;

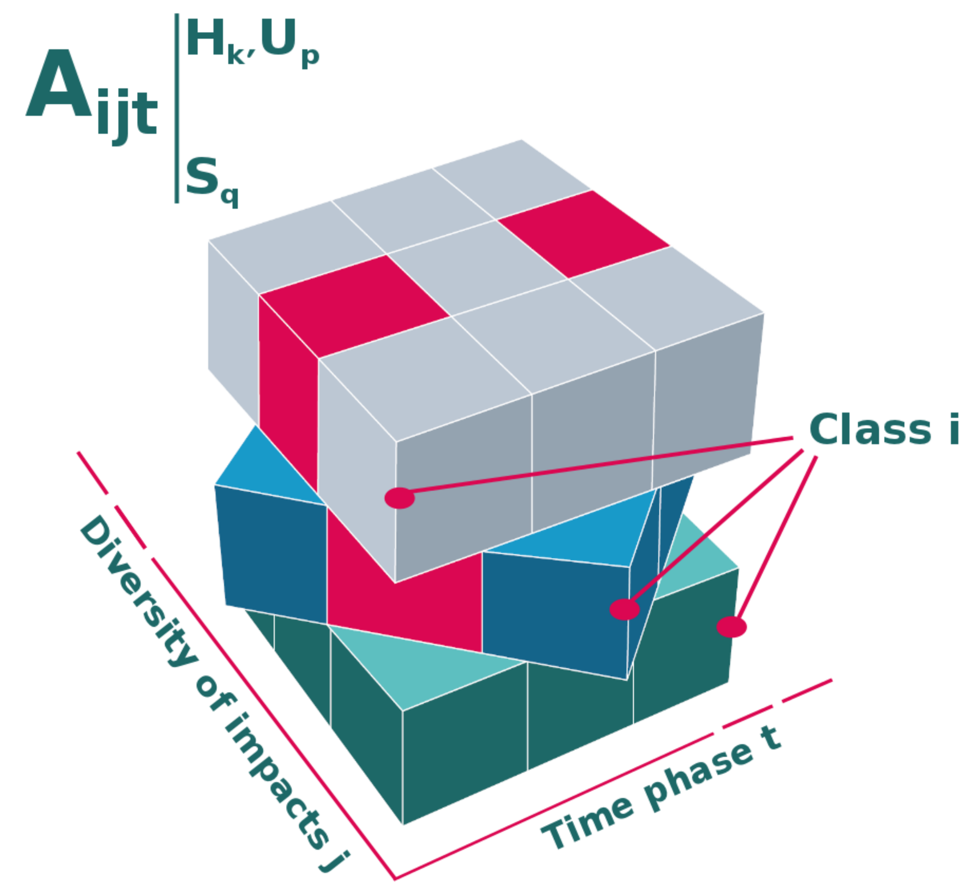

Fig. 1 DEA cube: Mathematical formalization of the vector representation of multi-user approach

The DEA cube

The vector representation of the space with the parameters introduced previously can be presented through a **mathematical representation at six dimensions.**

Let us consider a certain hazard H_k, where k=1,...,z are the different hazard that can be implemented in our model (i.e. flood, volcanic eruption, cyclon...) and a certain user U_p, where p=1,...,w are the different users that can be implemented in the model (i.e. urban planner, civil protection agency...). A certain territorial element A_{ijt} subject to a certain hazard and modelled for a certain user, conditioned to a certain geographic scale S_q, where q=1,..., v is the geographic scale (i.e. local, regional, national...), is univocally determined inside its reference system through the following three dimensions :

- the time phase t , with t=1,...,n that are the temporal phases (pre-cris, crisis, post crisis..)
- the diversity of impacts j, where j=1,...,m are the different impacts that can be considered (physical, social, economic, environmental...)
- the class of the element i, where i=1,...,r are the different classes of exposed elements (residential buildings, roads, parks...)

Diversity of impacts

The following four dimensions for the characterization of the elements have been identified:

physical, economic, social, environmental.

The physical damage is the necessary condition in order to have the other types of loss.

Physical vulnerability that characterize our territory can generate three classes of direct damage:

- economic damage, when the physical loss acts on buildings, roads, infrastructures, industrial sites and so on;
- social damage, when the physical loss acts on elements that contains people inside, or more in general when the hazard acts on populated areas;
- environmental damage, when the physical damage acts on vegetation, water and environmental resources in general.

Multi-hazard

Focusing on multi-hazard, three possible types of interaction between two hazards affecting the same area have been identified:

- the occurrence of a given event may change the probability of occurrence of another event;
- the occurrence of two or more hazardous events (not necessarily with a direct linkage among them) may imply changes to the vulnerability of the exposed elements, in particular a certain damage generated by the first event can influence the vulnerability of the system when it is prone to the second hazard;
- physical measures of risk reduction can be damaged. In this case the other elements of the system are not modified in their vulnerability but the physical damage of a certain class of elements (i.e. the physical measures for risk reduction) is able to change the hazard scenario and increase consequently the risk.

Study case

The methodology is tested through a study case. The study area is Grande Comore, an island of Comoros (Pacific Ocean). The multi-hazard is modelled considering two significant components of the **volcanic hazard** - lava flow and lahars - and the diversification of scenarios is done considering different elements at risk inside the study area subject to different losses (physical, social, economic, environmental). Two geographic scales have been investigated: point element scale and areal scale. For each of these scales three risk maps have been produced: only for lava, only for lahars and for the combined effect of both the hazards.

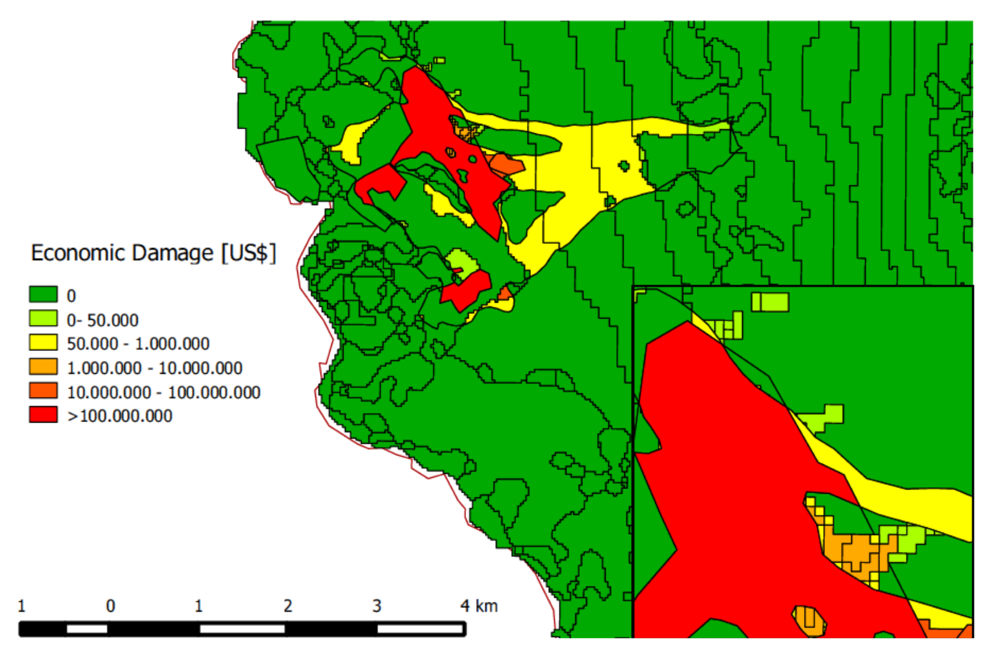

Fig.2 Economic damage scenario at areal scale due to the consecutive combined effects of lava and lahars

Findings

This work has tried to point out the different aspects that the method have to touch and it has tried to merge these aspects together in a **unique approach**. Nevertheless there are some open issues for further developments related to multi-hazard modelling and description of social, economic and environmental damage.

The second step of this project will be the effective implementation of the methodology in order to have an **operative tool** that different users can employ to develop their ad hoc risk scenarios. This approach is currently tested in operational study cases inside the European **RASOR project** *(www.rasor-project.eu)*