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The ANDROID case study; Venice and its territory: vulnerability and resilience in multi-hazard scenarios

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Abstract

The setting up of a framework for the vulnerability assessment in the case of Venice offers significant challenges in order to investigate the ability of the environment including the built environment, to anticipate and respond to the hazards identified, in view of unexpected events that may damage Venice and the surrounding territory. The hazards which can be experienced in the area are various, including earthquake, tsunami/meteo-tsunami, flooding, sea level rise (related to global warming, subsidence, coastal erosion, salt wedge intrusion), release of toxic substances from chemical plants, pollution, conservation of monuments and the impact of tourism. The resilience of the environment refers to key issues including ecology, economy, tourism and industry, society and the population, construction and infrastructure, cultural heritage. The paper includes a review of literature aiming at the definition of vulnerability and resilience. Reference is made to specific frameworks which are identified, with a special focus on MOVE - *Methods for the improvement of vulnerability assessment in Europe* presented as a conceptual framework for a holistic approach to disaster risk assessment and management. *MOVE* arose from the need to develop methods and indicators for improving vulnerability assessments to natural hazards in Europe, and established a consistent framework. In addition relevant experiences are analysed including the Regional Risk Assessment (RRA) for the North Adriatic Coast in Italy, the post-earthquake reconstruction plan for the Arsita Municipality (Abruzzo) in Italy and the UNISDR Program "Making Cities Resilient". The approach for vulnerability analysis and overall system resilience for Venice and its territory needs to cover a wide spectrum and is complicated. The review sets the framework, for the vulnerability assessment and the overall resilience analysis with reference to Venice and the surrounding North Adriatic area.

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Keywords: North Adriatic, Vulnerability Assessment, System Resilience, Hazard

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1. Introduction

ANDROID is an Erasmus academic network that aims to promote co-operation and innovation among European Higher Education to increase society's resilience to disasters of human and natural origin. Venice and its territory have been selected as a representative case study of a region including Italy, Slovenia and Croatia that could be affected by cross-border catastrophic events. This paper is part of a group of four articles, presented jointly at the "*4th International Conference on Building Resilience*"; with the other three presented by Indirli et al. (2014), Knezić et al. (2014) and Kaluarachchi et al. (2014). Venice is located in Italy's north-eastern coast at the northern end of the Adriatic Sea. The Adriatic forms a long, narrow, semi-enclosed section of the Mediterranean Sea between the eastern coast of Italy and the Balkans (Scearce, 2007). The Lagoon of Venice, which covers an area of about 500 km^2 and which has an average depth of approximately 1 meter, represents the major wetland connected to the basin (Lovato et al. 2010). The lagoon is a 52 km long and 8–14 km wide shallow water body. It is linked to the northern Adriatic Sea by three inlets namely Lido, Malamocco and Chioggia (Zonta et al., 2005). The lagoon of Venice, the largest of Mediterranean Sea, is not so different from many other tidal lagoons in the world and it is also subject to similar threats due to both natural processes and to also anthropic actions (Campostrini, 2004). Many natural phenomena, which are also accentuated by anthropic actions, have contributed towards a critical situation in Venice and its lagoon. Sea-level rise, subsidence, erosion, pollution, fishery activity, and wave motion have all contributed to the general crisis situation of the Venetian lagoon system (Deheyn et al. 2007). Venice is susceptible to various hazards. In a near future, several hazard scenarios are expected to occur and threaten Venice and its Lagoon on several fronts (environment, society/economy, infrastructures/buildings). Thus, the lagoon presents a highly complex case, and the Venice problem is representative of similar critical situations today, representing not just environmental complexity but also legislative, scientific, and institutional intricacy (Deheyn et al., 2007). In principle, the built environment comprises the substantive physical framework for human society to function in its many aspects including social, economic, political, and institutional (Geis 2000). As the population density increases, more utilities, transportation systems, and dwellings are required, with consequential increase in the potential for catastrophic losses due to disaster and extreme events (Mileti 1999).

Overall system resilience, a concept which originated in psychology during the 1970s, has already been used in social-ecology. Venice and its territory in the North Adriatic region is considered as a representative case for the assessment of vulnerability and overall resilience, i.e. the ability of environment and construction to anticipate and respond to the hazards identified, in view of unexpected events that may occur.

2. Hazard and multi-hazard scenarios

Various hazards can be experienced in the North Adriatic and the Venice region area and include earthquake, tsunami and meteo-tsunami, flooding and sea level rise as related to global warming, subsidence, coastal erosion, salt wedge intrusion, release of toxic substances from chemical plants, pollution and conservation of monuments and tourism impact. On the basis of a review of literature for the present study, reference is made in particular to earthquakes and tsunamis, subsidence, pollution, flooding and "aqua alta", salt intrusion and coastal erosion (see Table 1, adapted from Knezić et al. 2014). A couple of multi-hazard scenarios, in this complex context are described again in Knezić et al. (2014). As a result of climate change, there is also the strong evidence that global warming is likely to have significant impacts on coastal communities and ecosystems. Sea-level rise, increase in storm frequency, changes in water quality and coastal erosion are projected to pose increasing threats to population, infrastructure, beaches, wetlands, and ecosystems. At the same time, coastal zones represent an irreplaceable and fragile ecological, economic and social resource that needs to be protected from the increasing depletion of resources, conflicts between uses, and natural ecosystems degradation. Innovative, integrated and multidisciplinary approaches are expected to support the preservation, planning and sustainable management. In addition, climate change impacts in coastal zones are very much dependent on regional geographical and environmental features, climate, and socio-economic conditions. Therefore, impact studies should be performed at the local or, at most, at the regional level (Torresan, 2011).The particular circumstances of Venice and the lagoon, the effect of multi-hazard scenarios, including the increasing threats due to climate change, offer significant challenges in assessing the vulnerability and system resilience and in planning adaptation and mitigation measures (Kaluarachchi et al., 2014).

Table 1. Classification of the hazardous events in Venice and its Territory . Adapted from Knezić et al.(2014).

	Origin / Source	Environmental Impact	Built Environment Impact	Socio - Economic Impact
Earth-quake	▪ Tectonic movements	▪ Land subsidence ▪ Tsunami.	▪ Damage. ▪ Structural Failure. ▪ Cultural heritage	▪ Casualties ▪ Displaced population ▪ Economic losses
Acqua Alta	▪ Low air-pressure ▪ Scirocco wind, Bora wind ▪ Luni-solar astronomical forces ▪ Seiche phenomenon ▪ Combination of natural phenomena	▪ Flooding &water level increase of salt marshes. ▪ Endangered habitats. Change of water salinity. Island and channel erosion. ▪ Pollutants discharge. ▪ Change in ecological parameters	▪ Flooding influences - sewage system, roads, harbours, terrain and sub-terrain levels of buildings. ▪ Cultural heritage ▪ Sea salt impregnated walls- building material degradation incl. mortar, marble, limestone, brick.	▪ Economic impact, flooding affecting tourism, destroyed stocks, fish farms, supply chains. ▪ Loss/damage of property. ▪ Psychological impacts
Subsidence	▪ Acqua alta ▪ Groundwater over-extraction ▪ Geomorphologic processes ▪ Geochemical processes ▪ Earthquake ▪ Building surcharge & ground subsidence.	▪ Sea level rise	▪ Damage to built environment (buildings, roads, public facilities, heritage structures)	▪ Impact on economy – Tourism ▪ Impact on society ▪ Loss/damage of housing and property ▪ Psychological impact
Coastal erosion	▪ Acqua alta ▪ Wave action generated by sea craft.	▪ Loss of sediments, Surface area of salt marshes. ▪ Creation of tsunami	▪ Damage to infrastructure, built environment and cultural heritage.	▪ Economic losses
Salt intrusion	▪ Acqua alta ▪ Lowering of water table - Over-extraction of ground water reserves. ▪ Land subsidence	▪ Decline of water quality	▪ Cultural heritage ▪ Sea salt impregnated walls- building material degradation incl. mortar, marble, limestone, brick.	▪ Economic impact of maintenance and building management ▪ Threat to human health
Pollution	▪ Chemical industry Metallurgic industry ▪ Harbours - oil spills ▪ Sewage systems ▪ Porto Marghera discharge (heavy metals, oil, chemical products) ▪ City waste discharge ▪ Drainage basins from agriculture, livestock farms ▪ Water treatment plants ▪ Aerosols ▪ Urban waste incineration ▪ Traffic emissions	▪ Eutrophication of the lagoon- algal blooms and anoxic events ▪ Ecotoxicity ▪ Reduction of biodiversity ▪ Impacts on ecosystem services. ▪ Stored in sediments.	▪ Cultural heritage ▪ Air quality & Buildings	▪ Tourism ▪ Fisheries ▪ Loss from reduction of ecosystem services ▪ Threats to human health

3. Definition of vulnerability, risk, and resilience

3.1. Generalities

The concepts of vulnerability and risk are not new, but have been discussed in different communities already for several decades. In the disaster risk management field, it became obvious, during the 1990s, that disasters are not the sole result of natural hazard magnitude/intensity; in fact, a variety of society development-related aspects play an important role (Wisner et al. 2004; Alexander 2000; Birkmann 2013). The resilience approach was, amongst others, initially used in psychology (e.g. Garmezy et al. 1984; Rutter 1985) and ecology (e.g. Holling 1973); it became more popular in the field of disaster risk reduction during the last couple of years. Both vulnerability and resilience concepts/definitions have been addressed in a broad variety of scientific writings (Wisner et al. 2004; Bohle 2001;

Turner et al. 2003; Birkmann 2006 and 2013; as well as Paton and Johnston 2000; Klein et al. 2003; Adger et al. 2005; Cutter et al. 2008), while concrete definitions and conceptualization broadly vary. In general, vulnerability is understood as a lack of a system's capacity to deal with a natural hazard (e.g. UNISDR 2009), while resilience tends to focus on the existing abilities to resist, absorb, react, accommodate to, and recover from the effects of a hazards. Discussions as to how far vulnerability and resilience concepts have to be delineated or do overlap are ongoing (Cutter et al. 2008; Cardona 2011; Birkmann 2013). Despite a theoretic debate about the conceptualization of vulnerability and resilience, their application for assessment purposes is a different topic. Although the ability to measure vulnerability and resilience, in order to reduce disaster risk, was already made a priority in the Hyogo Framework for Action (UNISDR 2007), a concise and universal measurement methodology is still lacking. This is, on the one hand, owed to different conceptual approaches. On the other hand, different dimensions encompassing institutional as well as societal or technical aspects have to be addressed and quantitative data are often missing (Birkmann 2006 and 2013). As a result, the assessment of vulnerability and resilience does not only have to face conceptual challenges, but might also have to integrate qualitative aspects in order to be as encompassing as possible.

3.2. Vulnerability, Resilience and Adaptive Capacity

Within the context of disasters, vulnerability is generally described as the human product of any physical exposure to a disaster, that results in some degree of loss, combined with the human capacity to withstand, prepare for and recover from that same event. It takes into account the relative degree of 'risk, susceptibility, resistance and resilience' to a hazardous event. Vulnerability is a function of the exposure (who or what is at risk) and the system sensitivity (the degree to which people and places can be harmed), as well as the property named adaptive capacity (Cutter et al., 2008).

Exposure represents the risks that the local community is facing and how much a system is stressed. The severity of the stress is often measured by: magnitude, frequency, duration, and spatial extent.

Sensitivity addresses how much the stressors actually modify/affect the studied system. A sensitivity analysis of the sectors/areas that are most significantly affected is usually conducted as a part of the vulnerability assessment.

Adaptive capacity depicts the ability of a system to adjust in order to moderate potential damages and cope with the consequences (IPCC, 2001b). This includes issues of social capital, governance and coping experience, i.e. the role of institutions. Adaptive capacity is defined by Starr et al. (2004) as the ability of an enterprise to modify its "strategy, operations, management systems, governance structure and decision-support capabilities" to withstand perturbations and disruptions.

One can consider basic concepts as presented by Birkmann (2006 and 2013). *Exposure* describes the extent to which a unit of assessment falls within the geographical range of a hazardous event; exposure extends to fixed physical attributes of social systems (infrastructure), but also human systems (livelihoods, economies, cultures), that are spatially bound to specific resources and practices that may also be exposed. Then, exposure is qualified in terms of spatial and temporal patterns. *Susceptibility* (or fragility) describes the predisposition of elements at risk (social and ecological) to suffer harm. Although susceptibility and fragility imply subtle differences in various concepts, these can be used synonymously, in order to emphasize the core differences between exposure, susceptibility and lack of resilience. In this context, susceptibility (or fragility) can be calculated and addressed often independently of exposure. *Lack of resilience*, or societal response capacity, is determined by limitations in terms of access to and mobilization of the resources of a community or a social-ecological system in responding to an identified hazard. This includes pre-event risk reduction, in-time coping, and post-event response measures. Compared to adaptation processes and adaptive capacities, these concepts focus mainly on the ability to maintain the system in the light of a hazard event impacting the system or element exposed. In this sense, the capacity to anticipate, cope and recover can include significant changes to existing practices around a referent hazard event/scenario, but does not include learning based on the potential for future change in hazard and vulnerability contexts.

Resilience, vulnerability and adaptive capacity are closely linked terms. The conceptual interconnections are shown in Fig. 1. According to some researchers, resilience is an integral part of adaptive capacity. Adaptive capacity is a distinguished property within the resilience concept from the view of global climate change, but it is less important in the hazard perspective (Cutter et al., 2008).

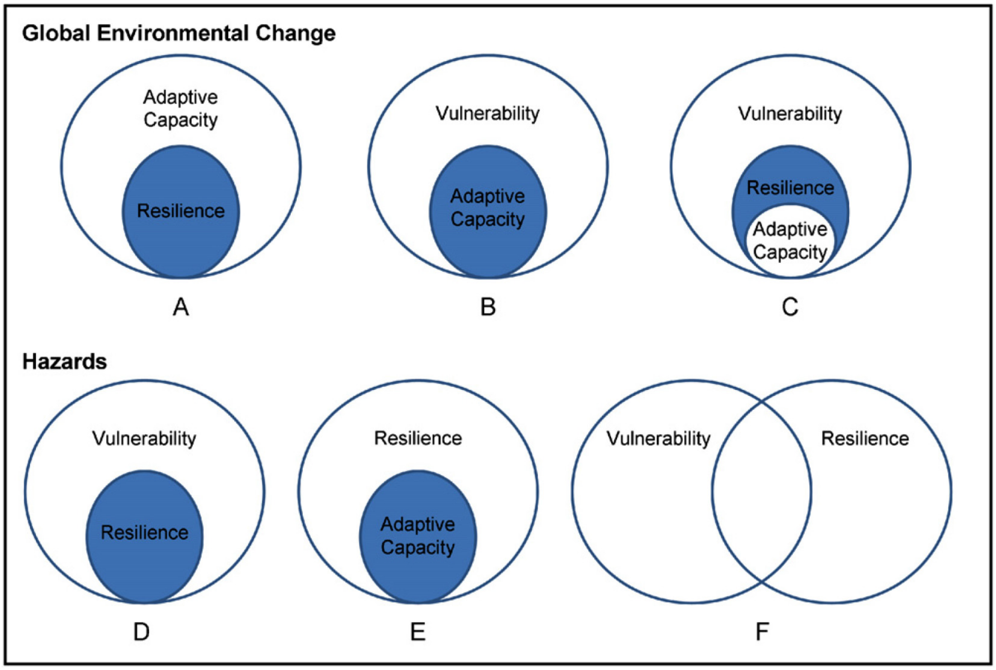

Fig. 1. Interconnections between terms “vulnerability”, “resilience” and “adaptive capacity” (Cutter et al, 2008).

3.3. Vulnerability Assessment

Although progress has been made with respect to the integration of different disciplines and conceptualizations of resilience and vulnerability, the implementation of assessment methodologies remains fragmented, specifically also with respect to the use measures and technological applications. The challenge in development of techniques for resilience measurements lays in its complex nature. Before performing the resilience assessment it is necessary to answer the question: the resilience of “what” and “to what” should be measured, and what is particularly understood by the term “resilience”. In addition, the choice of methodology depends on a particular case for assessment, as well as on the availability of data. The resilience assessment framework consists of several obligatory steps. First of all, the type of system (in other words, an object of assessment) should be defined. The main components and features of the system should be described. It is important to understand the main function (or functions) or services provided by the system. The type of potential disaster or extreme condition, as well as possible effects from the occurrence of the disaster should be determined, depending on the relevance to the particular system and environmental conditions. Different qualitative and quantitative methods for vulnerability assessment have been developed and applied. However, the field of resilience assessment is still in the development stage. Existing methods (each one has its own advantages and disadvantages) include: i) different approaches of Multi-Criteria analysis; ii) use of probability functions; iii) System Dynamics modelling; iv) Geographic Information System (GIS). A relevant work (Chen et al. 2008) presented the method for assessment of community resilience, based on constructing the hierarchies in order to systemize and simplify complex issues. The study developed the hierarchic structure for 5 levels of *Disaster Resilience Capacity* (DRC). The top level is DRC of communities; the second includes the factors associated with disaster resilience of communities, i.e. *Communities Preparedness for Disaster*(CPD) and *Community Environmental Conditions* (CEC). The CPD criteria include emergency response capabilities, warning and report systems. The CEC criteria are used to determine the hazard of disaster in the specific region. Spatial thinking and disaster risk reduction are inherently complementary to each other. Effective disaster risk management relies fundamentally on how we comprehend our life’s, physical and intellectual spaces. The use of GIS systems is very common and frequently applied into vulnerability assessments. Some authors (Berse et al. 2011) performed a research based on use of GIS maps; to provide understanding of the earthquake risk to the city, which poses the biggest threat to Kathmandu's development, GIS-generated maps were collected, revised and reproduced. The research was supplemented by field work. Other authors (Bell et al. 2012) used a raster-based approach to assess the risks of single hazard and multi-hazard processes. The calculation of the natural risk (Bell et al. 2012) can be based on these input parameters: hazard (H), vulnerability (of people, Vpe; property, Vp;, infrastructure, Vstr; powerline, Vpo), probability of the spatial impact (Ps), probability of the temporal impact (Pt), probability of the seasonal occurrence (Pso), and damage potential (number of people, Epe or Eipe), economic value, Ep). Another example is given in Indirli (2009) for the city of Valparaiso (Chile).A method adopting spatial multi-criteria techniques and considering functional, social, morphological, geological and dimensional characteristics of the urban system has been presented in Tilio et al. (2012). The approach represents a combination of methods, such as use of GIS and multi-criteria analysis. Various researches tried to express the risk and resilience through the number of probability functions. Cimellaro et al. (2010) developed a quality function to describe structural performance of power transmission networks for earthquakes and for the first time have interconnected probability functions, fragilities and resilience in a single integrated approach for acute care facilities under the occurrence of earthquakes. Ouyang (2012) presented the assessment method based on Poisson modelling. Authors have developed a novel time-dependent expected annual resilience (AR) metric for infrastructure, which is the mean ratio of the area between the real performance curve and the time axis to the area between the target performance curve and the time axis during a year. Henry and Ramirez-Marquez (2012) have developed an easy understandable and clear quantitative approach for the resilience assessment based on the basic meaning of the term "resilience" as the ability to "bounce back", e.g. to recover. Their suggested resilience concept (describing the functionality of a system as the ability to deliver products or services) is the ratio of recovery at time t to loss at some previous point of time t_d, and is expressed by a simple formula:

$$R(t)=Recovery(t)/Loss(t_d) \tag{1}$$

Todini (2000) analysed urban water distribution systems that are designed as a series of interconnected closed loops in order to increase the reliability. The question was formulated as a vector optimization problem, with cost and resilience as two objective functions that produces a Pareto set of optimal solutions.

3.4. The MOVE framework

In order to address some of the aspects mentioned, approaches have been adopted to integrate different conceptualizations of vulnerability and resilience, including a variety of disciplines in the disaster risk management field. One of these approaches is *MOVE* (MOVE, 2011), an EU Project (*MOVE*, *Methods for the improvement of vulnerability assessment in Europe*), which brings together aspects from political economy, social ecology, vulnerability and risk research, as well as from the climate change systems. Additionally, it also integrates resilience aspects; it was designed for different perspectives, including physical as well as economic and institutional dimensions (Birkmann et al. 2006 and 2013). *MOVE* arose from the need to develop methods and indicators for improving vulnerability assessments to natural hazards in Europe, and established a consistent framework. Therefore, one of the *MOVE* main deliverables is the web-based indicators metadata database (*MOVE wb-db*, Fig. 2), to support the transformation of research results into a suitable format for dissemination. *MOVE wb-db* comprises the indicators to assess vulnerability in the seven case study areas involved in the project (Barcelona, Spain; Salzach River, Salzburg, Austria; Prato, Pistoia, Florence Lucca, Italy; Cologne/Bonn, Germany; London, United Kingdom; North-Western Portugal, Portugal; South Tyrol, Province of Bolzano, Italy). The query tool of *MOVE wb-db* allows people to search for indicators to assess vulnerability, but also in relation with risk, risk governance and adaptation; furthermore, it offers the possibility to look for indicators in different dimensions/capacities in the vulnerability domain, as well as indicators related with the potential impacts of risk, factors included in risk governance and the interventions required for adaptation. Currently, *MOVE wb-db* has registered 260 indicators; 85% (220) corresponds to single indicators; the others 25% (40) are composite ones. In order to define the queries, it is important to take into account that there are four kinds of hierarchies, defined by colours. The main hierarchy (*grey*) is used for the main concepts: vulnerability, risk, risk governance and adaptation. The second hierarchy (*green*) is allocated for the vulnerability causal factors (exposure, susceptibility, fragility, lack of resilience), or risk potential impacts (economic, social, environmental, etc.); in the case of risk governance, the green colour is only for organization; for adaptation, instead, the green boxes are available for hazard/vulnerability intervention. The third hierarchy (*yellow*) is available only for the vulnerability causal factors, such as: temporal and spatial (exposure); physical, ecological, social, economic, cultural and institutional dimensions (susceptibility/fragility); or the capacities to anticipate, cope and recover (lack of resilience). A final category (*red*) is the scale; it is common for all the categories, as can be appreciated in the conceptual framework. All the partners involved in *MOVE* invite a wide audience to consult *MOVE wb-db*, in order to improve the methodologies to assess vulnerability in Europe, and contribute to the risk reduction and life protection all over the world. It must be pointed out that the MOVE framework was developed for natural hazards only. However, the integration of additional components including Climate Change and anthropogenic aspects (tourism, pollution, etc.) can be foreseen, as necessary for realistic multi-hazard scenarios.

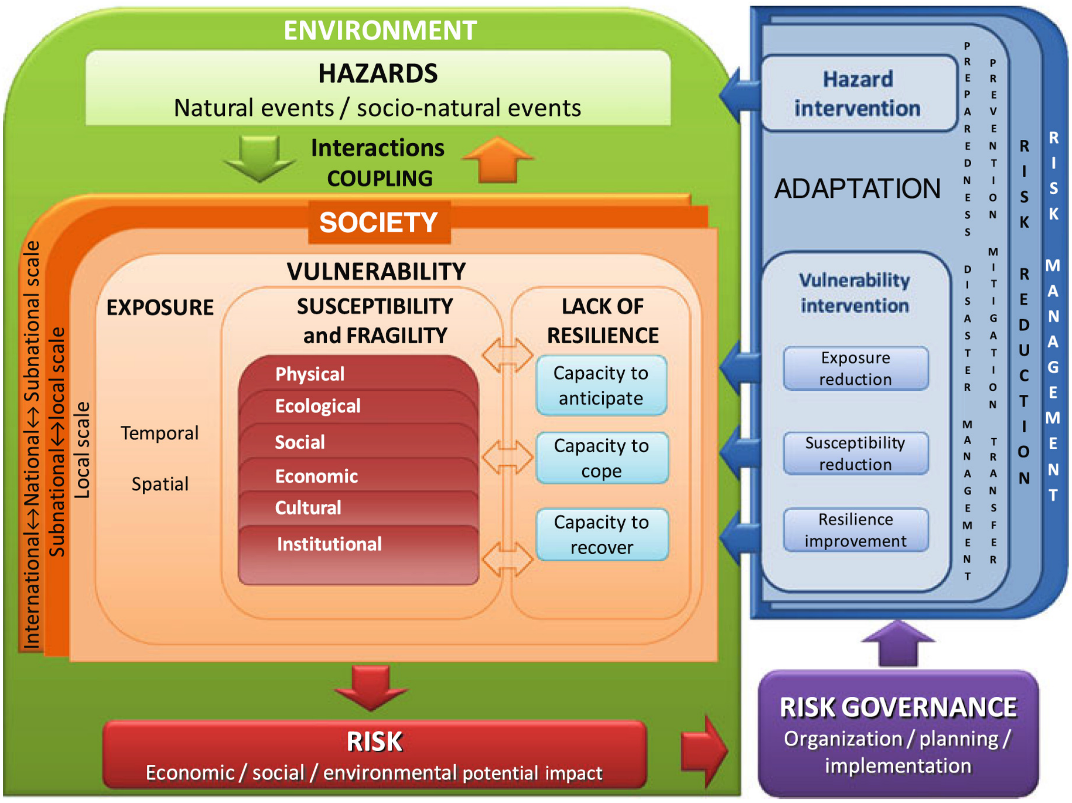

Fig. 2. Conceptual Framework for a holistic approach to disaster risk assessment and management (MOVE, 2011; Birkmann et al., 2013).

4. Examples of frameworks for vulnerability and overall system resilience

Reference is made to specific frameworks which are identified, with a special focus on *MOVE - Methods for the improvement of vulnerability assessment in Europe* (MOVE 2011) as a conceptual framework for a holistic approach to disaster risk assessment and management. Relevant experiences are analysed including the Regional Risk Assessment (RRA) for the North Adriatic Coast in Italy (Torresan, 201), the post-earthquake reconstruction plan for the Arsita Municipality (Abruzzo) in Italy (Indirli et al 2014) and the UNISDR Program "Making Cities Resilient" (UNISDR, 2009).

4.1. The Regional Risk Assessment (RRA) for the North Adriatic coast in Italy

Torresan (2011) presented a *Regional Risk Assessment* (RRA) methodology for the integrated assessment of climate change impacts in coastal zones at the regional scale and its application to the case study of the North Adriatic coast in Italy. Specifically, this RRA has been applied for the assessment and prioritization of targets and areas at risks in relation to possible sea-level rise and erosion impacts, considering a climate change scenario for the period 2070-2100 in the North Adriatic coastal area. The main strength of the proposed approach consists in the use of outputs coming from a multi-model chain, in order to gain information about the spatial and temporal distribution of climate change hazards at the regional scale (e.g. sea-level rise projections, wave height and bottom stress). Moreover, the originality of the approach consist in the use of *Multi-Criteria Decision Analysis*(MCDA) techniques in order to obtain relative rankings of targets and areas at risk in the examined coastal territory and to identify homogeneous geographic sites for the definition of adaptation and management strategies. GIS allowed a detailed analysis of the results and the estimation of several indicators and statistics for key coastal targets and administrative units (e.g. km^2 of beaches at higher risk for each coastal municipality; percentage of residential buildings and commercial buildings with higher damage in the considered region). On the whole, the RRA outputs (i.e. exposure, susceptibility, risk and damage maps) and the related indicators can be considered as a first-pass assessment for the spatial identification of areas and targets at higher risk from climate change and for the definition of sustainable management options at the regional (i.e. sub-national) scale. In order to properly use the RRA results, it is important to underline that the rankings produced by the methodology are unit less numbers, expressed in qualitative classes (i.e. very high, high, medium, low, very low), that assess the relative degree of risk and damage for the analysed receptors. Accordingly, regional risk and damage classifications do not provide absolute predictions about the impacts of climate change, rather they are relative indices which provide information about the sub-areas and targets within a region that are more likely to be affected by climate change impacts than others. The methodology takes into account of geographical information at the regional scale, requiring a great effort to deal with a huge amount of data at a detailed spatial resolution. Torresan (2011) reported that numerical models simulations used for the construction of climate change hazard scenarios and exposure maps have been validated through the comparison with observed data for a control period (Gualdi et al. 2008; Djurdjevic et al. 2008).

An important issue is related to the collection and organization of data coming from different sources into homogeneous formats for the whole case study area. In fact, it was necessary to perform a huge pre-processing phase in order to manage information with different geographic coordinate systems and allow the GIS overlay and calculations. All these steps represent potential sources of uncertainty and of geometrical errors in the final risk estimate. Future improvements of the methodology can be obtained by eliciting more potential receptors and extending their subset of vulnerability factors. Furthermore, the consistency of results provided by the methodology can be properly tested trough a sensitivity analysis allowing the ascertainment of how much the output of the assessment could be influenced by its input parameters (i.e. scores and weights).

It is noted that a relevant feature of the methodology is represented by its flexibility to manage input data (i.e. raster or shape files) provided by different numerical models and vulnerability datasets. This characteristic allows the methodology to be in principle applied at different spatial scales (i.e. from the local to the national and supra-national scales) and to be updated with the analysis of new climate change impacts on further ecosystems (e.g. groundwater, river basins, human health etc.). Moreover, based on available data and models, the methodology could be improved considering not only scenarios of climate change but also land use and population dynamics. It has also the potential to be integrated with socio-economic models in order to obtain a quantitative estimation of damages and losses associated with climate related impacts. Finally, the proposed methodology can take advantage from the involvement of stakeholders early in the process in order to improve the exchange of knowledge on relevant climate-related risks, to identify well defined needs and data gaps at the regional to local scale, and better support decision making processes in a climate service perspective (Torresan 2011).

4.2. The post-earthquake reconstruction plan for the Arsita Municipality (Abruzzo) in Italy

Two years after the 2009 earthquake, a scientific team set up by ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development; coordination), with the partnership of the Universities of Pescara-Chieti "G. d'Annunzio", Naples "Federico II" and Ferrara, was entrusted by the Municipality of Arsita to conduct both site based and off-site activities in relation to the post-earthquake reconstruction plan (RP). The activity refers to multi-disciplinary methodologies and skills, already adopted in previous projects (Indirli 2009). It was based on integrated approaches and refers to the following phases:

a) first phase

- general remarks; geographic background/site classification; hazards identification; acquisition and homogenisation of cartographic and photogrammetric data;

b) second phase

- sociological and ethnographical investigation;
- identification of urban aggregates and structural units interested by the RP;
- analysis of historic documentation; study of the evolution of the built environment;
- topographic, laser scanner, photographic surveys; urban planning/architectonic analyses of construction stock and open spaces;
- check and digitisation of damage/safety forms, drafted by the Civil Protection teams during the emergency;
- investigation of masonry typologies and damage patterns, by using a specific form; definition of a masonry abacus of local construction techniques;
- choice of quick methodologies to evaluate the structural vulnerability;

c) third phase

- geological, geo-morphological, hydro-geological investigations; suggestion of actions devoted to risk reduction;
- environmental, architectonic, urban planning studies/proposals to enhance town aesthetic appearance, sustainable development, life quality, economic growth;
- construction vulnerability analyses; use of compatible techniques and materials; identification of diagnostic test packages to be arranged by designers to deepen soil/building knowledge of the historic centre aggregates; maps/sketches for strengthening/restoring projects to be prepared afterwards in detail by the designers;
- organisation of the reconstruction consortia among the owners;
- analysis of lifeline/infrastructure layouts and proposals to improve their efficiency;
- identification of disposal and storage procedures/sites for debris and hazardous materials;
- identification and management of yard work areas; time schedule;
- rough computation of reconstruction costs.

During the whole activity, a GIS/WEBGIS database/building inventory was set up and a 3D model of the historic centre of Arista was completed.. The reconstruction plan has been definitively approved by the Arsita Municipality Council and the Regional Authority during Summer 2014 (Indirli et al 2014, and references therein).

4.3. Venice and the UNISDR Program "Making Cities Resilient"

The City of Venice takes part to the UNISDR Program "*Making Cities Resilient: My City is getting ready*". The main results concerning the implementation of the Hyogo Framework for Action (HFA) and 10 Essentials for Making Cities Resilient (2011-2013) are specifically reported in Kaluarachchi et al. (2014).

5. Conclusions

The paper presents preliminary insights regarding the assessment of vulnerability and overall system resilience with reference to multi-hazard events in the context of Venice its lagoon and territories in the North Adriatic region. The assessment of system resilience requires a framework adapted to multi-hazard scenarios, referring to both natural disasters and anthropogenic actions. Various challenges are identified including the collection of comprehensive data and the organization of information coming from different sources into homogeneous formats for the whole system. The Hyogo Framework sets the scene for the measurement of resilience to deal with potential unpredicted disruptive events to decrease the overall risk and risk management. However, multi-hazard scenarios offer significant challenges and necessitate a more comprehensive tool for overall resilience of the built environment, covering different levels including societal, economic, technical and policy/institutional criteria. Limitations in the process refer to the lack of quantitative data to assemble the complete/comprehensive system required for overall resilience assessment. Finally, some examples of frameworks have been provided, with a special focus on *MOVE* (*Methods for the improvement of vulnerability assessment in Europe*, MOVE 2011) and other significant experiences (Torresan 2011; Indirli et al 2014). In addition, an overview on mitigation measures for Venice and its territory is given in Kaluarachchi et al. (2014).

The work to be done in the future concerning vulnerability and overall system resilience for Venice and its territory needs to cover a wide spectrum and is complicated. The aim of the authors is to set the scene for further assessment through the collaborative activity proposed in the set of four articles regarding Venice, presented jointly at the "*4th International Conference on Building Resilience*" (Indirli et al. 2014; Knezić et al. 2014; Borg et al. 2014; Kaluarachchi et al. 2014). The articles represent the final result of the activities of the ANDROID Network Working Package 7 and are intended to constitute a starting point for discussion and future development.

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