Spatial Vulnerability Indicators: "Measuring" Recovery Processes after Earthquakes

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ABSTRACT

In order to analyze and evaluate any post-disaster phases it is necessary to address the pre-existent vulnerability conditions. The methodology consists of four steps: the first step comprises of a review of vulnerability and recovery indicators; the second step is to identify indicators based on spatial variables; the third step is to find the common variables among the subsets of spatial variables from vulnerability and recovery indicators; and the fourth step more pragmatic, is an investigation of the availability of data. The initial results are the set of vulnerability and recovery indicators. Reducing the set of indicators to the indicators represented in a spatial context and the indicators with common features of vulnerability and recovery indices bears the risk to ignore some important single indicators; nevertheless, the added value of the on-going research is to show the advantages of using indicators based on spatial variables.

Keywords

Vulnerability, recovery, spatial, indicators, earthquakes.

INTRODUCTION

Vulnerability assessment is a key contribution to formulate recovery and development policies in the risk management process. In the frame of the European Union financed MOVE project, vulnerability has been defined as "the degree of susceptibility or fragility of elements, systems or communities including their capacity to cope under hazardous condition" (MOVE, 2009). Likewise, a clear definition of recovery is essential.

Chang (2009) puts forward three possible definitions for recovery: a) reaching the conditions existent before the event; b) reaching the state what would have been attained "without" the disaster, or c) reaching a new stable state.

All these definitions are valid and all of them reflect different cases and recovery processes, taking into account the preexistent vulnerability conditions.

The assessment of the recovery process should be based on indicators, in order to be objective and to be able to compare (Shohei, 2007). Indicators are qualitative or quantitative measures resulting from systematically observed facts (OECD, 2008) which describe characteristics of certain phenomena and which allow their assessment (Dopheide and Martinez, 2007). According to Chang (2009) the comparability among indicators in regard to disasters depends on three criteria: a) universal significant across space, time and cultures; b) available

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data and c) standardization of measurements. Based on an extensive literature study which is partially reflected in MOVE (2009), we decided to base our quest for spatial indicators preferably on measurable and mappable spatial variables such as area, range, distance, direction, spatial geometries and patterns, spatial connectivity, isolation, diffusion, spatial associations, and scale of the affected area and surroundings (Abler et al. 1971;Meentemeyer, 1989).

Several indices have been developed to measure vulnerability, but only few studies yielded a recovery index. Since large-scale disasters are relatively rare it is difficult to accumulate the information and the experience 'across disasters' and to create a more generic model to evaluate recovery processes (Karatani and Hayashi, 2007). Some of the major hazards of the 20th and 21st century have been carefully studied and documented like the Kobe earthquake but the status quo of establishing benchmarks is not satisfying; to our knowledge there are no agreed protocols or benchmarks for recovery phases and it is repeatedly argued that every recovery phase is a unique combination of various external forces and disaster prevention policies applied in the area. Furthermore the recovery phase is determined by the unique history of the area (Karatani and Hayashi, 2007). Therefore, we proposed to develop a methodology for the recovery phase which includes pre-disaster vulnerability measures.

METHODOLOGY

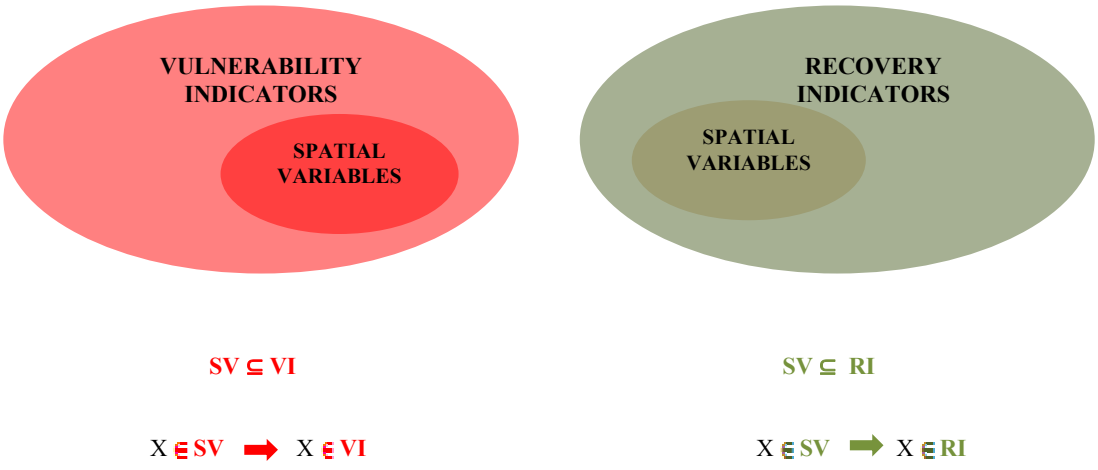
The methodology consists of four steps: the first step comprises of a review of vulnerability and recovery indicators. We take the vulnerability indicators identified in the MOVE project as a starting point. The MOVE project aims to develop methods for improving vulnerability assessments to natural hazards in Europe and establish a consistent framework. The case study areas of Barcelona (Spain) and Florence (Italy) are dedicated to identify earthquake vulnerability indicators; nevertheless it needs to be emphasized that this does not mean that some indicators are tied to a particular hazard. Rather, some indicators are more relevant to particular hazards and to particular case studies.

Recovery indicators are identified from secondary sources such as a) scientific publications which address the cases of Kobe and some cities in Italy, b) from periodical situation reports from Haiti and Chile issued by OCHA and c) the Magazine "Noi Abruzzo" published by the commissioner of the reconstruction in L'Aquila (Italy), which is the case study area of the present research.

For both cases, vulnerability and recovery, indicators are aggregated according to the following dimensions of susceptibility: physical, social, economic, cultural, institutional and ecological. The graphic and mathematical concept of selection of common indicators is depicted in figure 1.

The second step is an analysis to identify which of these indicators are based on spatial variables or which one they can be spatially mapped; the graphics and mathematical concepts of this step is shown in figure 1.

VI = Vulnerability Indicators
RI = Recovery Indicators
X = Variable

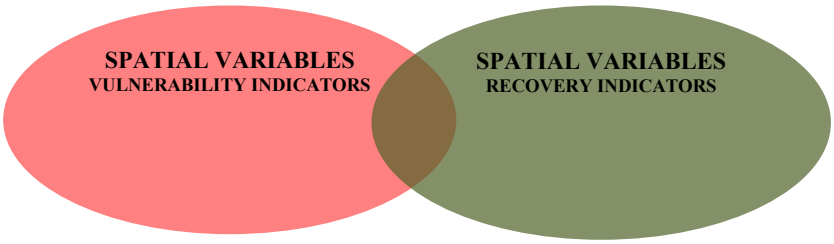


Spatial variables are a subset of vulnerability indicators. **Spatial variables are a subset of recovery indicators.**

Figure 1. Defining spatial variables into the set of vulnerability and recovery indicators.

The third step is to find the common variables among the subsets of spatial variables from vulnerability indicators and the spatial variables from recovery indicators. The concept of this step is depicted in figure 2.

VI = Vulnerability Indicators
RI = Recovery Indicators



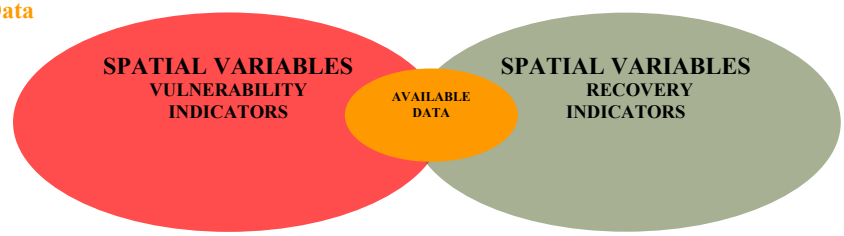
SVVI ∩ SVRI

SVVI ∩ SVRI is a set which has "spatial variables" from the "vulnerability indicators" in common with "spatial variables" from the "recovery indicators".

Figure 2. Defining spatial variables in common between vulnerability and recovery indicators.

The fourth step more pragmatic, but may sometimes limit the methodology and the respective results significantly: is an investigation of the availability of data to carry out spatial and statistical analyses and, subsequently, to determine the most suitable techniques in both cases. The concept is represented in figure 3.

VI = Vulnerability Indicators
RI = Recovery Indicators
AD = Available Data



AD ⊆ SVVI ∩ SVRI

AD is a subset of **SVVI ∩ SVRI**

Figure 3. Defining available data to measure spatial variables in common between vulnerability and recovery indicators.

INITIAL RESULTS

Table 1 shows a preliminary list of relevant indicators identified for the vulnerability assessment task in regard to earthquakes in the MOVE project; while table 2 displays a list of recovery indicators identified in the literature review and in the fieldwork of the case study area in L'Aquila, as it was mentioned before.

DIMENSION	INDICATORS
Physical	Network size, structural typology, roof type, built-up year, mezzanine type, maintenance condition, use; total housing units, proportion of buildings in hazards zones, population density.

DIMENSION	INDICATORS
Social	People living in hazard areas; residents per doctor, hospital beds, average time from each house to the closest facility, people with access to medical services; health status of the population, women head of households, children, elders, physically or mentally challenged people, immigrants; birth rate, population growth rate, mortality rate, total population, average of people per household; per capita income; elementary schools per resident.
Economic	Public assistance programs; jobs generated and industries located in the hazard areas, unemployment rate, key funds allocation; shops or stores located on hazard areas and jobs generated, municipality debts per resident, Gross Domestic Product (GDP) per capita.

Table 1. Vulnerability indicators identified in the MOVE project (Hazard: Earthquakes).

Recovery indicators identified in the literature and proposed by the authors are shown in table 2.

DIMENSION	INDICATORS
Physical	Degree of damage, secondary effects, provisional measures, restoration, improvement, homeless people, temporary shelters required, repaired houses, new built-up houses, retrofitted houses, recuperation of damaged areas, changes in the land use due to policies formulated with the aim of reducing the seismic risk, degree of decentralization of urban functions, new density conditions, creation of more public spaces and urban equipment.
Social	Hospitals beds, field hospitals required, hospitals repaired and/or retrofitted, hospitals with emergency plans and hospitals built-up with seismic criteria, improvement in the capacity and the quality of the services of the hospitals; casualties, injuries, population assisted, epidemics, vaccination campaign, special plans to assist the most vulnerable population, population with a satisfactory level of recuperation, special plans to assist the most vulnerable population; birth rate, population growth rate, mortality rate, total population, average of people per household; social welfare recipients, income per capita; schools available, tents required, schools repaired and/or retrofitted, schools with emergency plans, improvement in the capacity and quality of educations and schools built-up with seismic criteria.
Economic	Public support, financial incentives, improvement of infrastructure of irrigation land and/or docks capacity; disaster support funds, disaster compensation funds, job opening, job applicants; supermarkets available, supermarkets in works, disaster relief loans, access to loan, number of bankruptcies, retrofitted works in supermarkets, supermarkets with emergency plans, bank lending outstanding, number of bankruptcies, Gross Domestic Product (GDP) per capita.

Table 2. Recovery indicators considered.

The current tasks include the selection of a set of indicators based on spatial variables or that can be spatially mapped, and then choose indicators common to both vulnerability and recovery assessments. The final set of indicators needs to be proved in L'Aquila at the end of the present research, in order to measure the performance of the recovery process and to be in accordance with the recovery indicators established in literature.

INITIAL CONCLUSION

- Recovery indicators based on vulnerability indices need to rely on base-line data. They must prove whether or not the recovery process reaches the "pre-disaster" state, or if it goes even beyond this and may improve the conditions by reducing the same risk for the future.
- Reducing the set of indicators to the indicators represented in a spatial context and the indicators with common features of vulnerability and recovery indices – as suggested in our methodology – bears the risk to ignore some important single indicators; nevertheless, the added value of the on-going research is to show the advantages of using indicators based on spatial variables to monitoring and evaluate a recovery process. Furthermore, some indicators are usually assessed in the recovery time, but are not a part of a vulnerability assessment.

- In this methodology we argue for spatially explicit indicators. They will in most cases rely on physical aspects whereas the recovery indices need to look beyond the physical aspects in order to reflect the social and economic conditions of people along the period of the recovery process. The proposed methodology is based on extensive literature studies but needs further review in terms of the selection criteria of the indicators.

CONTRIBUTION OF THE PAPER

This paper presents a new approach to develop a recovery index based on spatial vulnerability indicators focused on spatial variables. It aims at generating a benchmark for future recovery processes but may also validate recovery indicators formulated in the pre-existent literature.

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