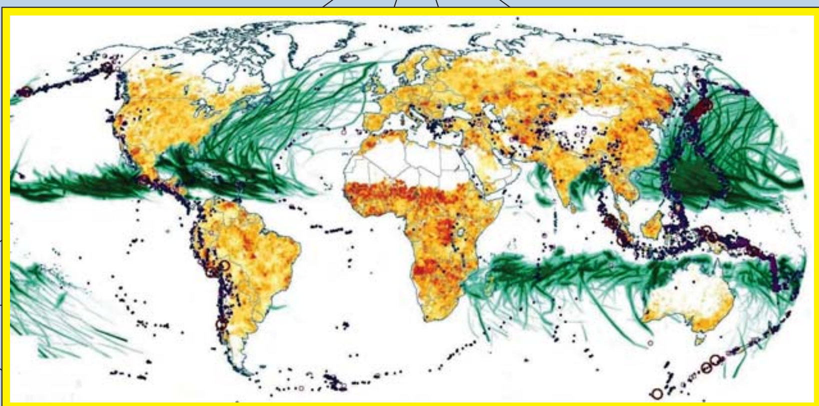
RESILIENCE AND SUSTAINABILITY OF

CITIES

IN HAZARDOUS ENVIRONMENTS

FLAVIO DOBRAN



RESILIENCE AND SUSTAINABILITY OF
CITIES
IN HAZARDOUS ENVIRONMENTS

Flavio Dobran
Editor

RESILIENZA E SOSTENIBILITÀ DELLE
CITTÀ
IN AMBIENTI PERICOLOSI

GVES

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Contents/*Contenuti*

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Preface

Throughout the human history, the cities have provided ideal settings for innovation and socio-economic development, and have contributed enormously to the increased standard of living. More and more people are moving to urban areas and by the end of this century the majority of world's population will live in cities and megacities. Both the internal and the external threats are aggravated with large exposures of people and especially when the threats have the capacities to produce catastrophic consequences in terms of the loss of life and immobilization of city operations. Many cities which are located close to or on geologic faults are threatened by large earthquakes and volcanic eruptions, and those situated along the coasts can experience frequent flooding from tropical storms and increasingly from the sea-level rise produced by climate change. The emissions of greenhouse gases into the atmosphere from the combustion of fossil fuels cause the warming of the atmosphere. This leads to the melting of polar ice and may produce severe disruptions of atmospheric and oceanic circulations that will affect all living beings on the planet. Many cities are also situated too close to chemical, biological, and nuclear energy generation facilities where the accidents can affect hundreds of thousands if not millions of people.

Many great cities of the past have been abandoned because they could not function properly after experiencing the large-scale consequences of hazards and not because their inhabitants reacted to the hazards before the consequences. On all continents, cities have been built in hazardous environments before the full consequences of hazards were known and that these cities continue to thrive without their inhabitants being overly concerned with the consequences attests to our capacity to react only after we gain direct experiences with the consequences. This ignorance is unfortunate and heartbreaking, not only in terms of the potential human casualties, but also in terms of the loss of opportunities for human development.

The International Conference on Resilience and Sustainability of Cities in Hazardous Environments, held from 26-30 November 2018 in Naples, Italy was organized for the purpose of bringing together academics, researchers, graduate students, engineers, urban planners, architects, geologists, geophysicists, environmentalists, economists, educators, local and national authorities and risk managers, representatives of United Nations agencies, and other related stakeholders dealing with resilience and sustainability of cities in hazardous environments. Many individuals in these fields and agencies that claim expertise in risk assessment, resilience, and sustainability were invited to participate and incentives were provided to graduate students and some key contributors to the conference.

The conference attracted researchers in structural mechanics, geophysics, modeling of volcanic and climate change processes, robotics, architecture, cultural heritage, urban planning, risk and resilience analysis, graduate students, and educators and students from the Neapolitan schools. The response from engineers working on cultural heritage preservation and geophysicists employing effective seismic hazard assessments methods was exceptional, and so was the response from the educators of the Neapolitan area. The participations of government representatives of the Italian Parliament, the Metropolitan City of Naples, cities of Naples and Torre del Greco, and Province of Potenza is very significant. From outside of Italy, the contributions came from Brazil, Colombia, Cuba, India, Portugal, Romania, Spain, United Kingdom, Uruguay, and USA. The theory and hands-on computer lectures on Neo-Deterministic Seismic Hazard Assessment attracted the interest of young and seasoned researchers. The one-day excursion to Campi Flegrei and Pompeii was of special relevance to the conference since it demonstrated the extent of the problem that the Metropolitan City of Naples has to deal with when a city of several million people is built on two active volcanoes. Following the excursion, the participants were treated at a banquet with Neapolitan entertainment.

The presentations of school students of their projects on risk perception occurred in the medieval castle of Maschio Angioino where, at the end of presentations, the Flag Wavers and Musicians of Torre del Greco closed the conference with a colorful exhibition. The conference also provided opportunities to the participants to publicize their works through press interviews that were widely reported in local and national newspapers, web news services, and by the largest Italian television networks. The conference was also reported in several European and American countries and by United Nations website dealing with disaster risk reduction and sustainable development.

The conference was organized around four Themes: Hazards and Vulnerabilities of Cities in Hazardous Environments, Education and Governance, Pathways and Resilience to Sustainability of Cities in Hazardous Environments, and Risks of Cities Perceived by Schools. The following brief overview of papers included in this volume attests to the high quality of conference participants, because the presentations at the conference were conditioned on the submissions of professional papers. The acknowledgements of individuals associated with conference organization, scientific committee, and reviews of papers appear at the end of this preface. This is followed with conference opening and closing remarks, papers arranged in four themes of the conference, and profiles of lead authors of papers. The list of all authors of papers appears at the end of this volume.

THEME: Hazards and Vulnerabilities of Cities in Hazardous Environments

In the paper on cities in hazardous environments, F. Dobran provides an overview of the central theme of the conference and defines such concepts as hazard, vulnerability, risk, resilience, sustainability, and other parameters referred to in the papers that follow. Here some examples of cities in different hazardous environments are identified and noted what is being done to confront resilience and sustainability of these cities. Risk, vulnerability, resilience, and sustainability are, however, imprecisely applied in too many studies of cities, and a new mathematical model for quantifying these terms is presented for applications to Naples and New York City. The following paper by A. Imperatrice on knowing the past to project the future underlines that it is the human ignorance of the past that is the cause of disasters because of the lack of preventive measures. As an example, it is demonstrated that the irresponsible urbanization of the city of Portici at 5 km from the crater of Vesuvius has placed this city at a very high risk from the eruptions of the volcano. The paper of C. Scarpati on human resilience in the Neapolitan area reports on the delicate balance between volcanoes and people living close to them, and on the impacts of the eruptions on human settlements.

For cities close to or on geological faults, some of which are also close to dangerous volcanoes, the availability of reliable seismic analysis methods for designing built environments is essential. The Neo-Deterministic Seismic Hazard Assessment (NDSHA) method, developed at the University of Trieste, has been proven reliable for assessing ground motions on local and regional scales, and its applications to Italy, and Naples area in particular, are reported in four papers by starting with an overview of G.F. Panza and continuing with lead authors A. Peresan, C. Nunziata, and G. De Natale. To construct built environments that can resist the eruptions of volcanoes it is also necessary to employ physical models which can provide reliable estimates of the forces produced by the eruptions. This is discussed in the paper dealing with Global Volcanic Simulator, where F. Dobran presents the ongoing work on the development of this simulator. The paper summarizes the physical-mathematical-computer model used by the simulator and its applications to modeling different parts of the volcanic system, for the purpose of assessing multiple hazards from the eruptions, with and without the built environment.

Robustness of a structure is its capacity to avoid a major collapse, and A. Formisano addresses the robustness of steel structures under the earthquake and gravity loadings for some buildings in Naples. N. Chieffo, A. Miano, G. Chiumiento, and coauthors address seismic vulnerability of a historic center near Naples with vulnerability indices and geographical information system, knowledge of buildings materials which can have a large influence on retrofitting cost, and life cycle assessments of steel and glued laminated timber structures that cause different kinds of environmental impacts, respectively. F. Clementi and his Ancona colleagues report the results of vibration testing of historic masonry towers in Marche and utilization of data for tuning of finite element models and identification of their uncertain parameters. A study of a building aggregate located in Frosinone and damaged after l'Aquila's earthquake, reported by G. Chiumiento and colleagues, shows that the Italian seismic guidelines for cultural heritage provide seismic results on the safe side when confronted with the results obtained from detailed numerical calculations of this building.

Innovative techniques for the conservation of ancient masonry buildings are discussed in the paper by the late M. Laterza and collaborators at the University of Basilicata at Matera. Among the techniques used is jacketing based on steel and glass fiber reinforced polymer for increasing the shear strength of the walls for responding better from seismic actions. The use of graphene in paints is also very promising for preserving cultural heritage. The modeling work of A. Formisano and G. Chiumiento on retrofitting of an existing reinforced concrete school building in Torre del Greco near Naples with four different intervention techniques shows that the global concrete bracings give better performance and lower environmental impact when compared to steel jacketing. Seismic vulnerability and risk assessment studies for building aggregates in Arsita, Italy based on probabilistic and mechanical software packages is presented in the paper of N. Chieffo and A. Formisano. The damage was estimated from fragility curves for the whole aggregate and for single structural units, and it is concluded that the methods are consistent when applied to the whole aggregate. The paper of G. Chiumiento and others on vertical addition interventions of existing masonry buildings shows that when different methods are used to determine the environmental impacts, the least impacting structure is the one made of hot-rolled steel.

Rocio Ortiz and colleagues report in their paper that the DELPHI and Fuzzy Logic methods are two different expert systems modeling approaches being proposed for use in making decisions for the preservation of cultural monuments. These tools with 10 experts were used to study three different churches in Seville and the results suggest further refinements. The following paper of the same lead author describes a study of resilience of buildings in Spain and Colombia where use is made of DELPHI methodologies and in-situ diagnosis for determining vulnerabilities of different structures and prioritizing resilience policies. According to M. Laterza and coauthors, the problems of cultural heritage preservation require technological solutions with innovative diagnostics, monitoring, and mathematical models that are simple and have been validated, in order to standardize investigative procedures leading to the knowledge of constructions of historic buildings.

The theory and computational aspects of NDSHA were delivered as lectures at the conference, with the summary papers included in this volume. The computation of seismographs by means of NDSHA, explains F. Romanelli, requires simulations of the rupture process on the faults and propagation of seismic waves through the medium of interest. The sources are modeled as point sources and can be distributed stochastically, the tectonic character is represented by a tensor, and the uncertainties are assessed through parametric studies. An application of the seismic model to Trieste shows the procedure involved in producing scenario-based seismic parameters. The hands-on experience with NDSHA allowed the conference participants to access the NDSHA software remotely with several computers, and the lecturer F. Vaccari explained how to access the web application with friendly graphical interface.

THEME: Education

Vesuvius is not only a symbol of Naples and source of scientific and cultural inspirations, writes G. Paolella, but also a destructive power and there is a great need for serious and practical actions of resilience and sustainability that would allow the surrounding populations to cohabit with this volcano. The schools, writes G. Gambardella, can help in this endeavor by educating the young in a clear, critical, practical, and consistent manner, and by conserving the values and sense of belonging of the place where the students live. It is only through these values, concludes the paper, that the necessary force will be found to produce tomorrow the necessary security of the territory. Teaching volcanic risk in Neapolitan schools is not obligatory and depends on the teachers that are willing to pursue this goal. Ida Mascolo is one of these teachers and in her paper reports the result of a project where the students were tasked to compare two different strategies for risk mitigation: One that requires and the other that does not require the resettling of populations surrounding Vesuvius all over Italy before an eminent eruption. On a project guided by L. Altavilla the students produced a questionnaire on the perception of Vesuvius in terms of benefits and risks and conducted a survey of population, from where they conclude that this perception is very superficial. The environmental ethics in education, writes M. Salvatore, must be founded on the responsibility and awareness and these values must be taught to the students and transmitted to their families.

The Italian Ministry of Education, Universities and Research issued a directive to the schools to promote the Sustainable Development goals of United Nations, and in her paper F. Nocera reviews the educational goals of this development that should be achieved by 2030 and discusses the challenges presented to the schools, prioritization of objectives, and promotion of active citizenship. Since 1995 GVES has been promoting volcanic and seismic risk education in the Neapolitan area schools and conducting hundreds of public seminars, and in the paper of F. Dobran and A. Imperatrice this work is summarized and some educational projects of elementary schools, middle level schools, and high schools are presented. This paper concludes that neither the Italian nor the European Union authorities appear to have the capacities to properly promote resilience and sustainability education in the Neapolitan area schools.

THEME: Pathways and Resilience to Sustainability of Cities in Hazardous Environments

With the Disaster Management Act of 2005, the government of India recognized the importance of resilience of cities and in the paper of R. Magotra and coauthors a study is presented where 10 diverse cities were evaluated for hazard vulnerability, governance, and socio-economic status. For each city, an integrated land-use and hazard assessment map was prepared, which served for identifying the most vulnerable elements of the city, required investments, and for setting up the appropriate disaster risk reduction management structures on both the municipal and national government levels. Many cities need to be transformed to become resilient and sustainable and the Campinas City, and the wider Campinas Metropolitan Area, in Brazil is no exception. Here a Mobilization for Ordination and Feasibility of Resilient Urban Spaces workshop was setup for identifying and developing opportunities to optimize green infrastructure and ecosystem services by involving different agencies and sectors. A. Young in her paper points out that the workshop helped to identify the weaknesses in disaster risk reduction and the necessity of producing guidance for different stakeholders on how to include green infrastructure and support services into policy and risk reduction management decisions.

The 2016-2017 Central Italy earthquakes produced an enormous damage to cultural heritage and in the papers of S. Lenci and D. Cagigas-Muniz and their collaborators two different methods are described that can be used for setting up priorities for the protection of such heritage. The method described in the paper of S. Lenci and others utilizes a numerical dynamic analysis for studying different masonry churches that were severely damaged in Central Italy in 2016. In the continuous modeling approach, where the cracks are continuously spread within the body, and in the discontinuous approach, where the masonry blocks can slide relative to each other, good comparison was obtained between real and numerical damages for the church of Sant Antonio in Ussita. In the second paper, the Art-Risk 3 model based on fuzzy logic and geographical information system is presented for assessing the priorities for restoring the cultural heritage in Spain. The input parameters to the model are those pertaining to vulnerability, building maintenance, static-structural risk, environment, and natural risk. The expert system of the model was designed to mimic human reasoning and can be applied to different heritage buildings. Prioritization of strategies for cultural heritage protection can also be pursued by evaluating vulnerability indices of structures, as shown in the paper of I. Turbay and collaborators. This method is being applied to different monuments of the historic center of Popayan in Colombia exposed to the seismic hazard.

In an open session of the conference, L. Alboul explored with the audience the roles of robotics and virtual reality gaming for cultural heritage preservation, and in her paper she explains how these technologies can be used not only at heritage sites but also in creating virtual museums. The paper also presents a virtual museum prototype being implemented at Sheffield Hallam University in United Kingdom.

Urbanization and climate change effects require new approaches to urban planning, and in her paper A. Young stresses that the urban master plans must provide clear guidance on land use. This requires more effective research and its translation into adaptation opportunities and urban resilience, where short- and long-term planning, investments, human rights, equitable distribution of public and private resources, and governance are some key requirements for an effective transition.

The Province of Potenza in Italy is actively applying the United Nations' goals on resilience and sustainability of cities, and A. Attolico in his paper summarizes some of this work on avoiding disasters through resilience and government policies. The first part of the paper reports the methodologies used to study vulnerabilities, exposures, and risks of earthquakes in different parts of the province, and in the second part are discussed the disaster management and disaster risk reduction strategies which are addressed at both the local and provincial levels. In particular, the gaps and barriers at the municipal levels are identified and suggestions made how to improve networking, governance, cooperation, and funding opportunities. The final considerations provide a list of requirements that are necessary for achieving resilience and sustainability.

The Italian Civil Protection adopted the evacuation plans of geologists to manage the risk from the eruptions of Vesuvius and Campi Flegrei volcanoes without conducting any feasibility study. These plans require the evacuation of more than one million people from the areas surrounding these volcanoes and dispersal all over Italy, without accounting for another million people in Naples that are only 5-10 km from the volcanoes and without considering the large-scale eruptions of the volcanoes. In the paper on Vesuvius and Campi Flegre Evacuation Plans, F. Dobran argues that these plans work against the creation of resilience and sustainability for Neapolitans, that they are unreliable, and that they only serve the special interests. In their paper, A. D'Auria and B. Sciannimanica also note that the evacuation plans are questionable and suggest that the "delocalization" of populations from different municipalities should be into the areas with the most suitable and congruent hosting territories with the socio-economic and cultural characteristics and vocations of the hosted locations.

VESUVIUS–CAMPIFLEGREI PENTALOGUE is a resilience and sustainability framework for the Neapolitan area that is not based on the vesuvian and flegreian cultural uprooting and is presented in the paper of F. Dobran. This framework calls for the achievement of five key objectives, foremost among which is that the area around each volcano should consist of an exclusion nucleus, a resilience belt surrounding the exclusion nucleus, and a sustainability area beyond the resilience belt where some of the populations from the resilient belt could be temporarily sheltered until the volcanic crises subside. The accomplishment of pentalogue objectives must be accomplished, firstly through a professional feasibility study involving interdisciplinary and transdisciplinary collaborations, and then with territorial reorganization. Flavio Dobran also notes that a more extensive resilience and sustainability feasibility study for the Neapolitan area and called VESUVIUS 2000 failed to be supported since 1995, because of special interest groups at both the national and European Union levels.

THEME: Risks of Cities Perceived by Schools

GVES has been organizing annual manifestations of schools of the Neapolitan area since 1995 for the purpose of creating a greater consciousness of the environment among the school students of the area. The manifestation of 2018 was therefore combined with the conference with the theme Risks of Cities Perceived by Schools and promoted one year in advance. The conference participants were invited to attend this manifestation held in Sala dei Baroni of Maschio Angioino, where the students presented their projects on the theme of the manifestation and where at the end of the event the Flag Waivers and Musicians of Torre del Greco closed the conference with a colorful exhibition. We report below a summary of these presentations.

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Ida Mascolo guided her students on a project dealing with the perception of volcanic risk on the part of the citizens of Gragnano by first interviewing the head of Civil Protection of the city and then some citizens on their knowledge of the evacuation plan prepared by the municipality. They found that the risk education is still uncertain and confusing. The students of G. Gambardella produced a book which illustrates various symbolic and fairytale aspects of the city of Ercolano, including its security with Vesuvius looming above the city. Another group of students, guided by L. Piovoso, investigated the risk of Vesuvius through history, geography, art, environment, culture, and folklore. A group of high school students of Naples, under the guidance of L. Altavilla, conducted a survey of Neapolitans on how they perceive the risk from Vesuvius and found that this perception is very superficial and inadequate. The students of M. Salvatore studied the perceptions of risk from Pliny the Elder to the present time, and the students of A. Esposito reported on how the National Park of Vesuvius has been polluted with hazardous waste that is affecting the health of the population. In Red Lands, a group of female students of G. Tramontano performed a dance to dramatize the polluted lands of Campania, produced from the illegal import of hazardous waste from the industrialized north. The dancers then distributed white roses to the audience with inscriptions on the attached hearts "No to toxic waste". From a school of the city of Pozzuoli in the area of Campi Flegrei, the students of D. Mastronardi focused their study on recovering genius loci through the morphologic and geologic context and recovery of historic sources of the places in reference to the Phlegraean Fields volcanic area.

The Flag Wavers and Musicians of Torre del Greco performed a colorful exhibition in the courtyard of Maschio Angioino, entitled "Our past, our roots", and closed the conference on Resilience and Sustainability of Cities in Hazardous Environments.

The conference was successful in attracting high quality researchers in hazard assessments; engineers involved in dynamic analyses of structures; cultural heritage researchers developing different methods for preserving monuments; resilience and sustainability professionals; Neapolitan school educators; and authorities from the Italian Parliament, cities of Naples and Torre del Greco, Metropolitan City of Naples, and Province of Potenza. The conference was widely reported on the national level and in several American and European countries, including the United Nations. Building resilient and sustainable cities in hazardous environments poses enormous challenges and when another similar conference takes place in 2020 we look forward to further contributions to these challenges.

Acknowledgements

Organization of an interdisciplinary and transdisciplinary conference is a risky undertaking, because the organized groups tend to maintain their homogeneities by not cooperating with groups outside of their immediate interests or expertise. The list of Scientific Committee members of the conference is included at the end of this preface and we want to express our appreciation for their support.

The list of paper reviewers is also included at the end of the preface, but this list excludes the anonymous reviewers. The reviewers dedicated considerable time and we want to thank them for their help.

Grazia Paolella contributed greatly to the local organization and cultural and educational aspects of the conference. Antonio Formisano involved many of his collaborators working on cultural heritage preservation and retrofitting of buildings, and Maurizio Indirli involved some of his collaborators. The Academician Giuliano Panza involved his collaborators and suggested possible contributors from earth sciences, cultural heritage, and other fields. For mobilizing the Neapolitan school students to participate with their projects at the conference requires a year of preparations and Ida Mascolo played an important role by involving several high school classes and teachers from the areas of Castellammare di Stabia and Gragnano. Gianfranco Gambardella from Ercolano not only participated at the conference and brought his students to present their project, but also contributed with original artistic material. Fabiana Mennella performed an outstanding work as the translator and public relations officer, Flora Imperatrice managed flawlessly the registrations, Nicola Chieffo managed the projections, and Giuseppe Ragosta served as an able press officer. My wife Annamaria Imperatrice worked tirelessly in the background to smooth out the organizational details and also participated at the conference as an active citizen of the Neapolitan area.

The geophysics group from Trieste deserves special thanks for conducting three lectures on seismic hazard assessment for graduate students and young researchers. As a tour guide of the deposits of eruptions of Vesuvius and Campi Flegrei volcanoes, Claudio Scarpati from the University of Naples Federico II provided such outstanding and enthusiastic explanations that all the participants greatly enjoyed. Special thanks must also go to the Commander Andrea Di Raimondo of Circolo Ufficiali della Marina Militare for being the host of the technical program of the conference; city of Naples for allowing the use of Sala dei Baroni of Maschio Angioino for the manifestation of schools; city of Torre del Greco and Metropolitan City of Naples, Province of Potenza, and Chamber of Deputies of the Italian Parliament for sending their representatives to the conference; Association of Flag Wavers and Musicians of Torre del Greco, and Order of Engineers of the Province of Naples, University of Naples Federico II, ENEA, UNISDR, and Habitat for Humanity International for acknowledging the relevance of the conference. Our sincere thanks must also go to the participants from Americas, Europe, and India for bringing to Naples their innovative ways for confronting resilience and sustainability of cities in hazardous environments.

Flavio Dobran
February 2019

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Prefazione

Nella storia umana, le città hanno fornito le condizioni ideali per l'innovazione e lo sviluppo socio-economico e hanno contribuito enormemente all'aumento del tenore di vita. Sempre più persone si trasferiscono in aree urbane e entro la fine di questo secolo la maggior parte della popolazione mondiale vivrà in città e in megalopoli. Sia le minacce interne che quelle esterne sono aggravate da grandi esposizioni di persone, soprattutto quando le minacce hanno la capacità di produrre conseguenze catastrofiche in termini di perdita di vite umane e immobilizzazione delle operazioni cittadine. Molte città che si trovano vicino o su faglie geologiche sono minacciate da grandi terremoti ed eruzioni vulcaniche e quelle situate lungo le coste possono subire frequenti inondazioni da tempeste tropicali e sempre più dall'innalzamento del livello del mare prodotto dai cambiamenti climatici. Le emissioni di gas serra nell'atmosfera prodotte dalla combustione di fossili causano il riscaldamento dell'atmosfera. Ciò porta allo scioglimento dei ghiacci polari e può produrre gravi interruzioni delle circolazioni atmosferiche e oceaniche che interesseranno tutti gli esseri viventi sul pianeta. Molte città sono anche troppo vicine a impianti di produzione di energia chimica, biologica e nucleare, dove gli incidenti possono colpire centinaia di migliaia, se non milioni, di persone.

Molte grandi città del passato sono state abbandonate perchè non potevano funzionare correttamente dopo aver sperimentato le conseguenze su larga scala dei pericoli e non perchè i loro abitanti reagivano ai pericoli prima delle conseguenze. In tutti i continenti, le città sono state costruite in ambienti pericolosi prima che le piene conseguenze dei pericoli fossero conosciute e che queste città continuassero a prosperare senza che i loro abitanti siano eccessivamente preoccupati delle conseguenze dimostra la nostra capacità di reagire solo dopo aver acquisito esperienze dirette con le conseguenze. Questa ignoranza è sfortunata e straziante, non solo in termini di potenziali vittime umane, ma anche in termini di perdita di opportunità per lo sviluppo umano.

Il Convegno Internazionale sulla Resilienza e Sostenibilità delle Città in Ambienti Pericolosi, tenutosi dal 26 al 30 novembre 2018 a Napoli, è stato organizzato allo scopo di riunire accademici, ricercatori, dottorandi, ingegneri, urbanisti, architetti, geologi, geofisici, ambientalisti, economisti, educatori, autorità locali e nazionali e gestori del rischio, rappresentanti delle agenzie delle Nazioni Unite e altre parti interessate che si occupano di resilienza e sostenibilità delle città in ambienti pericolosi. Molti addetti in questi settori che rivendicano esperienza in termini di resilienza e sostenibilità sono stati invitati personalmente e sono stati forniti incentivi agli studenti laureati e ad alcuni collaboratori chiave del convegno.

Il convegno ha attirato molti ricercatori in meccanica strutturale, geofisica, modellizzazione dei processi vulcanici e di cambiamento climatico, robotica, architettura, patrimonio culturale, pianificazione urbana, analisi di rischio e resilienza, studenti laureati, ed educatori e studenti delle scuole napoletane. La risposta degli ingegneri che lavorano sulla conservazione del patrimonio culturale e dei geofisici che utilizzano metodi di valutazione dei pericoli sismici efficaci è stata eccezionale, così come la risposta degli educatori dell'area napoletana. La partecipazione dei rappresentanti governativi del Parlamento Italiano, della Città Metropolitana di Napoli, delle città di Napoli e Torre del Greco e della Provincia di Potenza é stata significativa. Dall'estero, i contributi provenivano da Brasile, Colombia, Cuba, India, Portogallo, Regno Unito, Romania, Spagna, Uruguay e Stati Uniti. La teoria e le lezioni pratiche sul Neo-Deterministic Seismic Hazard Assessment hanno attirato l'interesse di ricercatori giovani e esperti. L'escursione di un giorno ai Campi Flegrei e Pompei è stata di particolare rilevanza per il convegno poichè ha dimostrato l'estensione del problema che la città metropolitana di Napoli deve affrontare quando una città di diversi milioni di persone è costruita su due vulcani attivi. Dopo l'escursione, i partecipanti sono intervenuti ad un banchetto con intrattenimento napoletano.

Le presentazioni da parte degli studenti scolastici dei loro progetti sulla percezione del rischio hanno avuto luogo nel castello medievale del Maschio Angioino dove, al termine delle presentazioni, gli Sbandieratori e Musici di Torre del Greco hanno chiuso il convegno con una esibizione colorata. Il convegno ha anche offerto ai partecipanti l'opportunità di pubblicizzare le loro opere attraverso interviste con la stampa, che sono state ampiamente riportate su giornali locali e nazionali, servizi di notizie sul web e dalle più grandi reti televisive italiane. Il convegno è stato anche segnalato in diversi paesi europei e americani e sul sito web delle Nazioni Unite che si occupa della riduzione del rischio di catastrofi e dello sviluppo sostenibile.

Il convegno è stato organizzato attorno a quattro temi: rischi e vulnerabilità delle città in ambienti pericolosi, educazione e governance, percorsi e resilienza alla sostenibilità delle città in ambienti pericolosi e rischi delle città percepiti dalle scuole. La seguente breve panoramica delle relazioni incluse in questo volume attesta l'alta qualità dei partecipanti al convegno, perchè le presentazioni al convegno sono state condizionate alle sottomissioni di articoli professionali. I riconoscimenti degli individui associati all'organizzazione del convegno, al comitato scientifico e alle recensioni di articoli appaiono alla fine di questa prefazione. Seguono le osservazioni di apertura e chiusura del convegno, gli articoli organizzati in quattro temi del convegno e i profili degli autori principali di articoli. L'elenco di tutti gli autori di articoli appare alla fine del volume.

TEMA: Pericoli e vulnerabilità delle città in ambienti pericolosi

Nella relazione sulle città in ambienti pericolosi, F. Dobran fornisce una panoramica del tema centrale del convegno e definisce concetti come rischio, vulnerabilità, resilienza, sostenibilità ed altri parametri riportati nei documenti che seguono. Qui vengono identificati alcuni esempi di città in diversi ambienti pericolosi e viene preso atto di ciò che viene fatto per affrontare la resilienza e la sostenibilità di queste città. Rischio, vulnerabilità, resilienza e sostenibilità sono tuttavia applicati in modo impreciso in troppi studi delle città e un nuovo modello matematico per quantificare questi termini viene presentato per la aplicazione a Napoli e New York. Il seguente lavoro di A. Imperatrice sul conoscere il passato per progettare il futuro sottolinea che è l'ignoranza umana del passato a causare disastri per la mancanza di misure preventive. Ad esempio, è dimostrato che l'irresponsabile urbanizzazione della città di Portici, a 5 km dal cratere del Vesuvio, ha messo questa città a un rischio molto elevato dalle eruzioni del vulcano. Il saggio di C. Scarpati sulla resilienza umana nell'area napoletana riporta il delicato equilibrio tra vulcani e persone che vivono vicino ad essi e sugli impatti delle eruzioni sugli insediamenti umani.

Per le città vicine o su faglie geologiche, alcune delle quali sono anche vicine a vulcani pericolosi, la disponibilità di metodi di analisi sismica affidabili per la progettazione di ambienti costruiti è essenziale. Il metodo neo-deterministico di valutazione dei pericoli sismici (NDSHA), sviluppato presso l'Università di Trieste, si è dimostrato affidabile per la valutazione del movimento del suolo su scala locale e regionale, e le sue applicazioni in Italia, e in particolare per l'area napoletana, sono riportati in quattro relazioni, iniziando con una panoramica di G.F. Panza e continuando con gli autori principali A. Peresan, C. Nunziata e G. De Natale. Per proteggere gli ambienti costruiti in grado di resistere alle eruzioni dei vulcani è anche necessario impiegare modelli fisici che possano fornire stime attendibili delle forze prodotte dalle eruzioni. Questo è discusso nella relazione che tratta il Simulatore Vulcanico Globale, dove F. Dobran presenta il lavoro in corso sullo sviluppo di questo simulatore. La relazione riassume il modello fisico-matematico-computerizzato dal simulatore e le sue applicazioni per modellare diverse parti del sistema vulcanico, allo scopo di valutare pericoli dalle eruzioni con e senza l'ambiente costruito.

La robustezza di una struttura è la sua capacità di evitare un maggiore collasso e A. Formisano affronta la robustezza delle strutture in acciaio sottoposte ai terremoti e cariche di gravità per alcune strutture a Napoli. N. Chieffo, A. Miano, G. Chiumiento e coautori affrontano la vulnerabilità sismica di un centro storico vicino a Napoli con indici di vulnerabilità e sistema informativo geografico, conoscenza dei materiali degli edifici che possono avere una grande influenza sui costi di ammodernamento e valutazioni dei cicli di vita di strutture in acciaio laminato e incollato che causano diversi tipi di impatti ambientali, rispettivamente. F. Clementi e i suoi colleghi di Ancona riportano i risultati delle prove di vibrazione delle torri in muratura storiche nelle Marche e l'utilizzo dei dati per la messa a punto di modelli ad elementi finiti e l'identificazione dei loro parametri incerti. Uno studio su un aggregato edilizio situato a Frosinone e danneggiato dopo il terremoto dell'Aquila, riportato da G. Chiumiento e colleghi, dimostra che le linee guida sismiche italiane per il patrimonio culturale forniscono risultati sismici prudenti quando confrontati con i risultati ottenuti da calcoli numerici dettagliati di questo edificio.

Tecniche innovative per la conservazione di antichi edifici in muratura sono riportate nella relazione del compianto M. Laterza e collaboratori all'Università di Basilicata a Matera. Tra le tecniche utilizzate ci sono le giacche a base di acciaio e il polimero rinforzato con fibra di vetro per aumentare la resistenza al taglio delle pareti per rispondere meglio alle azioni sismiche. L'uso del grafene nelle vernici è anche molto promettente per preservare il patrimonio culturale. Il lavoro di modellistica di A. Formisano e G. Chiumiento sull'adattamento di un edificio scolastico in cemento armato esistente a Torre del Greco, vicino Napoli, con quattro diverse tecniche di intervento dimostra che le controventature in calcestruzzo offrono migliori prestazioni e un minore impatto ambientale rispetto alle giacche in acciaio. La vulnerabilità sismica e gli studi di valutazione del rischio per la costruzione di aggregati ad Arsita, in Italia, basati su pacchetti software probabilistici e meccanici, sono presentati negli articoli di N. Chieffo e A. Formisano. Il danno atteso è stato stimato dalle curve di fragilità per l'intero aggregato e per le singole unità strutturali e si è concluso che i metodi sono coerenti quando applicati all'intero aggregato. La relazione di G. Chiumiento ed altri sugli interventi di aggiunta verticale degli edifici in muratura esistenti dimostra che, quando si usano metodi diversi per determinare gli impatti ambientali, la struttura meno impattante è quella realizzata in caldo-laminato acciaio.

Rocio Ortiz e colleghi riportano nel loro articolo che i metodi DELPHI e Fuzzy Logic sono due approcci diversi di modellazione di sistemi esperti proposti per l'uso nel prendere decisioni per la conservazione dei monumenti culturali. Questi strumenti con 10 esperti sono stati utilizzati per studiare tre diverse chiese a Siviglia e i risultati suggeriscono l'ulteriore sviluppo dei modelli. Il successivo articolo dello stesso autore principale descrive uno studio sulla resilienza degli edifici in Spagna e Colombia dove si utilizzano le metodologie DELPHI e la diagnosi in-situ per determinare le vulnerabilità di diverse strutture e dare priorità alle politiche di resilienza. Secondo M. Laterza, i problemi legati alla conservazione del patrimonio culturale richiedono soluzioni tecnologiche con diagnosi innovative, monitoraggio e modelli matematici semplici e validati, al fine di standardizzare le procedure investigative che portano alla conoscenza delle costruzioni degli edifici storici.

La teoria e gli aspetti computazionali di NDSHA sono stati riportati come lezioni al convegno, con le relazioni di sintesi inclusi in questo volume. Il calcolo dei sismografi mediante NDSHA, spiega F. Romanelli, richiede simulazioni del processo di rottura sulle faglie e propagazione delle onde sismiche attraverso il mezzo di interesse. Le fonti sono modellate come fonti puntuali e possono essere distribuite stocasticamente, il carattere tettonico è rappresentato da un tensore e le incertezze sono valutate attraverso studi parametrici. Un'applicazione del modello sismico a Trieste mostra la procedura coinvolta nella produzione di parametri sismici basati su scenari. L'esperienza pratica con NDSHA ha permesso ai partecipanti al convegno di accedere al software NDSHA da remoto con diversi computer e il relatore F. Vaccari ha spiegato come accedere all'applicazione web con un'interfaccia grafica amichevole.

TEMA: Educazione

Il Vesuvio non è solo un simbolo di Napoli e fonte di ispirazioni scientifiche e culturali, scrive G. Paolella, ma anche una potenza distruttiva e c'è un grande bisogno di azioni serie e pratiche di resilienza e sostenibilità che permettano alle popolazioni circostanti di convivere con questo vulcano. Le scuole, scrive

G. Gambardella, possono aiutare in questo sforzo educando i giovani in modo chiaro, critico, pratico e coerente e conservando i valori e il senso di appartenenza del luogo in cui vivono gli studenti. Solo attraverso questi valori, conclude la relazione, si troverà la forza necessaria per produrre domani la necessaria sicurezza del territorio. L'insegnamento del rischio vulcanico nelle scuole napoletane non è obbligatorio e dipende dagli insegnanti che sono disposti a perseguire questo obiettivo. Ida Mascolo è uno di questi insegnanti e nel suo scritto riporta il risultato di un progetto in cui agli studenti è stato affidato il compito di confrontare due diverse strategie di mitigazione del rischio: una che richiede e l'altra che non richiede il reinsediamento delle popolazioni circostanti il Vesuvio in tutta Italia prima di un'eruzione imminente. Su un progetto guidato da L. Altavilla gli studenti hanno prodotto un questionario sulla percezione del Vesuvio in termini di benefici e rischi e condotto un'indagine sulla popolazione da cui hanno concluso che questa percezione è molto superficiale. L'etica ambientale nell'educazione, scrive M. Salvatore, deve essere fondata sulla responsabilità e consapevolezza e questi valori devono essere insegnati agli studenti e trasmessi alle loro famiglie.

Il Ministero dell'Istruzione, dell'Università e della Ricerca ha emanato una direttiva alle scuole per promuovere gli obiettivi di sviluppo sostenibile delle Nazioni Unite e nella sua relazione F. Nocera esamina gli obiettivi educativi di questo sviluppo che dovrebbero essere raggiunti entro il 2030 e discute le sfide presentate alle scuole, prioritizzazione degli obiettivi e promozione della cittadinanza attiva. Dal 1995 la GVES sta promuovendo l'educazione al rischio vulcanico e sismico nelle scuole dell'area napoletana e svolgendo centinaia di seminari pubblici e nell'articolo di F. Dobran e A. Imperatrice questo lavoro è sintetizzato ed alcuni progetti educativi di scuole elementari, medie e superiori vengono presentati. L'articolo conclude che nè le autorità italiane nè quelle dell'Unione Europea sembrano avere le capacità per promuovere adeguatamente l'educazione alla resilienza e alla sostenibilità nelle scuole napoletane.

TEMA: Percorsi e resilienza alla sostenibilità delle città in ambienti pericolosi

Con il Disaster Management Act del 2005, il governo indiano ha riconosciuto l'importanza della resilienza delle città e nell'articolo di R. Magotra e coautori viene presentato uno studio in cui sono state valutate 10 città diverse per vulnerabilità, governance e stato economico. Per ogni città è stata preparata una mappa integrata di valutazione dell'uso del suolo e della valutazione del pericolo, che serviva per identificare gli elementi più vulnerabili della città, gli investimenti richiesti e per creare le appropriate strutture di gestione per la riduzione dei rischi di disastro sia a livello comunale che nazionale . Molte città devono essere trasformate per diventare resilienti e sostenibili e la città di Campinas, e la più ampia area metropolitana di Campinas, in Brasile, non fanno eccezione. Qui è stato allestito un workshop di mobilitazione per l'ordinazione e la fattibilità di spazi urbani resilienti per identificare e sviluppare opportunità per ottimizzare le infrastrutture verdi e i servizi ecosistemici coinvolgendo diverse agenzie e settori. A. Young nel suo articolo sottolinea che il workshop ha aiutato a identificare i punti deboli nella riduzione del rischio di catastrofi e la necessità di fornire rientamenti a diverse parti interessate su come includere le infrastrutture verdi e i servizi di supporto nelle decisioni di gestione delle politiche per la riduzione del rischio.

I terremoti dell'Italia centrale del 2016-2017 hanno prodotto un'enorme danno al patrimonio culturale e nella relazione di S. Lenci e D. Cagigas-Muniz e dei loro collaboratori sono descritti due diversi metodi che possono essere utilizzati per stabilire priorità per la protezione di questo patrimonio. Il metodo descritto nell'articolo di S. Lenci ed altri impiega un'analisi dinamica numerica per studiare diverse chiese in muratura che sono state gravemente danneggiate nell'Italia centrale nel 2016. Nell'approccio modellistico continuo in cui le crepe sono continuamente diffuse all'interno del corpo e nel discontinuo approccio in cui i blocchi di muratura possono scorrere uno rispetto all'altro, un buon confronto è stato ottenuto tra danni reali e risultati numerici per la chiesa di Sant Antonio in Ussita. Nella seconda relazione viene presentato il modello Art-Risk 3 basato su fuzzy logic e sistema di informazione geografica per valutare le priorità nel ripristino del patrimonio culturale in Spagna. I parametri di input per il modello sono quelli relativi alla vulnerabilità, alla manutenzione degli edifici, al rischio statico-strutturale, all'ambiente e al rischio naturale. Il sistema esperto del modello è stato progettato per imitare il ragionamento umano e può essere applicato a diversi edifici storici. La definizione delle priorità delle strategie per la protezione del patrimonio culturale può essere perseguita anche valutando gli indici di vulnerabilità delle strutture, come si dimostra nell'articolo di I. Turbay e collaboratori. Questo metodo viene applicato a diversi monumenti del centro storico di Popayan in Colombia esposto al rischio sismico.

In una sessione aperta del convegno, L. Alboul ha esplorato con il pubblico i ruoli della robotica e dei giochi di realtà virtuale per la conservazione del patrimonio culturale, e nella sua relazione spiega come queste tecnologie possano essere utilizzate, non solo nei siti storici, ma anche nella creazione di musei virtuali. La relazione presenta anche un prototipo di museo virtuale implementato presso la Sheffield Hallam University nel Regno Unito.

Gli effetti dell'urbanizzazione e dei cambiamenti climatici richiedono nuovi approcci alla pianificazione urbana e, nella sua relazione, A. Young sottolinea che i piani urbani devono fornire indicazioni chiare sull'uso del territorio. Ciò richiede una ricerca più efficace e la sua traduzione in opportunità di adattamento e resilienza urbana, dove la pianificazione a breve e lungo termine, gli investimenti, i diritti umani, l'equa distribuzione di risorse pubbliche e private e la governance sono alcuni requisiti chiave per una transizione efficace.

La Provincia di Potenza, in Italia, sta attivamente applicando gli obiettivi delle Nazioni Unite sulla resilienza e sostenibilità delle città. A. Attolico nel suo articolo riassume alcuni di questi lavori svolti per evitare i disastri attraverso la resilienza e le politiche del governo. La prima parte della relazione riporta le metodologie utilizzate per studiare vulnerabilità, esposizioni e rischi dei terremoti in diverse parti della provincia e nella seconda parte viene discussa la gestione delle catastrofi e le strategie di riduzione del rischio di catastrofi che sono affrontate sia a livello locale che a livello provinciale. In particolare, sono state identificate le lacune e le barriere a livello comunale e sono stati riportati suggerimenti su come migliorare il networking, la governance, la cooperazione e le opportunità di finanziamento. Le considerazioni finali forniscono un elenco di requisiti necessari per raggiungere la resilienza e la sostenibilità.

La Protezione Civile italiana ha adottato i piani di evacuazione dei geologi per gestire il rischio dalle eruzioni dei vulcani del Vesuvio e dei Campi Flegrei senza condurre alcuno studio di fattibilità. Questi piani richiedono l'evacuazione di oltre un milione di persone dalle aree circostanti questi vulcani e la dispersione in tutta Italia, senza allontanare un altro milione di persone da Napoli che dista solo 5-10 km dai vulcani e senza considerare le eruzioni su larga scala dei vulcani. Nell'articolo sui Piani di Evacuazione del Vesuvio e dei Campi Flegre, F. Dobran sostiene che questi piani sono contrari alla creazione di resilienza e sostenibilità per i napoletani, che sono inaffidabili e che servono solo gli interessi speciali. Nel loro articolo, A. D'Auria e B. Sciannimanica osservano anche che i piani di evacuazione sono discutibili e suggeriscono che la "delocalizzazione" delle popolazioni di diversi comuni dovrebbe essere nelle aree con i territori ospitanti più adatti e congruenti con i settori socioeconomici e le caratteristiche culturali dei luoghi ospitati.

VESUVIUS–CAMPIFLEGREI PENTALOGUE è un quadro di resilienza e sostenibilità per l'area partenopea che non si basa sul sradicamento della cultura vesuviana e flegrea e viene presentato nella relazione di F. Dobran. Questo quadro richiede il raggiungimento di cinque obiettivi chiave, tra i quali l'area attorno a ciascun vulcano dovrebbe consistere di un nucleo di esclusione, una cintura di resilienza che circonda il nucleo di esclusione e un'area di sostenibilità oltre la cintura di resilienza in cui alcune delle popolazioni della cintura di resilienza potrebbe essere temporaneamente riparata fino a quando le crisi vulcaniche non diminuiranno. Il raggiungimento degli obiettivi del pentalogo deve essere realizzato, in primo luogo, attraverso uno studio di fattibilità professionale che coinvolga collaborazioni interdisciplinari e transdisciplinari e in seguito con la riorganizzazione territoriale. Flavio Dobran osserva inoltre che uno studio di fattibilità di resilienza e sostenibilit più ampio per l'area napoletana e denominato VESUVIUS 2000 non è stato sostenuto dal 1995, a causa di gruppi d'interesse speciali a livello nazionale e dell'Unione europea.

TEMA: Rischi delle città percepiti dalle scuole

Dal 1995 la GVES organizza manifestazioni annuali di scuole dell'area napoletana allo scopo di creare una maggiore consapevolezza dell'ambiente tra gli studenti delle scuole della zona. La manifestazione del 2018 è stata quindi abbinata al convegno con il tema Rischi delle Città Percepiti dalle Scuole e promossa con un anno di anticipo. I partecipanti al convegno sono stati invitati a partecipare a questa manifestazione tenutasi nella Sala dei Baroni del Maschio Angioino, dove gli studenti hanno presentato i loro progetti sul tema della manifestazione e dove alla fine dell'evento gli Sbandieratori e Musici di Torre del Greco hanno chiuso il convegno con la esibizione colorata. Di seguito è riportato un riepilogo di queste presentazioni.

Ida Mascolo ha guidato i suoi studenti su un progetto di percezione del rischio vulcanico da parte dei cittadini di Gragnano, intervistando prima il capo della Protezione Civile della città e in seguito intervistando alcuni cittadini sulla loro conoscenza del piano di evacuazione preparato dal comune. Gli studenti hanno riportato che l'educazione al rischio è ancora incerta e confusa. Gli studenti di G. Gambardella hanno prodotto un libro che illustra vari aspetti simbolici e fiabeschi della città di Ercolano, compresa la sua sicurezza con il Vesuvio incombente sulla città. Un altro gruppo di studenti, guidati da L. Piovoso, ha studiato il rischio del Vesuvio attraverso la storia, la geografia, l'arte, l'ambiente, la cultura e il folklore. Un gruppo di studenti di una scuola superiore di Napoli, sotto la guida di L. Altavilla, ha condotto un'indagine sui napoletani su come percepiscono il rischio dal Vesuvio e ha riportato che questa percezione è molto superficiale e inadeguata. Gli studenti di M. Salvatore hanno studiato le percezioni del rischio da Plinio il Vecchio fino ad oggi e gli studenti di A. Esposito hanno riferito su come il Parco Nazionale del Vesuvio sia stato contaminato da rifiuti pericolosi che stanno compromettendo la salute della popolazione. In Terre Rosse, un gruppo di studentesse di G. Tramontano ha eseguito un ballo per drammatizzare le terre inquinate della Campania, prodotte dall'importazione illegale di rifiuti pericolosi dal nord industrializzato. I ballerini hanno poi distribuito rose bianche al pubblico con iscrizioni sui cuori attaccati "No a rifiuti tossici". Da una scuola della città di Pozzuoli, nella zona dei Campi Flegrei, gli studenti di D. Mastronardi hanno focalizzato il loro studio sul recupero dei genius loci attraverso il contesto morfologico e geologico e il recupero delle fonti storiche dei luoghi in riferimento al complesso vulcanico dei Campi Flegrei.

Gli Sbandieratori e Musici di Torre del Greco hanno eseguito una coloratissima esibizione nel cortile del Maschio Angioino intitolata "Il nostro passato, le nostre radici" e hanno portato a termine il Convegno sulla Resilienza e Sostenibilità delle Città in Ambienti Pericolosi.

Il convegno ha avuto successo nell'attrarre ricercatori di alta qualità che lavorano sulla valutazione dei pericoli; ingegneri coinvolti nelle analisi dinamiche delle strutture; ricercatori del patrimonio culturale che sviluppano metodi diversi per preservare i monumenti; professionisti della resilienza e della sostenibilità; educatori delle scuole napoletane; autorità del Parlamento Italiano, delle città di Napoli e Torre del Greco, Città Metropolitana di Napoli e Provincia di Potenza. Il convegno è stato ampiamente riportato nella stampa e televisione a livello nazionale e in alcuni paesi europei e americani, tra cui le Nazioni Unite. Costruire città resilienti e sostenibili in ambienti pericolosi pone sfide enormi e quando un'altro simile convegno avrà luogo nel 2020, attendiamo ulteriori contributi a queste sfide.

Ringraziamenti

L'organizzazione di un convegno interdisciplinare e transdisciplinare è un'impresa rischiosa, perchè i gruppi organizzati tendono a mantenere le loro omogeneità

non cooperando con gruppi al di fuori dei loro interessi immediati o competenze. La lista dei membri del Comitato Scientifico del convegno è inclusa alla fine di questa prefazione e vogliamo esprimere il nostro apprezzamento per il loro sostegno. L'elenco dei revisori degli articoli è incluso anche alla fine della prefazione, ma questo elenco non include quelli che preferiscono rimanere anonimi. I revisori hanno dedicato molto tempo e vogliamo ringraziarli per il loro aiuto.

Grazia Paolella ha contribuito notevolmente all'organizzazione locale ed agli aspetti culturali ed educativi del convegno. Antonio Formisano ha coinvolto molti dei suoi collaboratori che lavorano nella conservazione dei beni culturali e nell'adeguamento degli edifici, e Maurizio Indirli ha coinvolto alcuni dei suoi collaboratori. L'accademico Giuliano Panza ha coinvolto i suoi collaboratori e ha suggerito possibili contributori di scienze della terra, beni culturali ed altri campi. Per mobilitare gli studenti delle scuole napoletane a partecipare con i loro progetti al convegno è necessario un anno di preparativi e Ida Mascolo ha svolto un ruolo importante coinvolgendo diverse classi e insegnanti delle scuole superiori delle zone di Castellammare di Stabia e Gragnano. Gianfranco Gambardella di Ercolano, non solo ha partecipato al convegno e ha portato i suoi studenti a presentare il loro progetto, ma ha anche contribuito con originale materiale artistico. Fabiana Mennella ha svolto un lavoro eccezionale in qualità di traduttrice e addetta alle pubbliche relazioni, Flora Imperatrice ha gestito in modo impeccabile le registrazioni, Nicola Chieffo ha gestito le proezioni e Giuseppe Ragosta è stato un abile addetto stampa. Mia moglie Annamaria Imperatrice ha lavorato instancabilmente in sottofondo per appianare i dettagli organizzativi e ha anche partecipato al convegno come cittadina attiva dell'area napoletana.

Il gruppo geofisico di Trieste merita un ringraziamento speciale per aver tenuto tre lezioni sulla valutazione del rischio sismico per studenti laureati e giovani ricercatori. Come guida dei depositi di eruzioni dei vulcani del Vesuvio e dei Campi Flegrei, Claudio Scarpati dell'Università di Napoli Federico II ha fornito spiegazioni straordinarie ed entusiaste e i partecipanti hanno molto apprezzato. Un ringraziamento speciale va anche al Comandante Andrea Di Raimondo del Circolo Ufficiali della Marina Militare per essere stato ospite del convegno, alla città di Napoli per aver permesso l'uso della Sala dei Baroni del Maschio Angioino per la manifestazione delle scuole, alla città di Torre del Greco e alla Città Metropolitana di Napoli e alla Provincia di Potenza e alla Camera dei Deputati del Parlamento Italiano per l'invio dei loro rappresentanti al convegno, all'Associazione Sbandieratori e Musici di Torre del Greco, all'Ordine Degli Ingegneri della Provincia di Napoli, all'Università di Napoli Federico II, all'ENEA, all'UNISDR, e al Habitat for Humanity International per aver riconosciuto l'importanza del convegno. I nostri sinceri ringraziamenti vanno anche ai partecipanti delle Americhe, dell'Europa e dell'India per aver portato a Napoli i loro lavori innovativi per affrontare la resilienza e la sostenibilità delle città in ambienti pericolosi.

Flavio Dobran
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Conference Opening and Closing
Apertura e chiusura del convegno

The Commander Andrea di Raimondo of Circolo Ufficiali della Marina Militare of Naples hosting the International Conference on Resilience and Sustainability of Cities in Hazardous Environment opened the conference and welcomed the participants, and the conference organizers Flavio Dobran, Grazia Paolella, Antonio Formisano, and Maurizio Indirli expressed a deep appreciation for being hosted in such a unique Neapolitan landmark. The conference organizers also welcomed the participants to Naples and drew attention to the presence of authorities in the audience from the Metropolitan City of Naples and Italian Government.

Il Comandante Andrea di Raimondo del Circolo Ufficiali della Marina Militare di Napoli, che ha ospitato il Convegno Internazionale sulla Resilienza e Sostenibilità delle Città in Ambienti Pericolosi, ha aperto il convegno e ha dato il benvenuto ai partecipanti, e gli organizzatori del convegno Flavio Dobran, Grazia Paolella, Antonio Formisano e Maurizio Indirli hanno espresso un profondo apprezzamento per essere stati ospitati in una sede napoletana così unica. Gli organizzatori del convegno hanno inoltre accolto i partecipanti a Napoli e hanno attirato l'attenzione sulla presenza nel pubblico di autorità della Città Metropolitana di Napoli e del governo italiano.

Dr. Dobran noted that all the authorities from the City of Naples, Metropolitan City of Naples, Regione Campania, and the towns surrounding Naples and situated in the close proximities of Vesuvius and Campi Flegrei volcanoes, as well as the authorities representing the Neapolitan populations in the Italian government had been invited to the Conference. The Professor noted that those invited and declined to participate in the conference demonstrate little sensitivity to the achievement of resilience and sustainability of cities in hazardous environments. In what follows are the statements of those authorities that participated during the opening of the conference on 26 November, closing of technical sessions on 28 November at Circolo Ufficiali, and closing of the conference on 30 November at Maschio Angioino, where the students of Neapolitan area presented their works on the perception of risk.

Il Dott. Dobran ha sottolineato che erano state invitate al convegno tutte le autorità della Città di Napoli, della Città Metropolitana di Napoli, della Regione Campania e delle città che circondano Napoli e sono situate nelle immediate vicinanze dei vulcani del Vesuvio e dei Campi Flegrei, così come le autorità che rappresentano le popolazioni napoletane nel governo italiano. Il Professore ha evidenziato che coloro che sono stati invitati e hanno rifiutato di partecipare al convegno dimostrano poca sensibilità al raggiungimento della resilienza e della sostenibilità delle città in ambienti pericolosi. Nei paragrafi che seguono sono *riportate le dichiarazioni delle autorità che hanno partecipato durante l'apertura del convegno il 26 novembre, la chiusura delle sessioni tecniche il 28 novembre al Circolo Ufficiali e la chiusura del convegno il 30 novembre al Maschio Angioino, dove gli studenti dell'area napoletana hanno presentato i loro lavori sulla percezione del rischio.*

Monday 26 November/*Lunedì 26 novembre*

Giuseppe Cozzolino, General Director of Metropolitan City of Naples
Giuseppe Cozzolino, Direttore Generale della Città Metropolitana di Napoli

Mr. Cozzolino stressed that scientific research must combine with a joint political action to progress towards a sustainable development of the City of Naples. Moreover, he added that the next day (Tuesday 27 November) there would have been the approval of the town planning resolution. Mr. Cozzolino concluded his speech by expressing a favorable opinion of the Metropolitan City of Naples to discuss a common action plan for sustainable development with the academic and scientific world.

Il Dott. Cozzolino ha sostenuto che alla ricerca scientifica deve associarsi un'azione politica congiunta per progredire verso uno sviluppo sostenibile della Città Metropolitana di Napoli. Inoltre, questi ha aggiunto che il giorno dopo (martedi 27 novembre) ci sarebbe stata l'approvazione della delibera di pianificazione urbanistica. Il Dott. Cozzolino ha concluso il suo intervento esprimendo parere favorevole della Città Metropolitana di Napoli a discutere con il mondo accademico e scientifico un piano d'azione comune per uno sviluppo sostenibile.

Luigi Gallo, Member of the Parliament in the Chamber of Deputies, President of Commission on Culture, Science and Education
Luigi Gallo, Parlamentare della Camera dei Deputati, Presidente della Commissione Cultura, Scienza e Istruzione

Hon. Gallo opened his speech by saying that security is one of the most urgent and important issues to be addressed, especially in light of the climate change that we are witnessing. In addition, the MP said that security must be a common issue that must involve the scientific, academic, and institutional world, and that he is honored to attend a conference like this. Hon. Gallo then referred to the fact that he had proposed a new bill in Parliament on the "open access" of scientific research in order to facilitate the dissemination of scientific knowledge.

Il Dott. Gallo ha aperto il suo intervento sostenendo che il tema della sicurezza rappresenta una delle più urgenti e importanti questioni da affrontare, soprattutto alla luce del cambiamento climatico al quale stiamo assistendo. Inoltre, il parlamentare ha affermato che la sicurezza deve essere una questione comune che deve coinvolgere mondo scientifico, accademico e istituzionale e si è detto onorato di partecipare ad una Conferenza come questa. Il Dott. Gallo ha poi *accennato al fatto di aver proposto una nuova proposta di legge in Parlamento su "open access" della ricerca scientifica al fine di poter favorire la diffusione del sapere scientifico.*

Wednesday 28 November/*Mercoledì 28 novembre*

Annarita Ottaviano, Town Councilor and Deputy Mayor of the Municipality of Torre del Greco
Annarita Ottaviano, Assessore e Vicesindaco del Comune di Torre del Greco

Hon. Ottaviano affirmed the great vulnerability of the city of Torre del Greco in the face of the dangers posed by the surrounding environment and added that in this period the municipal council of Torre del Greco is wondering what the city council is or is not doing to increase resilience and sustainability. The deputy mayor then expressed surprise at the absence of institutions and mayors of other municipalities of Campania Region at the Conference, since the danger of a volcanic eruption of Vesuvius is a common problem that requires a common and shared approach. Finally, Hon. Ottaviano expressed the possibility of a collaboration through specific projects between the Municipality of Torre del Greco and Prof. Dobran and his staff and with the participation of various institutional authorities (municipalities, provinces, Metropolitan cities, regions), supporting and endorsing Prof. Dobran's proposal to have Prof. Paolella as the "bridge".
La Dott.ssa Ottaviano ha affermato la grande vulnerabilità della città di Torre del Greco di fronte ai pericoli posti dall'ambiente circostante e ha aggiunto che in questo periodo la giunta comunale di Torre del Greco si sta chiedendo cosa effettivamente il comune stia o meno facendo per aumentare la resilienza e la sostenibilità. Il vicesindaco ha poi espresso stupore per l'assenza di istituzioni e altri sindaci di altri comuni campani al Convegno in quanto il pericolo di un'eruzione vulcanica del Vesuvio è un problema comune che richiede un approccio comune e condiviso. Infine, la Ottaviano ha espresso la possibilità di una collaborazione attraverso progetti specifici tra il Comune di Torre del Greco e il Prof. Dobran con il suo staff e con la partecipazione delle varie autorità istituzionali (comuni, province, città metropolitane, regione), sostenendo e avallando la proposta del Prof. Dobran di avere la Prof.ssa Paolella come "ponte".

Friday 30 November/*Venerdì 30 novembre*

Angela Procaccini, Representative of the government of Naples
Angela Procaccini, in rappresentanza del Comune di Napoli

Mrs. Procaccini brought the greetings of the Mayor of Naples Luigi De Magistris and his wish for a continuation of work in the direction of resilience and sustainability in the near future. Procaccini continued her speech by saying that the City of Naples has accepted the invitation promoted by Prof. Paolella more than a year in advance, believing right from the beginning the value and the

goodness of her proposed initiative.
La Dott.ssa ha espresso i saluti del Sindaco de Magistris e il suo augurio per un prosieguo di lavori nella direzione della resilienza e sostenibilità in un futuro non lontano. La Procaccini ha continuato il suo intervento affermando che il Comune di Napoli ha raccolto l'invito promosso dalla Prof.ssa Paolella con oltre un anno di anticipo, credendo fin dall'inizio al valore e alla bontà di questa iniziativa prospettata dalla stessa Prof.ssa.

Luisa Liguoro, Councilor of the Municipality of Torre del Greco
Luisa Liguoro, Consigliere Comunale del Comune di Torre del Greco

The City Councilor expressed great sensitivity to the issue of resilience and sustainability and a strong appreciation for the involvement of schools. The lawyer also expressed a favorable opinion on the realization of conditions of resilience and sustainability.

Il Consigliere Comunale ha espresso grande sensibilità rispetto alla tematica della resilienza e sostenibilità e vivo apprezzamento per il coinvolgimento del mondo della scuola. L'avvocato ha espresso parere favorevole alla realizzazione di condizioni di resilienza e sostenibilità.

Alessandro Attolico, Executive Director of Territorial and Environmental Services, Province of Potenza
Alessandro Attolico, Direttore Esecutivo dei Servizi Territoriali e Ambientali, Provincia di Potenza

As an advocate for the United Nations International Strategy for Disaster Reduction "Making the Cities Resilient" Campaign, Dr. Attolico stressed the importance of resilience in government policies. His vision for resilience combines territorial safety, sustainable development and climate change, and for achieving improved governance requires engaging communities, inducing behavioral change, attracting investments, and establishing cooperation and accountability.
Come sostenitore della Campagna Internazionale per la Riduzione delle Calamità delle Nazioni Unite "Making the Cities Resilient", il Dott. Attolico ha sottolineato l'importanza della resilienza nelle politiche del governo. La sua visione di resilienza mette insieme sicurezza territoriale, sviluppo sostenibile e cambiamento climatico e per ottenere una governance migliore richiede il coinvolgimento delle comunità, l'induzione di cambiamenti comportamentali, l'incentivazione di investimenti e la realizzazione di cooperazione e senso di responsabilità.

Fabiana Mennella
Interpreter and Public Relations

GVES, Napoli – New York, ISBN 978-88-903183-1-3

From left to right and top to bottom. Circolo Ufficiali della Marina Militare, Maurizio Indirli, Grazia Paolella, Andrea Di Raimondo, Flavio Dobran, Antonio Formisano, Annamaria Imperatrice, Flora Imperatrice, Fabiana Mennella, Giuseppe Cozzolino, Luigi Gallo.

From left to right and top to bottom. Grazia Paolella, Annarita Ottaviano, Flavio Dobran, Castle Maschio Angioino, Alessandro Attolico, Luisa Liguoro, Angela Procaccini, musicians and flag wavers from Torre del Greco, participants at Circolo Ufficiali on 26 November 2018, participants at Maschio Angioino on 30 November 2018.

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THEME

Hazards and Vulnerabilities of Cities in Hazardous Environments

Pericoli e vulnerabilità delle città in ambienti pericolosi

From left to right and top to bottom. Annamaria Imperatrice, Flavio Dobran, Claudio Scarpati, Antonella Peresan, Flora Imperatrice, Lyuba Albouf, Concettina Nunziata, Maurizio Indirli, Fabio Romanelli, and Franco Vaccari conducting NDSHA lecture.

Cities in Hazardous Environments Risk Assessment, Resilience, and Sustainability

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Abstract. Cities can concentrate disaster risk from the aggregation of people, infrastructure, assets, expansion, inadequate management, and the surrounding hazardous environments. Many cities are located close to geologic faults and active volcanoes, in coastal areas exposed to tropical cyclones and climate change conditions, and in the vicinities of nuclear, chemical, biological, and hazardous landfill facilities. By the end of this century most of the people will live in cities, which will present enormous exposure problems and invite human catastrophes. In the first part of the paper some cities in hazardous environments are identified where the consequences of hazards can be catastrophic, and the tools used in these cities to address their hazards are examined. To achieve resilience and sustainability of complex socio-technical systems like cities requires an appropriate modeling strategy, and in the second part of the paper a mathematical model is presented for addressing risk, vulnerability, resilience, and sustainability of cities. This model incorporates deductive and inductive logic for defining the sample space of events, consequences, and sustainability attributes, and employs the data base associated with the propositions and their memory information content, including the knowledge base not logically connected with the sample space propositions. This modeling strategy is presently applied to the cities of Naples in Italy and New York City in the United States.

Keywords: Cities, hazards, risk, vulnerability, resilience, sustainability, climate change, earthquakes, floods, landslides, volcanoes, tsunami, probability theory, modeling

1. Introduction

The human population is becoming more numerous, healthier, wealthier, and more concerned for its security and thus aware of its surroundings. Today, more than half of the world's population lives in cities and by the middle of this century an additional two billion people will join the urban dwellers [1]. The cities in the developing countries will experience most rapid urbanization and

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thus be exposed to the fastest rate of increase in the incidents of disasters. On average and in recent decades some 100,000 people have been killed annually by 200 disasters, and 100 million people were affected and $40 billion losses were sustained every year [2]. The cities, and those in hazardous environments in particular, will be confronted with increasing challenges on how to deal with possible consequences of the threats, from both the internal and the external city environments.

The policy makers are being increasingly aware of the global nature of threats and disasters and the United Nations (UN) in 1990 started a process of this awareness with the International Decade for Natural Disaster Reduction (IDNDR) [3]. This was followed in 1994 with the World Conference on Natural Disaster Reduction in Yokohama, Japan, where the significance of human vulnerability to disasters was recognized. In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) [4] recognized the concerns about climate change, and in 1997 with the adoption of Kyoto Protocol [5] and passage into law in 2005 the nations of the world placed legal requirements on developed nations to reduce the emissions of greenhouse gases into the atmosphere. In 2000 the world leaders formalized 18 Millennium Development goals for reducing poverty and improving lives, and expressed the concern that the disasters can undermine these goals [6]. Following up on IDNDR, the UN adopted in 2004 the International Strategy for Disaster Reduction (ISDR) [7], consisting of partnerships comprising governments, intergovernmental and nongovernmental organizations, scientific and technical bodies, financial institutions, private sector, and civil society. The 168 countries that adopted the Hyogo Framework of Action (HFA) during the Hyogo World Conference on Disaster Reduction held in Kobe, Japan in 2005 placed emphasis on building more resilience to disasters and again encouraged collaborative strategies, but this resolution had no legal binding requirements [8]. Building on the HFA, the Sendai Framework for Disaster Risk Reduction 2015-2030 aims to achieve [9]:

> *The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience.*

These objectives should be achieved through the four priority areas: Understanding disaster risk, strengthening disaster risk governance to manage disaster risk, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response. The 100 Resilient City Initiative aims that the cities around the world become more resilient to the physical, social, and economic challenges that are confronting the 21st century [10].

All of these initiatives highlight the importance of identifying threats and their consequences, reducing risk, producing resilience, encouraging sustainable development, and achieving sustainability in the future. But what precisely is meant by the terms “hazards”, “consequences”, “disasters”, “risk”, “vulnerability”, “resilience”, and “sustainability”, and how are these terms supposed to be *operationally implemented* for building resilient and sustainable cities in hazardous environments? We will first briefly discuss what is meant by hazards, events, disasters, risk, and vulnerability, and in Section 4 will elaborate on resilience and sustainability and quantify all of these terms.

For humans, *hazards* are interpretations of events and an *event* is an occurrence happening or potentially happening at a determinable time and place, with or without the participations of humans. Hazards are thus the potential threats to humans and their welfare arising from dangerous phenomena and substances [11]. Although certain events can be triggered by one or more natural phenomena (such as the motions of tectonic plates and atmospheric circulations), the resulting consequences associated with earthquakes, tsunami, floods, landslides, pollutants, etc. can be influenced by human actions. The technological hazards originate from commercial and industrial activities of humans, such as accidents, failures of human built environments, etc. Hazards can produce *consequences*, *circumstances*, or something that the humans value, such as life, health, environment, economic assets, careers, power, and is often difficult not only to enumerate all possible consequences but also the potential events when both the nature and human organizations are involved. If the most relevant events and consequences are known, or sufficient information is available for judging their occurrence, it is possible, in principle, to apply the deductive reasoning to define the treatments to prevent the occurrence of undesirable consequences and eliminate a need for making inductive reasoning. For real problems, however, and in particular for those involving human societies, this information is seldom available and we must resort to inductive or plausible reasoning for optimal processing of incomplete information, so that the likelihoods of most significant harms affecting these societies and their surroundings can be established (Section 4).

Risk is used to denote the occurrence of unwanted circumstances that can produce harmful effects, but neither the United Nations [7], the European Union [12], nor countless researchers and practitioners agree on its precise use. Risk is generally determined through the probability theory and used by the decision makers to reduce it, but if it cannot be properly defined and quantified it cannot be properly used. This presents an enormous problem for cities in hazardous environment where there are many different hazards, consequences, stakeholders, and insufficient information to produce all the data necessary for proper risk evaluation. Under these circumstances a proper “risk control” can be highly uncertain and a proper risk analysis should be able to account for this *uncertainty* [13], which has not yet been clearly incorporated into risk analyses. The generation of more knowledge will lead to the reduction of uncertainty, but not to its elimination, because of the ontological and epistemological issues associated with this word [14].

The degree of severity of consequences depends on *vulnerability* of values that we place on things relative to the financial, ethical, cultural, ecosystem, or other measures expressed through some sort of measurable quantities or *indicators*. Like risk, vulnerability can also be expressed by the probability that a damage and loss can or cannot occur, and as such vulnerable are the social systems, ecosystems, infrastructure, habitats, industrial facilities, etc. Both risk and vulnerability depend on the background knowledge or information that is available and that is not available but must be consistent with the available data. Without a proper inference procedure that requires a model, all possible outcomes, and some other structure discussed in Section 4, we cannot properly use the probability theory to determine for whom or for what, where, and for how long risk and vulnerability assessments will be valid.

The specification of a *system* is a fundamental attribute of this assessment, since this is simply a region in space set aside for investigation whose size and properties can change with time. The choice of this region is arbitrary, but we should select it in a such a way that the specification by its properties which define the *system state* becomes as simple as possible for the solutions of real problems. Once a system is defined, everything else outside of the system becomes the *surroundings* and the interaction between the system and its surroundings is through the system *boundary* or boundaries that can change with time. We will see later on that without this clarity there is a great deal of confusion when confronting the concepts of communities, cities, resilience, sustainability, and other buzzwords (defined bellow) that are widely used in professional literature but seldom clearly defined. The threats to a community, region, or system can, therefore, be *internal* or coming from within the system and *external* or coming from the system's surroundings. The more vulnerable are the properties of a system exposed to (internal and/or external) hazards, the higher is the risk that these properties will change to those that are unsuitable for living beings.

By *disasters* we mean that the losses from hazards are sufficiently large to disrupt the functioning of a community or a society beyond its ability to cope. The loss of life is the principal indicator of a disaster [11], and since 1900 the most deadliest disasters caused by nature are the 1931 China floods (1-4 million deaths), 1970 Bhola cyclone in Bangladesh ($\geq$ 0.5 million deaths), 1920 Haiyuan earthquake in China ($\sim$ 0.3 million deaths), and 1976 Great Tangshan earthquake in China (0.2-0.7 million deaths) where the city of Tangshan of one million people ceased to exist [15, 16]. More recently, in 2005 Hurricane Katrina struck the Golf Coast of the United States and in New Orleans and surroundings caused some 2000 deaths and $125 billion in damage, in 1992 Hurricane Andrew made the landfall in Florida and Louisiana and caused 50 deaths and $30 billion in damage, in 1995 the Great Hanshin earthquake caused some 6000 deaths and $100 billion in damage in Kobe, Japan, and in 1985 the Mexico City earthquake caused 5000-10,000 deaths [17]. The rise of large urban agglomerates or megacities[1] underscores the increasing potential for much larger disasters.

[1] A *city* consists of at least 50,000-100,000 inhabitants, whereas a *megacity* is usually considered a city with greater than one million inhabitants.

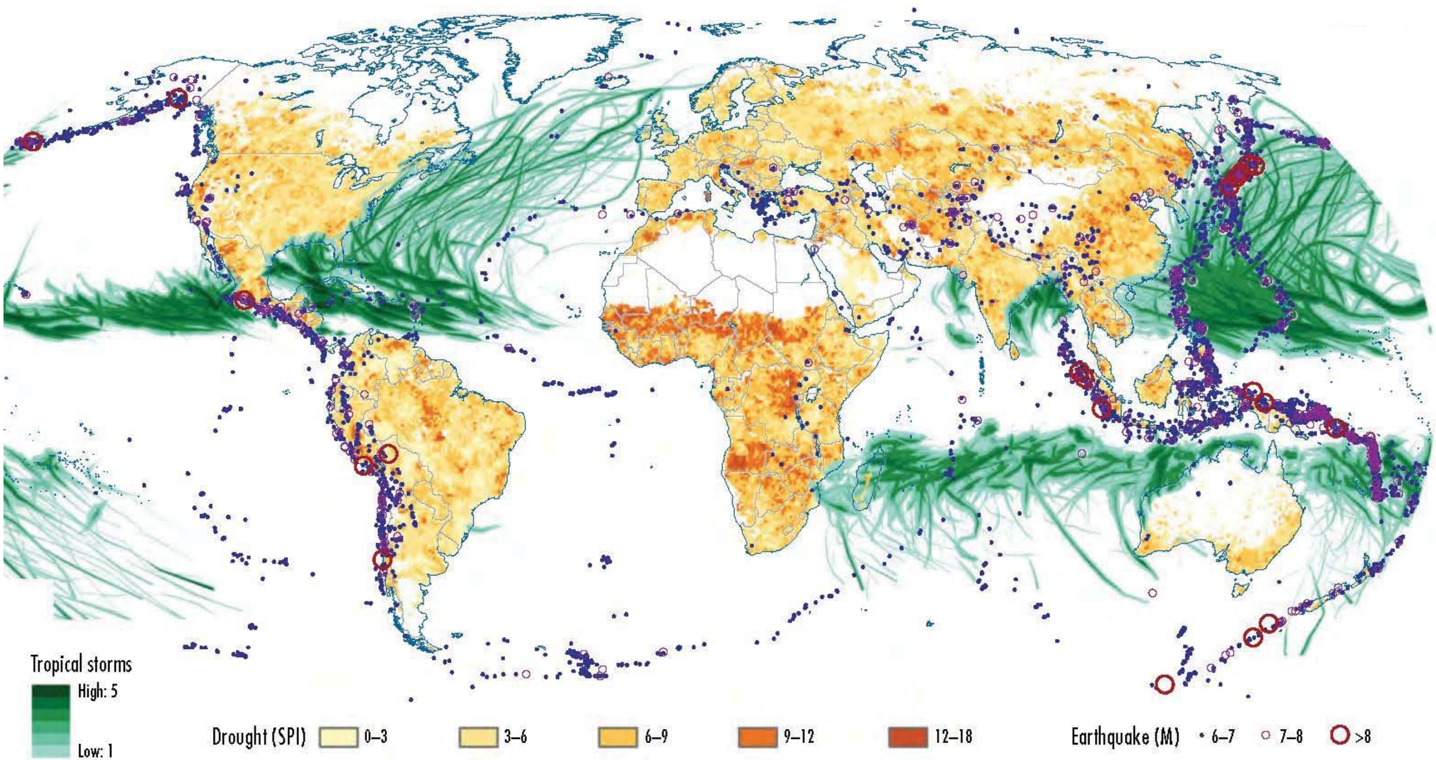


Figure 1. Distribution of storms and earthqakes worldwide [18]. Many earthquake locations are also associated with the locations of volcanoes, such as around the "ring of fire" in the Pacific, Central America, Mediterranean, and West Africa.

Cities can, therefore, concentrate the *disaster risk*, not only due to the aggregation of people, infrastructure, assets, expansion, and inadequate management, but also from the surrounding hazardous environments. Cities on volcanoes and on geologic faults, cities exposed to meteorological and climatological conditions, cities in the vicinity of nuclear, chemical and biological facilities, and cities neighboring hazardous landfills containing industrial and medical waste and stockpiles of spent fuel from nuclear reactors can be found all over the world. San Francisco, Naples, Istanbul, Tokyo, Rabaul, Mexico City, Lima, and many others are all situated in active geologic areas, whereas the coastal cities of North and South America, West Africa, Mediterranean, Bay of Bengal, and South China Sea, such as Dhaka, Sidney, Miami, Seoul, and Rio de Janeiro, are exposed to tropical cyclones (storms, hurricanes, typhoons), inundations, and tsunami (Fig. 1) [18]. The global warming will increase the potential hazards from the sea-level rise and changes in atmospheric and oceanic circulations [19]. Many nuclear power stations and chemical and biological facilities are today located close to large metropolitan areas (Los Angeles, New York, Paris, and others) with questionable safety nets and this problem will proliferate with the need to double the energy supply for humanity by the middle of this century and development of the African Continent [20].

Urban areas both affect and are affected by the hazards, because of both the natural and anthropogenic threats. Cities demand materials for production and consumption, alter ecosystems, and their waste products affect biogeochemical cycles and climate [21]. Throughout the human history the concentrations of individuals have made ideal settings for innovations and agglomerations of economies that resulted in higher standards of living [22], and given the advantages that the cites are providing it is thus not surprising that more and more people have been moving to urban areas on the expense of creating different risks for themselves and their offspring. For cities in hazardous environments this risk becomes especially elevated when the urban dwellers are ignorant of the consequences of cities' hazards or fail to prioritize security over emergency. Building security with preemptive prevention strategies instead on relaying on dealing with emergencies or promoting emergency culture should be the key pursuits of civil societies, but, unfortunately, managing the disasters instead of preventing disasters takes precedence, because managing the long-term preventive strategies are apparently more "risky" than managing the short-term risks. It should be, therefore, of no surprise that the people in hazardous environments thrive in the *apparent security* just because they have no personal experiences with the possible consequences of their hazards and allow their representatives to behave as the catastrophic consequences of these hazards will not occur during their lifetimes [23].

Most city habitats have been built without adequate urban plans and their key structures and infrastructures have been designed only on the basis of the *most probable* levels of natural and anthropogenic hazards, where the severe consequences for the populations and built environments from low probability events (large earthquakes, nuclear reactor accidents, large volcanic eruptions) have been marginalized. Such practices for cities in hazardous environments are inviting disasters and should change, because *the consequences of small probability events are often catastrophic* for large urban centers.

Every city in a hazardous environment has specific issues, and what may be acceptable to one socio-economic and cultural group does not necessarily imply that it will be acceptable to another group. One of the central pillars of sustainability is the *sense of belonging* [24], where the people prefer to cohabit whenever possible with the environment where they have been raised and where they built their culture, instead of relocating to potentially more secure environments but have to face socio-economic and cultural uncertainties. The populations of many cities in hazardous environments have thrived and will therefore continue thriving in apparent security as long as the advantages of sense of belonging and apparent security outweigh the apparent disadvantages of natural and anthropogenic threats.

Some key natural and anthropogenic hazards that many cities are confronted with are discussed in Section 2. Section 3 presents some examples of cities where these hazards pose great dangers to populations and what is being done to confront these hazards seriously. Risk assessment, vulnerability, resilience, and sustainability for cities in hazardous environments are elaborated in Section 4 where a probability theory model for quantifying these terms is presented. The agglomeration of people in cities offers extraordinary opportunities for innovations leading to the creation of security culture, but these collaborative interdisciplinary and transdisciplinary opportunities are often suffocated by too many special interests.

2. Natural and Anthropogenic Hazards

According to UNISDR [25], a *hazard* is "a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" and can be of *natural* or *anthropogenic* origin, and often appearing in combination. A hazardous thing or event can cause other hazardous events, and when defining the hazards for cities it is necessary to consult carefully the historic sources to ascertain the nature of past events and their consequences. The knowledge base of past and projected future events and consequences is an integral part of the definition of risk and may thus make its assessment subjective or produce only an illusion of risk control, and especially for large cities where there are complex perceptions of risks and decision makers can easily marginalize all those risks that for them are little relevant during their short-term of governance.

Earthquakes are ubiquitous (Fig. 1) and often cause catastrophic losses of lives on the Earth's surface. They are produced from the fracturing of rocks produced by the movements of tectonic plates, by the rising of magma or molten rock from the mantle through the crust and producing volcanic eruptions, or from the man-made explosions in mines, wars, and explorations for fossil fuel resources.

Some volcanic eruptions produce slowly moving lava flows which are not very hazardous for humans but can cause large property damage, whereas the more explosive volcanic eruptions producing high rising and collapsing plumes cannot only greatly affect the local environments, but also the entire climate system of the Earth and cause the extinctions of most life forms [26]. Tsunami are produced from the relative motions of tectonic plates and landslides from underwater volcanoes and land-based mountain ranges. *Technological hazards* form a subset of anthropogenic hazards that are associated with failures of human built environments, such as human habitats, infrastructures, and industrial structures. Industrial facilities can release potent chemical and radioactive materials into the atmosphere and into the ground, and possibly contaminate large areas for hundreds and millions of years and change global atmospheric and oceanic circulation patters that change the Earth's climate. Global warming drives sea-level rise which leads to coastal flooding that can affect socio economic development by affecting the supply of food and water resources and global trade patterns. As shown in Fig. 1, hurricanes and typhoons pose great problems to humanity and depend on atmospheric and oceanic circulations. Human settlements and resettlements can produce fatal diseases, and the wars produce devastations of food supply chains by dismantling the often fragile human collaborations [17, 27, 28].

A single hazardous event, such as an earthquake, can produce a variety of consequences, depending on the surrounding environment. A fracture in a building produced from the lateral and vertical motions of the building can lead to the collapse of the entire building, which may produce fires, loss of electricity, and block city traffic. This in turn causes economic hardships and may produce loss of life. The built environments of cities on volcanoes can be especially vulnerable from the construction practices that may or may not have been properly implemented to account for earthquakes of different strengths, ash fall from volcanic eruptions accumulating on rooftops, pyroclastic flows from collapsing volcanic columns rushing down the volcanoes at several hundred kilometers per hour and at temperatures exceeding 1000 K, large chunks of rocks being ejected from the decapitation of volcanic cones as the ascending magmas in volcanic conduits violently interact with underground aquifers, and lahars produced from the condensing water vapor in the volcanic plumes. All of these volcanic events can occur during a single eruption, and often simultaneously [29]. Nuclear reactor accidents, such as at Chernobyl, Ukraine in 1985 [30] and Fukushima, Japan in 2011 [31], can release radionuclides that make the local areas uninhabitable for hundreds of years and contaminate large surrounding areas, whereas the releases of toxic gases from industrial facilities can cause thousands of deaths in very short time, such as that at Bhopal, India, which in 1984 produced some 6000 deaths and over half a million injuries [32]. Combinations of two or more hazards can also produce unforeseen consequences that are dependent on the local conditions of the environment.

In a complex system, such as city and an ecosystem, there are many events taking place in different parts and at different times, and it may happen that a small event in such a system can cause its state to be defined by completely different properties that may or may not be suitable for living beings. The Earth's atmosphere is such a system, where the global warming and the non-linear behavior of the atmosphere and oceans may trigger abrupt changes with different atmospheric and oceanic circulation patterns that could not only greatly affect the adaptation of humanity, but also produce mass extinctions, as happened several times during the Earth's history [26]. Cities are human-constructed environments that shield their inhabitants from many threats, but when these environments become inadequate for human well-being they can become very unpleasant. High cost of land in cities encourages crowding that exacerbates both the internal and the external threats, and the changing population densities and their economic and cultural functions affect the cities' intellectual and innovative activities. Urban planning and security management become interactive in megacities and the cities have different susceptibilities to disasters.

Urban areas are, therefore, the places where many disasters can occur: Natural, technological, biological, chemical, and societal. Floods can dispense toxic materials and earthquakes can rupture fuel distribution and unbalance information systems. Cities on volcanoes can become uninhabitable for centuries by large volcanic eruptions. Nuclear reactor accidents can produce local and surrounding areas uninhabitable for thousands of years, and the droughts, tsunami, and tropical cyclones can uncover waste disposal sites, disrupt city services, and even terminate their existence. Social inequality can produce unrests and crime can take control of cities innovative capacities. These and other *multihazards* are difficult to assess for any large city, because our knowledge on how the complex systems function are rudimentary [33]. But hazards can also produce *hazard opportunities* for producing higher levels of safety and human development, as the great cultures of the past (in the Middle East, Asia, and Central America) demonstrated by their central preoccupation with avoidance, prevention, and mitigation of hazards and disasters. The megacities of tomorrow have a great potential of becoming not only the key places of unprecedented disasters, but also the places of extraordinary growth of humanity.

3. Cities Exposed to Natural and Anthropogenic Hazards

By the middle of this century 70% of world's population will live in cities and almost two billion people will be exposed to tropical cyclones and earthquakes, and the urban management will have to perform better in generating and disseminating credible information on city hazards and their associated risks [34, 35]. The economics of cities is related to favorable geographical locations that are often exposed to the increased likelihoods of hazard events, such as floods, cyclones, and volcanoes. The agriculture in particular is beneficial in the proximities of volcanoes and about 10% of population lives within 100 km of historically active volcanoes, with high concentrations in Southeast Asia (Indonesia, Philippines) and Central America (Mexico) [36]. Low elevation coastal zones cover some 2% of the world's land area and contain more than 10% of the world's population

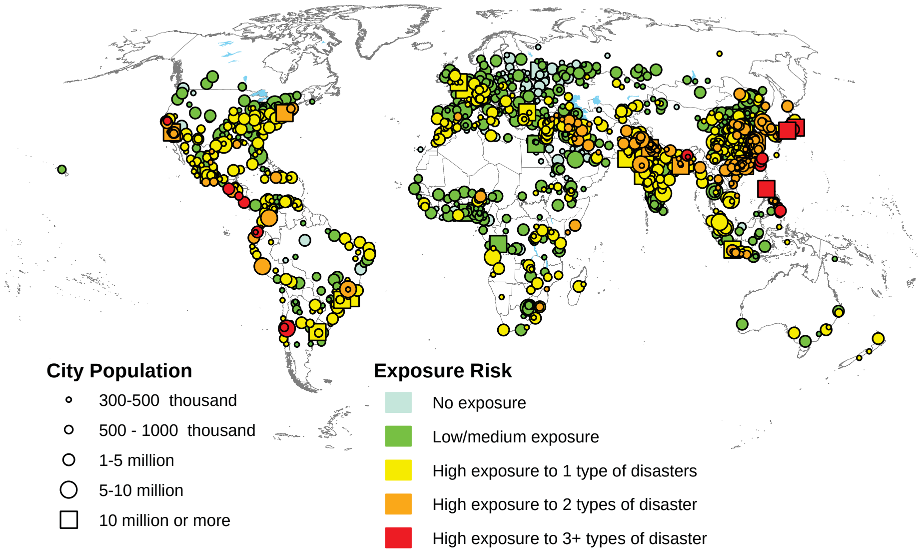


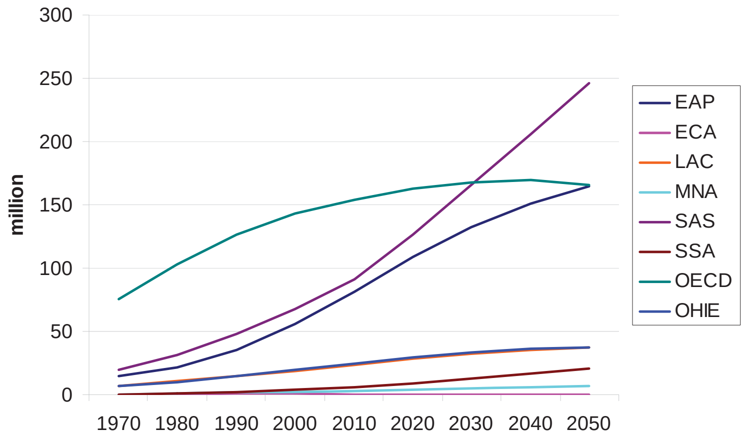
Figure 2. World cities at risk [38].

and 15% of the world's urban population [37]. The intense competition for land in urban areas not only leads to higher population densities but also to the increasing risk from the rise in exposure. Figure 2 shows the world's cities exposed to different levels of risk and Fig. 3 the projected population increases in large cities exposed to cyclones and earthquakes for different regions of the world defined by the World Bank Organization. Nuclear reactor accidents at Chernobyl in 1986 and Fukushima in 2011 produced large exclusion areas for hundreds of years and contaminated hundreds of square kilometers of fertile soils [30, 31], and only in imagination can we perceive what could happen if such accidents occurred in the close proximities of cities with millions of people. In 1984 the Union Carbide pesticide plant in India released some 30 tons of a highly toxic gas and some 600,000 people were exposed and several thousand people died from the release of methyl isocyanate gas [32].

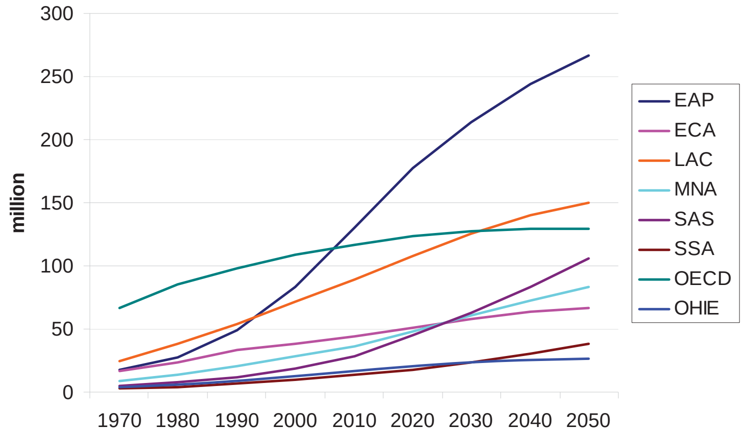
The following brief tour of some of the cities on geologic faults, cities on volcanoes, cities exposed to tropical cyclones and climate change, and cities exposed to hazardous industrial facilities attest to the challenges imposed on the technical and governance organizations to ensure that these cities thrive in security and prosperity in spite of their surrounding hazardous environments.

3.1 Cities on Geologic Faults

Figure 4 presents a sample of some cities of the world that are exposed to earthquakes by their virtues of being situated on or close to the *geologic faults*. The faults are ruptures on the Earth's crust or *lithosphere* consisting of six large



(a) Populations in large cities exposed to cyclones will increase from 310 million in 2000 to 680 million in 2050.



(b) Populations in large cities exposed to earthquakes will increase from 370 million in 2000 to 870 million in 2050.

Figure 3. Exposures of populations to cyclones and earthquakes [35]. EAP (East Asia Pacific), ECA (Europe and Central Asia), LAC (Latin America and Caribbean), MNA (Middle East and North Africa), OECD (Organization for Economic Cooperation and Development, 34 democracies with market economies).

(a) Istanbul (left). San Francisco (right).

(b) Mexico City (left). Wellington (right).

(c) Tokyo (left). Amatrice after 2016 earthquake (right).

Figure 4. Cities on geologic faults: Istanbul (Turkey), San Francisco (United States), Mexico City (Mexico), Wellington (New Zealand), Tokyo (Japan), Amatrice (Italy).

(African, Eurasian, Indo-Australian, North American, Pacific, and South American) and many small *tectonic plates*, each 50-150 km thick [29].

Istanbul is the oldest and the largest city in Turkey with a population of about 15 million people and growing at an estimated 400,000 a year and containing close to 2 million buildings located on the two continents of Europe and Asia. The European side of Istanbul in built on soft rock and the Asian side sits on hard old rock. The North Anatolian Fault Zone with two tectonic plates (Eurasian and Anatolian) sliding past each other is only a few kilometers away from the city's center and passing through the Sea of Marmara along which the earthquakes occur and affect Istanbul. The 1999 Izmit or Marmara earthquake on this fault had a moment magnitude of 7.6 and killed some 20,000 people, left half million homeless, and the city of Izmit, some 110 km east of Istanbul, was severely damaged. This raised a concern for Istanbul where the probability of a major earthquake affecting this city by 2030 exceeds 60%. The World Bank is investing significantly in the city's quake readiness measures and the building regulations have been tightened, but an estimated 65% of buildings in Istanbul still don't meet building regulations and many people are fatalistic [39, 40].

San Andreas Fault is the 1200 km long sliding boundary between the Pacific Plate and the North American Plate, and slices California in two, with San Diego and Los Angeles on the Pacific Plate and San Francisco on the North American Plate [41]. A scientific study [41] projects that this fault has reached a sufficient stress level for an earthquake of greater than 7 on the moment magnitude scale, and a U.S. Geological Survey report [42] states that a magnitude 7.8 earthquake could cause several thousand deaths and over $200 billion in economic losses, in spite of aggressive retrofitting programs that have increased the seismic resistance to buildings and infrastructure.

Mexico lies on top of three great tectonic plates: North American Plate, Cocos Plate, and Pacific Plate, and when these plates move the vibrations felt by the soft soil of a former lake bed on which Mexico City is built can be trapped in the bed and amplified, causing large movements of the buildings in the city. When in the morning of 19 September 1985 a moment magnitude 8 struck this city from the 500% amplification of vibrations it seriously damaged the greater part of the city and caused over 5000 deaths. This and the subsequent aftershocks, produced from the earthquakes some 350 km away, caused several billion USD in damage, over 400 building collapses, and several thousand seriously damaged structures [43]. More recent 7.1 magnitude earthquake that struck the coast of Mexico in 2017 topped some 40 buildings and killed over 100 in Mexico City [44]. The highlands plateau on which Mexico City is built is also populated by volcanoes, and the active volcano Popocatépetl, at 70 km southeast of the city, majestically overlooks this metropolis and may one day cause large population movements from the valleys below the volcano. After the 1985 disaster, Mexico changed its building regulations and pushed for better design and materials [45]. Today there are dedicated warning receivers in schools and public places of Mexico City and warnings issued through radio and television broadcasts [46].

Wellington Fault is an active seismic fault in the southern part of the North Island of New Zealand and is associated with the boundary of Indo-Australian Plate and Pacific Plate. This fault runs right through the New Zealand's capital Wellington City whose major hazards are earthquakes and tsunami generated from the earthquakes. Although no historic earthquake has been recorded for this fault, the potential impact of rupture along the Wellington-Hutt Valley section in the Wellington area makes it one of the greatest natural hazards in New

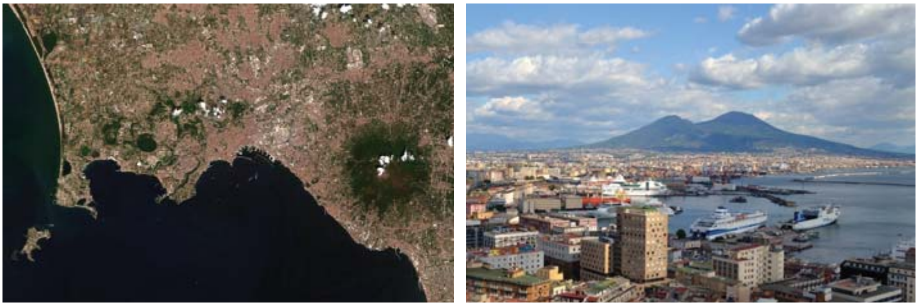
Zealand. The last time that Wellington Fault ruptured through the Wellington region and caused a major earthquake was 300-500 years ago and is capable of producing earthquakes of up to magnitude 8 [47, 48].

Another majestic volcano Mt. Fuji overlooks the megacity of Tokyo some 100 km away, but it is the earthquakes that this city is most concerned with. Tokyo is located on the three layers of tectonic plates: North American Plate on the top, Philippine Sea Plate under it, and Pacific Plate underneath both of them. These plates move regularly and the probabilities of major earthquakes occurring in the Tokyo Metropolitan Area range from 50-85% in different areas [49]. Eastern Tokyo is at the highest risk of major earthquake damage and as a result of redevelopment in densely populated residential areas (wider roads, quake-resistant houses) the updated 2018 map shows 20% reduction for building collapses and 40% reduction of fires since 2013. The risk levels were analyzed based on ground stability, building structures, road conditions, and oil stoves of households. The Japanese government estimates, however, that a 7.3 earthquake in the city could cause over 5600 deaths, 160,000 injured, and destroy 850,000 buildings. The Great Kanto earthquake of magnitude 7.9 that struck the Tokyo-Yokohama Metropolitan Area in 1923 produced an estimated 140,000 fatalities and $1 trillion in damage [50]. A disaster prevention guidebook prepared by the government of Tokyo describes in great deal how the population needs to be prepared to confront earthquakes and associated tsunami, typhoons, and other natural and anthropogenic hazards [51].

The 24 August 2016 Central Italy earthquake, with the epicenter near the town of Amatrice and measuring 6.2 on the moment magnitude scale, almost raised to the ground this small town with a population of 2650 inhabitants. Over 300 people lost their lives, several thousand had to find shelter in emergency camps, and an estimated $1-10 billion in damage was sustained. The loss of cultural heritage was widespread, since many constructions and renovations did not follow the antiseismic law [52]. Amatrice is today on the list of the world's most endangered heritage sites, empty, and strewn with rubble, and waiting to be resurrected from the disaster.

3.2 Cities on Volcanoes

Volcanoes are openings in the Earth's crust that allow the escape of molten rocks or magma from the Earth's interior onto the surface. There are about 500 volcanoes that have erupted during historic time and the larger the repose time of a volcano, the more energetic its resumption becomes. Most volcanoes are situated along the edges of tectonic plates: Andes in South America; Central American Mountain Range; Cascades Range in North America; Aleutian Islands in Alaska; western Pacific Ocean from New Zealand, through the Indonesia, Philippines, Japan, and Kamchatka; northern Mediterranean; and west of Africa [29]. Most of the Earth's volcanoes are, however, hidden beneath the oceans along the mid-ocean ridges and some pierce the tectonic plates, but these do not concern us in this paper. Figure 5 illustrates some examples of large cities



(a) Aereal view of volcanoes Vesuvius to the east and Campi Flegrei to the west of Naples (left). Naples with Vesuvius in the background (right).

(b) Arequipa with Misti (Putina) volcano in the background (left). Kagoshima City with Sakurajima volcano in the background (right) .

(c) Legazpi City with Mayon volcano in the background (left). City of Puebla with Popocatépetl volcano in the background (right).

Figure 5. Cities on volcanoes: Naples (Italy), Arequipa (Peru), Kagoshima City (Japan), Legazpi City (Philippines), City of Puebla (Mexico).

(Naples, Arequipa, Kagoshima, Legazpi, and Puebla) too close to the volcanoes Vesuvius, Campi Flegrei, Misti, Sakurajima, Mayon, and Popocatépetl.

Naples in Italy is situated between two explosive volcanoes: Vesuvius to the east and at 14 km from the center of the city, and Campi Flegrei to the west whose 12 km wide caldera is only 5 km from Naples. Vesuvius produces large plinian eruptions every few thousand years and an order of magnitude less powerful sub-plinian eruptions every 3-6 centuries in between the plinian eruptions. The Campi Flegrei volcanic complex has been active for at least 60,000 years and during this time produced two super eruptions, with each erupting 10-100 times more material than the largest eruptions of Vesuvius and on which the city of Naples is built [53, 54]. The official plan is to relocate one million people surrounding the volcanoes all over Italy in the event of impending eruptions, but these plans are unreliable from the technical, social, and cultural perspectives [55]. The alternative resilience and sustainability framework for the Neapolitan area proposed more than 20 years ago does not require such a dispersion of population and requires territorial intervention for the people being able to cohabit with the volcanoes in security and prosperity [23]. Naples and its surroundings have an inestimable cultural value and the nearby ancient cities of Pompeii and Herculaneum that were buried by the eruption of Vesuvius in A.D. 79 attract millions of visitors each year.

The volcano El Misti (also known as Putina) stands at 5,822 m above the sea level and last erupted in 1985. The world heritage city of Arequipa with 1.5 million inhabitants is the second largest in Peru and the city center is only 17 km from the craters of El Misti, with new settlements only 13 km away. In the event of a major eruption like that of 2000 years ago, the city faces being inundated with ash fall, pyroclastic flows, and lahars [56, 57]. Although the hazard maps of the city are shared with public and nonpublic institutions, much of the city remains at high risk levels [58].

On the south-western tip of the island of Kyushu in Japan, Kagoshima City with about 600,000 inhabitants stands in the Kinko Bay, with the volcano Sakurajima situated at 4 km across the bay where 7000 close by residents are being exposed to frequent eruptions of this volcano. A major lava flow eruption in 1914 connected the Sakurajima volcanic island with the mainland. The Sakurajima Volcano Hazard Map [59] instructs the people living close to the volcano of the precursory phenomena of the eruption, dissemination of volcanic warnings, and evacuation procedures. The authorities of Kagoshima City also instruct the citizens of the impending dangers of the volcano and confront resilience and sustainability with an evacuation plan [60].

In January 2018 steam and ash plumes rose above the volcano Mayon on the large island of Luzon in the Philippines and warned the 200,000 inhabitants of Legazpi City which is only 15 km away of the impending danger of ash fall, lava and pyroclastic flows, and lahars [61]. The 2018 eruption caused the evacuation of people from the permanent danger zone (6 km radius of the volcano) and preparation was underway to relocate people from more distant areas if the volcano alert levels increase [62]. The government of Albay Province has a general resilience strategy for the cities surrounding Mayon [63].

As one of the most active volcanoes in Mexico, Popocatépetl (El Popo) is situated 70 km southeast of Mexico City and 40 km west of the City of Puebla with a population that exceeds 3.2 million. Its major eruption 23,000 years ago produced an avalanche that reached up to 70 km from the summit [64] and a major pyroclastic flow eruption can, therefore, reach Puebla. During the active periods of the volcano this city is frequently exposed to the ash fall [65].

3.3 Cities Exposed to Tropical Cyclones and Climate Change

Tropical cyclones (also called hurricanes and typhoons) are rotating and organized systems of clouds and thunderstorms that originate over tropical or subtropical waters in Atlantic, Pacific, and Indian Oceans. They can produce sustained winds as high as 250 km/hr with gusts exceeding 300 km/hr and heavy rains, high waves, storm surges up to 10 m, and have the potential of spawning tornadoes when making landfall. Flooding caused by the storm surge is responsible for most of the deaths and is particularly severe in low-lying areas such as in Bangladesh and the Gulf Coast of the United States. Mountains and canyons can concentrate the rainfall from tropical storms that can then cause landslides and wash away entire towns and far away from the coasts as in Himalayas [66].

Processing and combustion of fossil fuels from industrial operations, such as materials processing and energy generation, produce *greenhouse gases* (carbon dioxide, methane, water vapor, nitrous oxides, and synthetic compounds made of carbon, fluorine, hydrogen, phosphorus, sulfur) which trap the radiation emitted from the surface of the Earth and warm the atmosphere. *Global warming* [67, 68] causes the melting of glaciers that can greatly affect the Earth's atmospheric and oceanic circulations [69] and thus exacerbate the already large problems of many cities caused by tropical cyclones and produce new problems for those cities not yet affected by the cyclones. New York City, Venice, Dhaka, Jakarta, and Manilla (Fig. 6) are only a few of such cities that can be affected by tropical cyclones and/or climate change.

New York City is almost completely surrounded by water from the Atlantic Ocean on the east and Hudson River on the west, and is subjected to storm surges from hurricanes and sea-level rise from global warming, tsunami arriving from the landslides at volcanic Canary Islands off the coast of west Africa, and releases of long/acting radionuclides from a nuclear power station located 60 km from Midtown Manhattan. When the Hurricane Sandy swept up the East Coast of the United States and made a landing near New York City on 29 October 2012 with 140 km/hr winds it flooded a large part of the city's subway system and some tunnels, closed Lower Manhattan services, caused large damage to the houses and businesses along the Atlantic coast of Long Island, over 2 million people lost electricity services, and many locations required emergency services. From Caribbean to New York, Sandy caused 159 deaths, damaged or destroyed some one million homes, 10 million customers lost electricity, produced 10 m high storm surges, and incurred $65 billion in damage [70–72]. Following the Sandy disaster, the New York City government produced a resilience plan for providing additional protection for New York's infrastructure, buildings, and communities from the impacts of cyclones and climate change, so that the water can find it more difficult to enter the city and thus reduce future economic losses [73].

(a) New York City (left). Venice (right) .

(b) Bangladesh (left). Dhaka (right), capital city of Bangladesh.

(c) Jakarta (left). Manilla (right).

Figure 6. Cities exposed to tropical cyclones and climate change: New York City (United States), Venice (Italy), Dhaka (Bangladesh), Jakarta (Indonesia), Manilla (Philippines)

The sea-level rise and human interventions of deep-water extraction causing the subsidence of soil risk permanent flooding of Venice by the end of this century. The Venice Lagoon is supplied with water from the Adriatic Sea through three inlets and the water circulation in the lagoon is essential for maintaining Venice a habitable environment. About two thirds of city's population lives on mainland and one third is spread over 100 islands in the lagoon. Many of city's historic buildings and walkways are compromised from the corrosive effects of sea water, soil erosion, boat wakes, etc. The 1966 storm surge flooded the city and the Save Venice effort was launched to start protecting this former republic [74]. The project adopted to save Venice from floods is knows as MOSE (MOdulo Sperimentale Elettromeccanico) and consists of a set of mobile gates to be built across the three inlets to the lagoon and closed only during high water events [75]. The construction of this project is expected to be completed in 2022 [76].

Eighty percent of Bangladesh is floodplain and can be flooded from severe tropical storms [77]. Thousands of people perish and millions of homes are destroyed every year in this country from flooding and the capital city Dhaka with 10 million inhabitants is paved with water during the monsoon season. The largest slum Korail in Dhaka is raised on sticks above the water level and is especially vulnerable to floods, and most of the country will be flooded if the sea-level rises more than 1 m during this century. The floods in Bangladesh have caused devastations in 1966, 1987, 1988, and 1998.

While India is the most exposed country in the world to natural disasters and Bangladesh has the highest exposure rate, Manilla, Tokyo, and Jakarta are the most exposed cities [78]. Jakarta with 10 million inhabitants is projected to double its population in the following decade and its thirst for drinking water is causing severe subsidence in many areas of the city. Jakarta is situated on the north coast of the island of Java in the Indonesian archipelago and in a deltaic plain crisscrossed by rivers. Some 40% of Jakarta is below sea-level and prone to flooding from water draining through the city from the hills in the south and from tidal flooding and climate change. There is no comprehensive risk management program for Jakarta [79, 80].

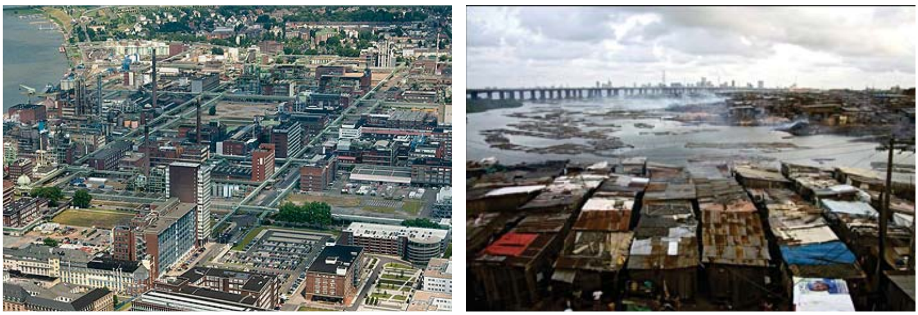
Manilla is one the most densely populated cities in the world and its two million inhabitants are not only exposed to the hazards from earthquakes, volcanic eruptions, and tsunami, but also from half a dozen typhoons that each year cause extensive flooding of the city. In 2009 the typhoon Ketsana claimed over 700 lives and produced 1$ billion in damages [81]. The informal settlements in this city are especially vulnerable to typhoon hazards [82] and the Philippine Development Plan 2017-2022 [83] aims to build resilience to hazards through the geohazards maps and economic investments [84].

3.4 Cities Exposed to Hazardous Industrial Facilities

The Chernobyl Power Complex included four nuclear fission reactors prior to the accident on 26 April 1996 when one of the reactors suffered a core meltdown and produced a release of radionuclides into the atmosphere and surrounding soils. Within few weeks 28 people died and 600 emergency workers were exposed to high levels of radiation, and some 120,000 people from the 30 km radius of the plant were evacuated, including the 49,000 residents from the city of Pripyat that was only 3 km away from the plant [85] (Fig. 7a,left). The exact degree of radioactive contamination in the vicinity and beyond the nuclear power plant is still being debated, and today this facility is covered with a sarcophagus and the people are prohibited to enter into the 10 km radius exclusion area of the plant.

(a) Chernobyl with the former city Pripyat in the foreground (left). Fukushima Daiichi (right).

(b) Indian Point (left). Diablo Canyon (right).



(c) Leverkusen (left). Lagos (right).

Figure 7. Cities and towns exposed to hazardous industrial facilities: Chernobyl (Ukraine), Fukushima (Japan), New York City (United States), Los Angeles (United States), Leverkusen (Germany), and Lagos (Nigeria).

The Chernobyl disaster occurred from operator errors and poor safety measures, and when in 2011 a similar accident occurred at the Fukushima Daiichi nuclear power plant in Japan, new questions were raised as to the safety and security of such facilities [31, 86].

The Fukushima Daiichi disaster (Fig. 7a,right) was triggered by the magnitude 9 earthquake off the coast of the largest and most populous island Honshu of Japan, where the Pacific Plate subducts the North American Plate. The energy accumulated from the movements of these plates was released through a slip that raised the top plate which produced a tsunami 40 m high. This wave then overflowed the protective barrier of the Fukushima Daiichi nuclear power plant and immobilized the plant's cooling and safety systems. The meltdown of two of four reactor cores followed and large quantities of radionuclides were released and dispersed over the mainland Japan and Pacific Ocean. Some 13% of Japanese mainland was contaminated with radioactive cesium-137, and from 1000 km^2 exclusion area adjacent to the plant more than 150,000 people have been evacuated [87]. The Fukushima Daiichi disaster occurred because the power company TEPCO managing the plant also managed to control the government's regulatory process that did not require building the plant to withstand the historical tsunami intensities in the region of the plant, and once the accident occurred the authorities failed to properly manage some 10 million people in the contaminated area [86, 88].

The Indian Point Energy Center (Fig. 7b,left) is a nuclear power plant station on the Hudson River, 60 km from the Midtown Manhattan in New York City, and its 40-year operating license expired in 2013, but was extended for another 8 years [89]. The plant contains some 2 tons of cesium-137 in its spent fuel pools, and any release of radionuclides is easily transported downstream to New York City with 20 million people. The Indian Point plant also sits 2 km from a fault whose activity is disputed. But this is not the case with the Diablo Canyon nuclear power plant (Fig. 7b,right) in California with several small cities close by and megacity Los Angeles 300 km away. This plant is located in the earthquake red zone containing several faults, including the major San Andreas fault 80 km away [90]. Diablo Canyon is, however, under intense pressures to shut it down.

In France, about 75% of electricity is produced from nuclear energy and a dozen of nuclear fission power reactors are located within 50 km radius of large cities [91]. Bordeaux, Lyon, Marseille, and Paris, among others, would all be exposed to radionuclides in the event of severe accidents, triggered by either operator errors, terrorist acts, or possibly earthquakes produced from the nearby geologic faults.

The cities of Leverkusen in Germany and Lagos in Nigeria have, however, the problems of being close to the processing of chemical materials and decomposition of hazardous waste. More than 5,000 chemicals are manufactured in CHEMAPARK of Leverkusen (Fig. 7c,left) where over 30,000 people work and live [92]. The production of these chemicals produces emissions into the air and waste products, and it is claimed that their disposal in the huge landfill next to CHEMPARK is safe. Olusosun landfill in Lagos, Nigeria is the largest in Africa and one of the largest in the world, where over 1000 families live on the site and scavenge for scrap being delivered from all over the world (Fig. 7c,right) [93]. This 100 acres landfill receives about 7000 tons of trash a day, is surrounded by commercial and residential areas, and is not subjected to regulations.

For many cities in hazardous environments the future does not appear very promising, unless large resources are employed to make these cities safe and prosperous. This requires producing *professional feasibility studies* that detail how, what, and for whom should the cities be reorganized, so that the perturbing effects of natural and anthropogenic hazards do not produce disastrous consequences, nor make the cities uninhabitable for future generations. To produce such feasibility studies and make optimum decisions we must be able to quantify vulnerability, risk, resilience, and sustainability for cities, which we address in the following section.

4. Risk Assessment, Resilience, and Sustainability

4.1 Complex System Modeling

Can the risks and vulnerabilities of cities in hazardous environments be properly assessed and can effective decisions be taken for making these cities more resilient and sustainable so that their inhabitants can live in security and prosperity without compromising similar aspirations of populations elsewhere? In order to answer the first part of this question requires appropriate models for quantifying risks, vulnerability, and other related quantities, such as resilience and sustainability which we will discuss shortly. Without this quantification proper decisions cannot be made reliably and instead of making concrete progress we will continue producing subjective judgements on how to achieve this goal, as the vast literature on this subject is attesting. But what kind modeling approaches could serve our purpose when dealing with a complex system such as a city?

Transformation, reorganization, and adaptation to the surroundings in central for the survival of a complex system, and an effective model of this system should account for these attributes. A model of such a system should deal with all the relevant information of past events and consequences and be able to quantify all relevant future events and consequences that *may* affect the functioning of the system. Given the system complexity and uncertainty about its future state, such as model should be defined by the *plausibility* (degree to which the statements about the system can be believed) of propositions or hypotheses regarding its functioning, evidence or data pertaining to these propositions, and any additional knowledge pertaining to the system but not connected with the propositions. We then need to express this information in a mathematical form that includes both the *physical causality* or determinism, where the past determines the future, and *logic* which mimics the human brain through its memory content. The incorporation of this *memory information* into the model is necessary for allowing system transformation, reorganization, and adaptation.

The model that we are proposing is based on the “logical” interpretation of *probability theory* and requires only finite number of propositions, common sense correspondence, and consistency [94, among others]. Consider, therefore, the plausibility of assigning a space of propositions or hypotheses $H = \{H_1 \dots H_h\}$ by knowing that some other space of propositions $B = \{B_1 \dots B_b\}$ is true,

$$H \mid B \tag{1}$$

and seek a real number between 0 and 1 that measures this possibility through the definition of *probability* of $H \mid B$ (probability of H, given B), i.e.

$$0 \leq P(H \mid B) \leq 1 \tag{2}$$

where B may or may not include some knowledge of the propositions H of causual (deterministic) and logical nature. In addition, we need some structural elements of probability theory, the *product rule* and the *sum rule*,

$$P(AB \mid C) = P(A \mid BC)P(B \mid C) = P(B \mid AC)P(A \mid C) \tag{3}$$

$$P(A \mid B) + P(\bar{A} \mid B) = 1 \tag{4}$$

where $A = \{A_1 \ldots A_a\}$ and $C = \{C_1 \ldots C_a\}$. $AB \mid C$ is the plausibility that A and B are true, given that C is true, $A \mid BC$ is the plausibility that A is true, given that B and C are true, and $\bar{A} \equiv A$ is false.

The fundamental principle of probabilistic inference is that of forming a judgement about the likely truth or falsity (probability) of any proposition, or which one of a given a set of hypotheses is most likely to be true, conditioned on *all* the available evidence and not only on partial evidence. For practical purposes, there is no such thing as the absolute probability. We can decompose the evidence (information or knowledge base) B into three types of knowledge: (1) data $D = \{D_1 \ldots D_d\}$ about the propositions or hypotheses, (2) data $M = \{M_1 \ldots M_m\}$ about some key attributes of H stored in system's memory, and (3) *prior information* X of the system with no logical connection with the hypotheses. The division of evidence into data and prior evidence serves only to organize the chain of inferences and X should not contain any major premise such as a physical law. The data M or the *memory data* can be interpreted as the data pertaining to the uncertainties of probabilities of hypotheses through which the system draws certain information about the propositions (like their social values) without remembering all historical details about their relevance.

Using Eq. (3) we can then compute the *posterior probability* $P(H \mid DMX)$ of inferring the likelihood of hypotheses H, given the data DM and prior information $X = \{X_1 \ldots X_x\}$,

$$P(H \mid DMX) = P(H \mid X)\frac{P(DM \mid HX)}{P(DM \mid X)} \tag{5}$$

Borrowing the language from statistics, $P(H \mid X)$ and $P(DM/X)$ are the *prior probabilities* (or priors, since they are conditions on X alone), $P(DM \mid HX)$ is the *sampling probability*, and the last factor is the *likelihood* (not a probability) and can be represented by $L(H)$. If $P(H \mid DMX)$ turns out to be close to one (zero), we may conclude that H is very likely to be true (false), but if $P(H \mid DMX)$ is close to 0.5 the available evidence is not sufficient for confident decision making and we need more evidence for obtaining higher confidence. So far our theory does not allow assigning prior and sampling probabilities and in the literature they are often confused and require the utilization of some guiding principles involving maximum entropy, group invariance, coding theory, etc. [95].

The determination of priors is an important issue when employing probabilistic methods and we should keep this in mind as we proceed with the probabilistic definitions of risk and other relevant variables. The use of uncertainty in probability theory has been addressed in some recent works without operationalizing it [96]. In this work we interpret the uncertainty of propositions as the loss of their detailed histories and remembering only their overall characteristics, such as mean values, stabilities, values, etc. Our brain works in this manner and serves us to build new knowledge from the knowledge retained in its memory [97].

4.2 Risk, Vulnerability, and Risk Assessment

Equation (5) is our *fundamental principle* and we can apply it to quantify risk and vulnerability. If we denote risk by R, events by $E = \{E_1 \dots E_e\}$, consequences by $C = \{C_1 \dots C_c\}$, and knowledge base by DMX, we should be able to quantify the risk (likelihood) of any hypothesis on the occurrences of E and C, given the evidence DMX, i.e.

$$R(EC, DMX) \equiv P(EC \mid DMX) = P(EC \mid X)\frac{P(DM \mid ECX)}{P(DM \mid X)} \tag{6}$$

To evaluate this probability requires the specification of relevant hazard events and consequences (hypotheses or propositions) that often cannot be clearly separated, because: (1) some events can produce other unforeseen events and consequences, and (2) some consequences can produce both foreseen and unforeseen events. In addition, the data associated with hypotheses and any other knowledge not logically connected to hypotheses must also be made available, which, as we will see below, requires an interdisciplinary and transdisciplinary team of experts for their specification. Knowledge may come from various types of (deterministic and probabilistic) simulations of hazards and consequences or scenarios, historical records, geological and archeological studies, etc.

When evaluating risk for a city one should be able to determine if the current risk is acceptable (close to 0) and if not what needs to be done to bring it to this level. Most if not all of the cities in hazardous environments have not undergone such a scrutiny and "risk" facing severe consequences. They do not even have credible emergency plans to confront the hazards, and Naples in Italy is a good example of this deficiency [98].

Consequences are sometimes identified as *objectives* and the risk description is made in terms of objectives, uncertainties of objectives, and "background knowledge on which consequences and the assignment of uncertainties are made" [99], but no operational model is provided on how to systematically conduct such a risk analysis. In our probabilistic definition of risk, both the events and consequences[2] enter into the definition of risk, and the uncertainties of their probabilities (variances and higher moments) are automatically determined from

[2] Events and consequences are treated as independent because we want to assess the probabilities of one or more events producing one or more consequences, and vice versa.

these probabilities and stored in memory data M for subsequent updating of risk probabilities. This allows for two or more states of knowledge to have the same mean values (equalities of first order moments of probability density functions), but representing different knowledge, because of the difference in higher order moments (variances and cross correlations).

Risk assessment is a process for evaluating hazards, deciding who or what might be harmed (defining a system) and how, evaluating risks and deciding on precautions, implementing the findings through the appropriate control measures that reduce the risks, and periodic evaluations of risks based on updated knowledge. The complexity of a system such as a city requires that the risk assessment team consists of the right mix of experiences and responsibilities, and that the team's goal is to reduce risk to tolerable levels. Central to the risk assessment is *risk perception*, since different individuals or groups, with different experiences and knowledge, interpret differently the potential for negative consequences. Some well-known tools used in risk assessments are: Interviewing; historical records; scenario hazards analysis; expert judgement; failure mode and effects analysis; event, fault, and decision tree analysis; probabilistic risk assessment; human reliability analysis; critical function analysis; etc. This risk assessment tool box and the more fundamental one noted above and associated with the determinations of prior and sampling probabilities, provide no absolute rule as to how and to what depth a risk assessment should be performed, but it must be systematic to be most effective and begin early in the life cycle of complex systems and include all relevant hazard scenarios and consequences [100]. The complexity of a city and its exposure to threats, and the resulting consequences that may ensue, places a severe burden on the risk assessment team, and especially when the city must reorganize its built environment, and likely that of its surroundings, to resist the threats that have the potential of producing great human catastrophes [23, 101].

We noted above that the degree of severity of consequences depend on the *vulnerability* V of values that we place on things relative to the financial, ethical, cultural, ecosystem, or other measures. Vulnerability should, therefore, represent the likelihood or probability that damage and loss can or cannot occur, following the initiation of *one or more* given events E', data $D'M'$ pertaining to C', and knowledge X' not connected with C'. Using Eq. (5), vulnerability or the likelihood of consequences V can then be expressed as

$$V(C', D'M'X'E') \equiv P(C' \mid D'M'X'E') = P(C' \mid X'E') \frac{P(D'M' \mid CX'E')}{P(D'M' \mid X'E')} \tag{7}$$

from where we have that the prior probabilities $P(C' \mid X'E')$ and $P(D'M' \mid X'E')$ are now conditioned on the knowledge $X'E'$. Note also that the set of vulnerability consequences is smaller than the set of risk consequences and that the knowledge base of vulnerabilities is greater, which implies that it is easier to assess vulnerabilities than risks.

4.3 Resilience

The word "resilience" comes from "being able to resist" *one or more* consequences and as such is applicable to social and non-social systems (individuals, families, businesses, communities, economies, governments, ecosystems, facilities, objects). Systems can be resilient to internal and external impacts if they resist loosing their functional capacities, and, failing this, are able to overcome, adapt, and recover from these impacts. Our probability theory can be employed to operationalize resilience by performing two separate analyses. In the first analysis we compute resilience by searching for very high (almost 1) likelihoods of those consequences that lead to the loss of functional capacity of the system, and in the second analysis we determine the likelihood of reducing these consequences to acceptable low values (almost 0) by mitigating these consequences trough a *reorganization* of the system. As an example, if flooding is threatening a community we can construct barriers, move the communities to higher grounds, protect better the infrastructure from flooding, etc. To produce a non-resilient system resilient requires, therefore, intervening or rearranging the system, which generally requires adopting long-term preventive actions. The two analyses above can be combined by including in the hypotheses of events, consequences, and knowledge base also those events, consequences, and knowledge base associated with the reorganized system and then computing the probabilities of all consequences.

Thus, if we denote resilience by Res, consequences from both non-reorganized and reorganized system by C'', all events by E'', and data and prior information pertaining to the hypotheses C'' by $D''M''$ and X'', respectively, our resilience probability problem becomes,

$$Res(C'', D''M''X''E'') \equiv$$
$$P(C'' \mid D''M''X''E'') = P(C'' \mid X''E'')\frac{P(D''M'' \mid C''X''E'')}{P(D''M'' \mid X''E'')} \tag{8}$$

where X'' is the prior information not logically connected with C''. The priors depend on $X''E''$, where E'' includes the events from the non-reorganized and reorganized system and not only a subset of these events as in the vulnerability. Another difference between vulnerability and resilience is that the former operates on a smaller set of consequences than the latter, because a *resilient system should resist all the consequences from all the events.* Looking in a different manner, the knowledge base used to determine resilience must be larger than that involved in determining vulnerability.

Like risk and vulnerability, resilience is also a product of social and non-social order, and thus a system exposed to a threat or threats has the power to become less vulnerable and more resilient. Resilience requires change, internal reorganization, and transformation to a new set of operating parameters which can be stable or meta-stable. Metastable systems operate at higher energies than stable systems, and one can argue that *all desirable and evolving systems* (like cities) must belong to the former category, because they can more easily adapt to the circumstances of their changing surroundings. If sufficiently large, the internal and external perturbations on a metastable system can render it stable, metastable, or unstable in terms of its energy content, which for a socio-technical system can lead to a disaster, since the transition of system properties to new properties may not be suitable anymore for the survival for system inhabitants. The lack of water supply to cities, exposure to disease-prone environments, loss of business opportunities, etc. has in the past led the people to desert many great urban centers in different parts of the world [102].

4.4 Sustainability

The word "sustainability" appears in many publications of United Nations and national and local governments attempting to improve the socio-economic status of the people. That what can be maintained under the existing conditions can be considered sustainable, but both the natural systems and the societies are self-organizing systems that are in general in non-equilibrium and thus dynamical entities that can change gradually and abruptly and coexist at best in local or metastable equilibrium [103].

According to the report Our Common Future of World Commission on Environment and Development of the United Nations, sustainable development points to a directional and progressive change of humanity [104, 105]. This report defines *sustainable development* as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs and aspirations". Sustainability in this form is an anthropocentric concept where the human-induced changes of the environment do not threaten the exchange processes between the humanity and the natural environment in which the society is expected to survive for an indefinite time. But how is sustainable development to be achieved and what exactly are the needs and aspirations that we should be aiming at and over what space and time frames remains unclear. To achieve sustainability we should sustain economy, protect the environment, achieve social goals, and maintain institutions that are able to safeguard such visions into the distant future. Sustainability is, therefore, influenced by value judgments and ethics, and Agenda 21 Program of Action, and more recent elaboration of the principles in this document, suggest 10 sustainability principles [106]. These principles require clear definition, focus on holism or self-contained systems, underline the importance of time and spatial scales in the assessment of sustainability, and emphasize the use of a limited number of indicators or attributes and how they should be developed and employed. United Nations, International Atomic Energy Agency, and many other national and international agencies and organizations made noble attempts to compile extensive lists of sustainability indicators, but some of the problems with these compilations are that they are general, voluminous, and left as guides to the nations, organizations, and businesses to develop their own strategies of sustainability and place their own specific weights on them [103].

Sustainability is thus more difficult to operationalize than risk, vulnerability, or resilience, because of a much larger *sampling space* (all possible outcomes). Returning to our fundamental principle of probability theory as expressed by

Eq. (5), we can include into the hypotheses a wishful list of sustainability hypotheses or *sustainability indicators and consequences* and seek to determine their likelihoods, conditioned on the data connected with the hypotheses and prior information not logically connected with these hypotheses. Operationally, we can express the *sustainability probability* S as,

$$S(H''', D'''M'''X''') \equiv \\ P(H''' \mid D'''M'''X''') = P(H''' \mid X''') \frac{P(D'''M''' \mid H'''X''')}{P(D'''M''' \mid X''')} \tag{9}$$

where H''' are the sustainability indicators and consequences, $D'''M'''$ are the data pertaining to H''', and X''' is the prior information of sustainability propositions that does not have logical connection with H'''. Note now that the priors depend on X''', unless we also condition sustainability on some particular sustainability attributes or indicators.

Sustainability hypotheses or sustainability propositions should be defined for each city by a team of individuals possessing multidisciplinary and transdisciplinary knowledge and grouped into 3 categories: (1) Technical system propositions, (2) environmental system propositions, and (3) human system propositions. The technical system propositions can include subpropositions of mass and energy flows, built environment characteristics, telecommunication services, etc. The environmental system propositions should involve the consumption of natural resources, emissions, ecosystems degradation, etc., and the human system propositions should specify the economic, social, and cultural metrics of the city [103, 107]. Once a model, sample space of propositions of the system, data associated with these propositions, and information relative to the system but not logically connected with propositions are specified, the analysis proceeds as in the risk, vulnerability, and resilience analyses, with the aim of determining the likelihoods of sustainability propositions. Further details of this analysis are available elsewhere [107].

4.5 Decision Making

There is nothing in our probability theory by which a decision can be made to either accept or reject probability assignments to different hypotheses. The orthodox decision theory suggests that we first complete the inference problem by assigning probabilities to the "states of nature" Θ_p, given the evidence data of these states and prior information not connected with such states. To solve the problem of decision we have to first enumerate the possible decisions Δ_q and associate a *loss function* $\Lambda(\Delta_p, \Theta_q)$ that specifies what needs to be accomplished, and make the decision Δ_q which minimizes the expected loss over the posterior probabilities for Θ_p. As we noted earlier, there are some general formal principles (maximum entropy, transformation groups, etc.) to remove the arbitrariness of prior probabilities, but there are no such principles for determining loss or utility functions. This then places a severe limit of using the orthodox decision theory for making decisions and inviting the development of new strategies.

One possibility may be to express the propositions not only with their plausibility but also how valuable they are. For each proposition we would then have a two dimensional function and could then make decisions on the basis of those propopositions that are both very likely and valuable. Another possibility is to incorporate *values of propositions* into the memory data M in Eq. (5) and then choose those propositions with largest probabilities. But all of this needs to be tested with concrete examples to see how far our probability model can be generalized and validated.

The probability theory model discussed in this section is currently employed to assess resilience and sustainability of Naples in Italy and New York City in the United States. Naples is a city with one million people and is bordered by two active volcanoes Vesuvius and Campi Flegrei on whose slopes live another two million people. The proposed resilience and sustainability framework is called VESUVIUS–CAMPIFLEGREI PENTALOGUE [101] and requires that around each volcano be defined an *exclusion nucleus* where all human settlements are prohibited, a *resilience belt* surrounding the exclusion nucleus where the population can live in security and from where it can be evacuated temporarily if necessary until the volcanic crises subside. The area surrounding the resilience belt is the *sustainability area* which would also serve as the temporary area for housing the evacuees from the resilience belt. The exact boundaries of these three areas are being determined through the five key objectives of the pentalogue and use of the above probability theory model for assessing resilience and sustainability, without and with territorial reorganizations. The knowledge base of propositions is determined through the simulations of relevant eruption, seismic, economic, environmental, and urban planning scenarios [23, 108]. The Metropolitan Area of New York City includes more than 20 million people and is exposed to tropical storms, tsunami, climate change, and nuclear reactor hazards. Here we have a different set of propositions and methods for obtaining the knowledge base of these propositions, but the resilience and sustainability modeling approach is similar to that of Naples.

5. Summary and Conclusions

The majority of people on Earth will reside in cities by the end of this century and many of these cities are situated on/or close to dangerous geologic faults, volcanoes, and industrial facilities. Many cities, and in particular those along the coasts, are subjected to severe flooding caused by tropical storms and cyclones. With climate change the flooding risk will increase because of the sea-level rise and changes of atmospheric and oceanic circulations. The high concentrations of people in large cities present great exposure problems and these cities must begin confronting these problems much more seriously than is currently being practiced through rudimentary warning systems, plans, and evacuation plans, if they intend to function without disruptions or face the consequences of being depopulated and the humanity losing another great achievement.

Cities are complex socio-technical systems involving many stakeholders with different socio-economic and cultural values, and the built environments are composed of many poorly constructed habitats and infrastructure systems. All of this information should be included in the reliable assessments of risk, resilience, and sustainability based on the models that can quantify these variables. Such models should be able to deal with all plausible propositions of hazard events, consequences and attributes associated with sustainability, and process all relevant data pertaining and not pertaining to propositions.

The terms risk, vulnerability, resilience, and sustainability are currently poorly defined operationally for complex socio-technical systems such as the cities and in this work we presented a mathematical model that involves sufficient structure for better quantifying these parameters. The sample space of this probability theory model involves plausible propositions consisting of events, consequences, and sustainability indicators, and the model incorporates memory and other data associated and not associated with these propositions. Based on the sampling and prior probabilities computed from simulations of all relevant scenarios of events, consequences, and sustainability attributes, and some generalized principles that are useful for better defining these probabilities, the model can evaluate the likelihoods of sample space propositions and thus serve for making decisions for producing more resilient and sustainable cities in hazardous environments. This approach is currently being used for assessing the resilience and sustainability of Naples in Italy and New York City in the United States.

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Conoscere il passato per progettare il futuro

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Riassunto. Spesso si dá la colpa alla *natura matrigna* quando ci si trova dinnanzi a catastrofi naturali originate da terremoti, alluvioni, dissesti idrogeologici, eruzioni, e non si considera che i territori interessati sono stati giá nel passato soggetti a fenomeni ricorrenti dello stesso tipo. Lo studio della storia dei territori dovrebbe insegnare che non é la natura matrigna, ma é l'irresponsabilitá umana a creare i presupposti per disastri che in realta sono "naturali" nei territori in cui si verificano. L'elenco delle disgrazie verificatesi negli ultimi decenni é lungo, ma é lunga anche la poca memoria di chi avrebbe dovuto prestare attenzione alla natura del territorio in cui tali disgrazie si sono verificate. Non si riesce a dare la giusta importanza alla prevenzione, generalmente gli amministratori si attivano solo nelle emergenze mentre quando si cerca di fare prevenzione, anche attraverso la divulgazione, ci si trova di fronte ad ostacoli continui. Purtroppo prevenire é un lavoro lungo e faticoso e spesso non porta guadagni immediati, né in termini economici né in termini di risultati visibili. Limitandoci ad una analisi del territorio di Portici, nel vesuviano, in questo lavoro si vuole mettere in evidenza come la dimenticanza del passato possa portare a gravi danni nel futuro.

Parole chiave: Disastri naturali, emergenza, prevenzione

1. Introduzione e metodologie

La cronaca dell'ultimo decennio ci dimostra che i territori colpiti da terremoti non sono storicamente nuovi a tali fenomeni. Si prenda ad esempio l'Aquila, la cittá in cui nel 2009 il disastroso terremoto ha provocato 309 vittime ed é storicamente accertato che terremoti in questa zona si sono sempre avuti in periodi riccorrenti. E cosí a Casamicciola, nell'isola di Ischia, solo nel 2017 si é avuto un evento sismico che ha causato il crollo di un intero rione con due vittime (Fig. 1). Anche qui, si é saputo dopo, le case erano state costruite in un punto che giá nel passato, in seguito a terremoti, aveva subito crolli. Per non dimenticare il recente disastro di Amatrice dove violente scosse hanno causato la distruzione di una vasta area e delle zone limitrofe. Con una analisi della cittá di Portici, a sette chilometri da Napoli e a cinque chilometri dal cratere del

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Vesuvio, si vuole mettere in evidenza come la dimenticanza del passato possa portare a disastri simili nel futuro. L'obiettivo di questo lavoro é quindi educare i cittadini, attraverso lo studio del passato, a conoscere meglio il territorio in cui si vive per poter evitare, per quanto possibile, gli effetti delle calamitá naturali nel futuro.

Figura 1. Terremoto a Casamicciola (Iscihia) del 2017. Localitá Maio e Fango.

In piú di venti anni di insegnamento di materie letterarie nel vesuviano ho fatto interessanti esperienze sul territorio con i miei alunni di scuola media. Il mio obiettivo era indurli a conoscere il territorio in cui vivevano per poterlo amare e rispettare. La conoscenza della storia infonde una nuova visione del territorio in cui si abita e vive: sapere di camminare su un pavimento fatto con la lava vesuviana, vedere incastonata in un muro la lapide fatta affiggere dal Viceré spagnolo dopo la devastante eruzione del 1631, entrare nella Reggia di Portici e nella annessa Universitá agraria godendo dei bellissimi materiali in essa custoditi, ci porta a vivere diversamente il territorio. Una scuola *vera maestra* di vita insegna attivamente come si é sviluppato il territorio e finisce anche per imprimere il rispetto di ció che si guarda giornalmente ma che spesso non si *vede*. La storia fatta, dunque, non solo attraverso lo studio sui testi, ma anche attraverso la scoperta personale, con foto, interviste, visite, ricerche sulle tematiche studiate.

Aderendo come referente della scuola al progetto *La Scuola Adotta un Monumento* della Fondazione Napoli99 di Mirella Barracco con l'adozione di villa d'Elboeuf a Portici, e al progetto *Educazione al Rischio Vesuvio* della GVES di

Flavio Dobran [1], si sono fatte interessanti indagini, studi, ricerche che hanno arricchito i ragazzi con la conoscenza del territorio da essi abitato. Ci sono stati, durante lo studio delle varie tematiche, importanti incontri con gli esperti: il dottor Caliendo della sezione didattica del Comune di Napoli, lo storico porticese Formicola e il professore Flavio Dobran, presidente della GVES, hanno arricchito con seminari, dibattiti e incontri interdisciplinari, gli orizzonti degli alunni. Si é collaborato spesso con il Comune di Portici: la biblioteca comunale, la sezione urbanistica e demografica hanno permesso la consultazione di libri e documenti. Momenti di verifiche annuali si sono avuti con la partecipazione alle manifestazioni di maggio dei monumenti. Per alcuni giorni gli alunni illustravano ai cittadini di Portici tramite cartelloni, video e brevi spettacoli teatrali, la storia del monumento adottato Villa D'Elboeuf al Granatello. Altri momenti di verifica periodica si sono avuti con la partecipazione nei mesi di dicembre alle manifestazioni organizzate dalla GVES a Pietrarsa, a Villa Campolieto e a Villa Savonarola per il progetto *Educazione al Rischio Vesuvio*. Queste metodologie si sono rivelate proficue, perché hanno reso gli alunni parte attiva nello studio delle tematiche loro presentate.

2. Dal passato alla urbanizzazione del presente

Un input a una ricerca sul territorio durante l'ultima eruzione del Vesuvio nel 1944 si é avuto con la consultazione di un atto conservato nella New York Public Library [2]. In quel tempo eravamo in piena seconda guerra mondiale e l'esercito anglo-americano presidiava l'Italia meridionale con installazioni militari. Questa eruzione inizió il 18 marzo con un'esplosione che, richiudendo il condotto, fece fuoriuscire la lava da una frattura sul lato est. Il fiume di lava si diresse verso il Monte Somma e lo raggiunse, e dopo un'ora e mezza devió verso l'Atrio del Cavallo e, attraverso *il passo dell'osservatorio*, si diresse verso le cittadine di Massa di Somma e San Sebastiano al Vesuvio [3]. L'agente inglese Norman Lewis ce la descrive in modo tale che sembra di vivere il momento in prima persona.

> *La lava si stava inoltrando tranquillamente lungo la strada principale e ad una cinquantina di metri dal margine di questo cumulo di scorie che lentamente avanzava, una folla di centinaia di persone, in gran parte vestite di nero, pregava inginocchiata. La lava si muoveva alla velocitá di pochi metri all'ora e aveva coperto metá della cittá con uno spessore di circa 10 metri. La cupola di una chiesa emergendo intatta dall'edificio sommerso veniva verso di noi sul suo letto di cenere. Una casa, prima accuratamente circondata e poi sommersa, scomparve intatta dalla nostra vista. Vidi un grande edificio con diversi appartamenti, affrontare la spinta della lava in movimento. Riuscí a resistere per quindici o venti minuti, poi il tremito, gli spasmi della lava sembrarono passare alle sue strutture e anch'esso cominció a tremare, finché le sue mura si gonfiarono e crolló.*

L'eruzione del 1944 (Fig. 2) non e' stata la piú forte registrata negli ultimi secoli di eruzione del Vesuvio, eppure produsse 26 vittime da ricaduta di cenere

Figura 2. La eruzione del Vesuvio del 1944 [4].

.

fu causa dei crolli dei tetti delle abitazioni e, inoltre, l'eruzione distrusse due centri abitati con colate laviche e furono persi tre anni di raccolti nelle aree interessate da ricaduta di ceneri. Il 21 marzo l'esercito americano aveva iniziato l'evacuazione degli abitanti di San Sebastiano, Somma e Cercola, e l'evacuazione fu rapida grazie all'aiuto della quinta armata comandata dal generale Clark. Eppure i danni furono egualmente consistenti, con numero ridotto di popolazione come era allora. E se l'eruzione avvenisse oggi si potrebbero spostare in tempo centinaia di migliaia di persone senza contare sull'aiuto di un efficiente esercito di occupazione?

Le cittadine di Portici, San Giorgio a Cremano, San Sebastiano al Vesuvio, Massa di Somma, Pollena Trocchia, Ercolano e Torre del Greco furono interessate dall'ultima eruzione. Alcuni centri perché colpiti direttamente dalla lava, altri perché vicini ai primi, furono coinvolti nell'allarme e nella possibilitá di una evacuazione. Sono proprio questi centri che nel giro di pochi decenni hanno subito radicali trasformazioni. Il boom edilizio, sostenuto da una errata politica di costruzione basata sulla mancanza di un efficace piano urbanistico, ha creato piú danni all'ambiente di quelli che il Vesuvio stesso aveva fatto in centinaia di anni. Dopo la seconda guerra mondiale un pó in tutta Italia si é avuta una dissennata politica di costruzione edilizia, tuttavia le cittá vesuviane si trovano in un'area vulcanica fra le piú pericolose al mondo per cui il rischio urbano, dovuto a sovraffollamento, é maggiore che in altre zone. Analizziamo il caso di Portici la

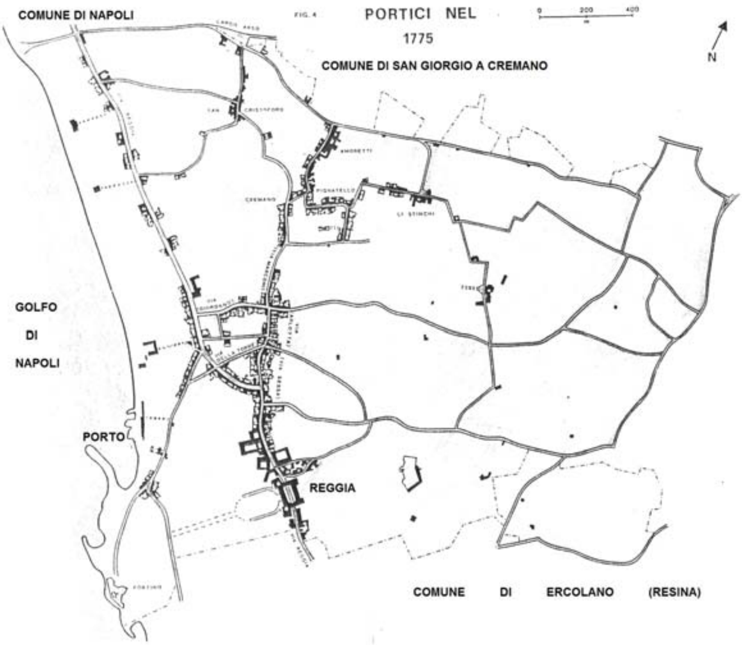

Figura 3. Portici nel 1775 [5].

cittadina che, fino a pochi anni, fa veniva paragonata alle cittá asiatiche perché ad altissima densitá abitativa.

Tutta la zona costiera napoletana é una delle aree piú densamente popolate della Campania e giá in epoca romana questa zona fu scelta per la costruzione di *ville marittime* destinate ad accogliere la villeggiatura dei ricchi romani. Dopo l'eruzione del Vesuvio del 79, la zona fu quasi completamente abbandonata e venne sostituita da fitti boschi cresciuti sulle lave. Solo nel Medioevo si ebbero i primi insediamenti, costituiti da zone rurali, che portarono alla costruzione di nuovi villaggi che, intorno al 1200, furono chiamati Casali: Portici, Resina, Turris Octavae ecc. Con l' impianto di colture costituite da piante di viti, olive, agrumi, si formarono aziende agricole dette Masserie. Nel 1699 i casali di Torre del Greco, Portici, Ercolano e Torre, con il riscatto dalla Baronia, si costituirono in zone separate. Con l'arrivo dei Borbone a Napoli, Portici fu scelta per la costruzione di una reggia. Il re fu attratto dalla zona ricca di boschi che ospitavano volpi, lepri e cinghiali e che era adatta alla caccia. La residenza estiva era vicina agli scavi che riportarono alla luce l'antica Ercolaneum e anche per questo il sovrano fece edificare la Reggia per poter seguire personalmente la campagna di scavi. Sebbene la cittadina contasse meno di 2000 abitanti, il luogo costiero attrasse molte famiglie nobili che fecero a gara nel farsi costruire le loro ville lungo la fascia costiera, dando luogo al Miglio D'oro (Fig. 3).

GVES, Napoli – New York, ISBN 978-88-903183-1-3

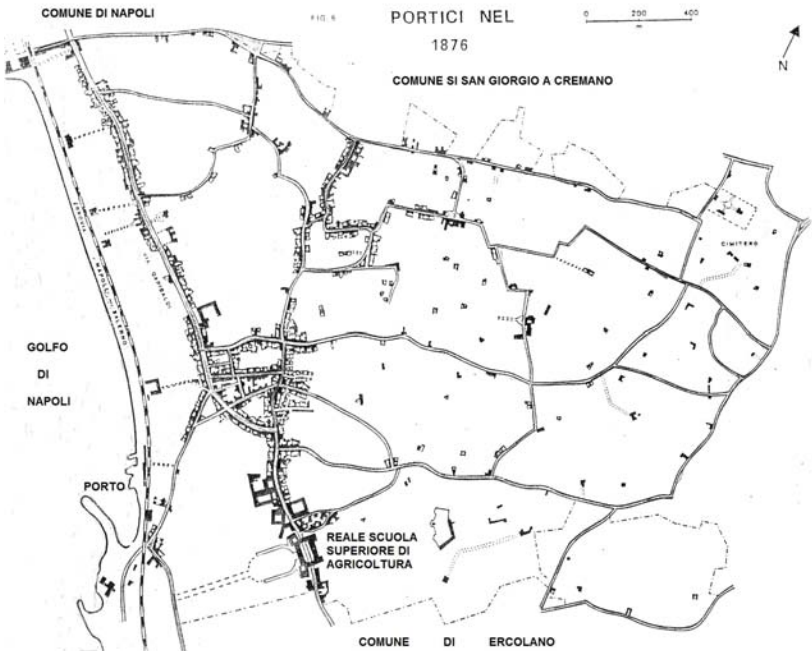

Figura 4. Portici nel 1876 [5].

Alla fine del diciannovesimo secolo, l'allora sindaco Sebastiano Poli diede il via alla risistemazione delle reti stradali con l'ammodernamento di piazza San Ciro, corso Umberto, piazza san Pasquale e corso Vittorio Emanuele. La maggioranza delle residenze estive era situata nella parte alta di Portici, denominata Bellavista, e proprio in questa zona, sull'attuale Armando Diaz, furono costruite una cinquantina di ville in stile liberty che, nonostante non seguissero un piano urbanistico, non danneggiarono il verde del paesaggio perché le costruzioni non superarono l'otto per cento del territorio (Fig. 4).

Dai dati del censimento del 1951 Portici contava poco piú di 35.000 abitanti con circa 8000 abitanti per chilometro quadro (Fig. 5). Da allora con il sorgere di interi condomini e una dissennata politica urbanistica, la popolazione, nel giro di soli venti anni, si raddoppió. Nel 1977 Portici contava piú di 83.000 abitanti, con una densitá abitativa di 18.580 abitanti per chilometro quadrato – la piu' alta d'Europa. Da quanto emerge dal censimento del 2011, la popolazione residente é scesa a 55.765. C'é stata, dunque, una certa diminuzione, ma comunque la popolazione risulta eccessiva in una zona a grande rischio vulcanico. Le numerose foto e immagini aeree del novecento presenti nel libro dello storico Formicola e del Coiro [6] testimoniano visivamente lo scempio fatto in questa ridente cittadina trasformatasi, nel giro di mezzo secolo, in un agglomerato edilizio, senza strutture, strade sufficienti e senza spazi verdi (Fig. 6). Se non si considerano le zone verdi della villa comunale e del bosco, su corso Umberto, Portici é priva di aree

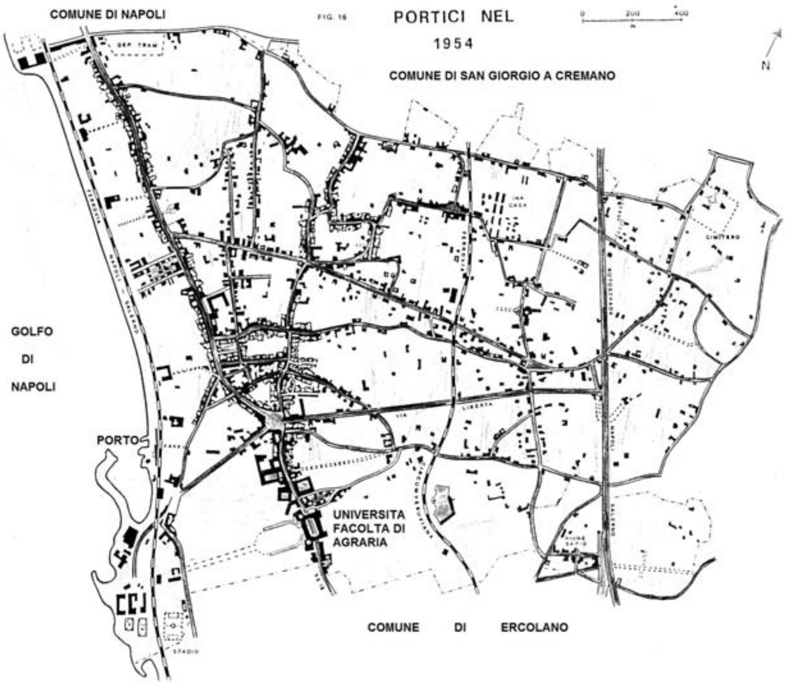

Figura 5. Portici nel 1954 [5].

verdi, infatti le costruzioni hanno completamente occupato il bellissimo paesaggio naturale che era il vanto e la maggiore attrattiva della cittadina vesuviana. Le numerose mappe geografiche consultate in questo lavoro evidenziano come nel giro di pochi decenni si sia passati da un luogo ameno e vivibile ad un luogo sovraffollato e caotico. In particolare, confrontando le due mappe del 1954 e del 1968, si nota come lo spazio edificato sia piú che raddoppiato nel giro di soli 14 anni.

3. Dal presente ad un incerto futuro

La causa di questo vertiginoso aumento della popolazione é da ricercare nel fatto che Portici, a soli sette chilometri da Napoli, ha raccolto i napoletani in aumento nel centro cittadino. Non essendoci piú spazio edificabile a Napoli, la cittá si é estesa a nord e a sud del propio confine e Portici é diventata la cosidetta cittá *dormitorio*, termine che sta ad indicare il fatto che ancor oggi gli abitanti si spostano giornalmente per lavorare a Napoli, rientrando la sera nella cittadina.

A segnare il destino di Portici fu nel 1947 la costruzione di una nuova via che doveva collegare piazza San Ciro con il casello autostradale della Napoli–Salerno. Per l'apertura della nuova strada fu necessario abbattere una storica costruzione affacciata su piazza San Ciro: villa Matera. L'arteria nascente si inerpicó tra

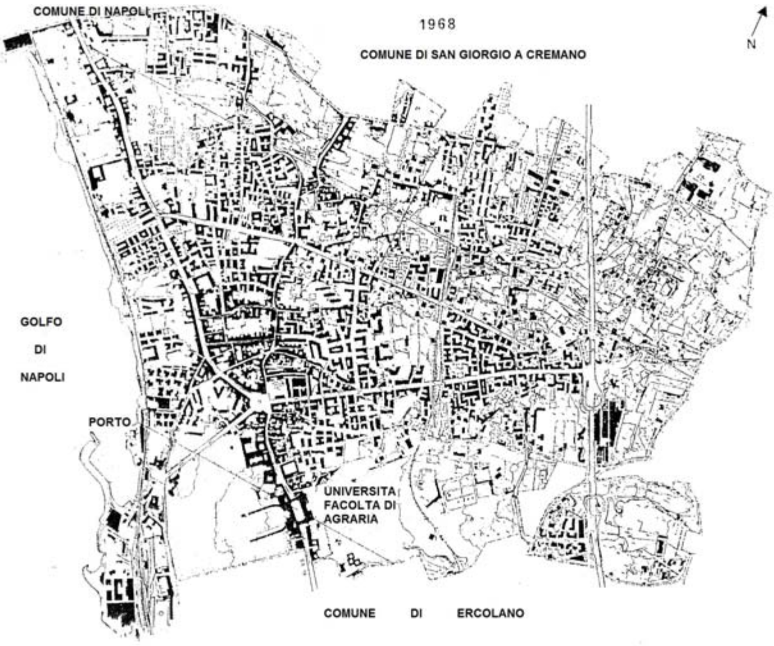

Figura 6. Portici nel 1968 [5].

aree verdi e masserie che furono completamente distrutte dalle costruzioni sorte ai lati della stessa strada, chiamata, nel 1955, via Libertá. Sparirono nel giro di pochi anni antiche ville e i loro parchi e cosí Portici, da ridente zona di villeggiatura estiva, é diventata l'attuale cittadina moderna, senza tuttavia che nella sua trasformazione sia intervenuto un corretto piano urbanistico, con il 91 per cento del territorio urbanizzato.

4. Conclusioni

Basta una giornata di pioggia intensa e un incidente imprevisto per intasare le strade della cittadina di Portici. In realtá non ci sono arterie sufficienti alla normale circolazione automobilistica per cui il traffico nelle ore di punta intasa la circolazione. É utopistico pensare che una emergenza improvvisa come l'eruzione possa garantire la circolazione viaria in ordine e pacificamente come previsto nel piano di evacuazione della Protezione Civile [7].

Errrori ce ne sono stati nella pianificazione del territorio vesuviano, ma lamentarsi ributtando le responsabilitá su chi li ha fatti e non cercando di costruire un qualcosa di diverso per porvi un qualche rimedio, é da irresponsabili. Gli irresponsabili rifiutano il confronto diretto, credono che il loro comportamento non sará mai scoperto, deludono chi li ha accettati, ed amano parlare di tutto fuorché di cose concrete.

Questo ci porta a concludere che il passato ha insegnato poco e che il futuro appare pieno di problematiche e incognite. Come potrebbe reagire una simile cittá di fronte a una nuova eruzione? Probabilmente creerebbe piú vittime e caos la paura che l'eruzione stessa, cosí come prevedono gli esperti che studiano tale possibilitá [8, 9]. Se non ci si organizza al piú presto il disastro in caso di eruzione é certo. Bisognerebbe diffondere una mentalitá disponibile alla prevenzione e che non guardi all'emergenza come unica soluzione dei problemi dei vulcani partenopei.

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Human Resilience in the Neapolitan Area

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Abstract. Hundreds of millions of people live close to active volcanoes around the world and cohabit with them on the basis of a delicate balance that inherently considers benefits (fertile soils, raw materials, geothermal sources) and risks. The violence of the emplacement mechanisms of explosive eruptions (ash fall from high rising eruptive columns and pyroclastic currents from collapsing plumes) and the rapid burying of the landscape makes these types of eruptions extremely dangerous, because they can wipe out whole towns (such as Pompeii and Herculaneum close to Naples). Furthermore, even small eruptions produce well-known volcanic crises when they occur in close proximities to population centers (such as Montserrat in West Indies), and why people live close to the volcanoes is not easy to answer. This work documents some case studies of the impacts of the eruptions of Neapolitan volcanoes on human settlements and provides new insight into the human behavior after different kinds of eruptions.

Keywords: Vesuvius, Pompeii, Campi Flegrei, impact of explosive eruptions

1. Introduction

The fertile Campanian Plain has been inhabited since the prehistoric age [1] (Fig. 1) and the two volcanoes, Vesuvius and Campi Flegrei that border the city of Naples, vary in size and character of their eruptions. Several plinian and subplinian explosive eruptions have occurred in the last 100,000 years from the Campi Flegrei volcanic field and 22,000 years from Somma-Vesuvius [2-4]. The volcanic eruptions at Campi Flegrei are prevalently explosive, whereas at Somma-Vesuvius they alternate between the explosive and effusive stiles.

During the quiescent periods, the subaerial and marine erosions dissected and reworked a large part of volcanic successions, transporting a voluminous sediment load to the level part of the city.

The hazards and impacts of future eruptions of Neapolitan volcanoes depend on the types and locations of the eruptions and it is desirable that the people living around them be aware that their habitats are prone to the volcanic risk. The local population

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should be involved in understanding, making decisions, and taking responsibility in the management of risk reduction.

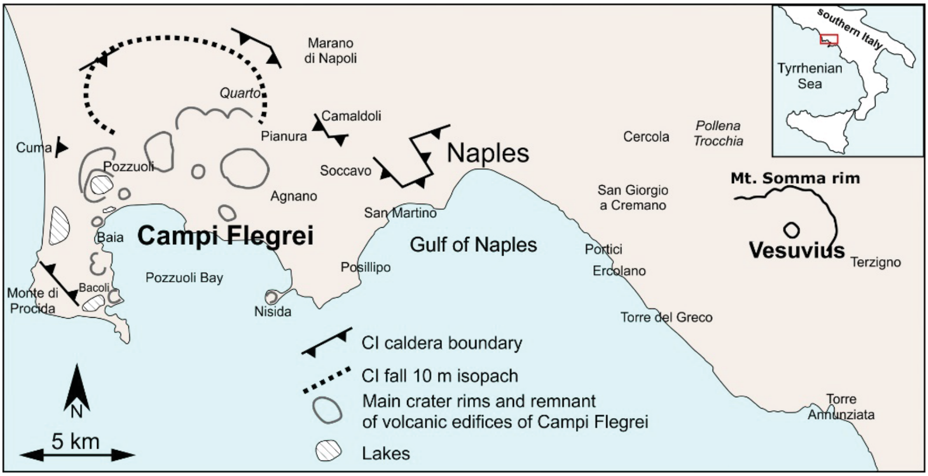

Figure 1. Sketch map of Campi Flegrei and Somma-Vesuvius volcanic areas bordering the city of Naples.

2. Campi Flegrei and Somma-Vesuvius Eruptive Histories

2.1 Campi Flegrei Eruptive History

The complex history of Campi Flegrei volcanic field is characterized by the superposition of minor effusive, large explosive, and some reworked volcanic products, together with the presence of volcano-tectonic structures (caldera rim) and several monogenetic volcanoes. This field is a vast area that includes a large part of the city of Naples and the Island of Procida; it is characterized by the presence of diffuse monogenetic volcanic cones and two nested calderas associated with the Campanian Ignimbrite (39 ka) [5] and the Neapolitan Yellow Tuff (15 ka) [6] eruptions, respectively. The oldest volcanic rocks crop out well inside the city of Naples (San Martino hill) and are dated at ca. 78 ka. Numerous small volcanic centers have been identified, including lava domes and scattered monogenetic vents located in the city of Naples, along the morphological border of Campi Flegrei and on Procida Island. The products of this early activity are covered by tephra from different sources: (1) coarse fallout and flow deposits from Ischia Island; and (2) stratified fall deposits from the eastern part of Campi Flegrei. An ubiquitous succession formed by coarse welded beds (Piperno) and lithic breccia (Breccia Museo) associated with the Campanian Ignimbrite eruption covers the ancient sequence. These proximal deposits dated at 39 ka mark the oldest caldera rim that occupies the Campi Flegrei region and part of the city of Naples. Some small volcanoes (Solchiaro and Trentaremi) are located inside and outside the caldera and some local tephra layers crop out below the Neapolitan Yellow Tuff. This huge pyroclastic deposit (50 km^3 dense rock equivalent), which crops out extensively in the Neapolitan area, produced a second caldera collapse inside the preexisting Campanian Ignimbrite caldera. Tens of small volcanic edifices (most made up by lithified yellow tuff) were emplaced almost exclusively within the Neapolitan Yellow Tuff caldera, both during prehistoric and historic times (e.g., Monte Nuovo volcano, 1538 A.D.).

2.2 Somma-Vesuvius Eruptive History

The first phase of volcanic activity in the area of Somma–Vesuvius (as recorded in the unique 2072 m deep Trecase well) began about 0.4 myr B.P. and ended 0.3 myr B.P. with the emplacement of almost 400 m of lava flows. The oldest Plinian activity crops out in distal sites and is represented by the Codola pumice fall deposit. Several plinian eruptions occurred every few thousand years with more frequent subplinian to strombolian and effusive episodes. The volcano's summit caldera has experienced incremental collapses associated with various plinian eruptions [2].

The destructive impact of major vesuvian eruptions on the surrounding volcanic territory is documented both by the numerous archaeological sites that suffered extensive damage and by historical chronicles of the more recent eruptive events. In fact, many villages, towns and rural farms in a large area around the volcano have been destroyed and buried under a blanket of tephra and mass flows in prehistoric and historic time. Some examples are the burying of a Bronze Age village entombed by the products of the Avellino plinian eruption in 3400 B.P. and the most famous cities of Pompeii and Herculaneum destroyed during the 79 A.D. eruption. Thousands of people were killed during the several days of this eruption [7].

The major eruptions following the 79 A.D. event were explosive subplinian eruptions and occurred in 472 and 1631. Historical records report over 4000 people killed and some 40,000 people displaced as a consequence of the latter eruption. Several other smaller explosive episodes were reported in 512 A.D. during the Medieval Age and during the final 1631–1944 activity cycle.

3. Volcanoes and Human Resilience

The above brief summary of the volcanic activity in the Neapolitan area attests to the continuity and intensity of volcanic events that the prehistoric and historical populations have had to face. Do frequently erupting volcanoes produce areas without settlements within the boundaries of previously destroyed zones, and if this occurs how quickly do people come back to their original settlements? By incorporating new volcanological and archaeological results [8] it is possible to reveal a complex history of destruction of human settlements in the Neapolitan area extending over hundreds of years and how these settlements were reused few years after the violent explosive activities (Fig. 2).

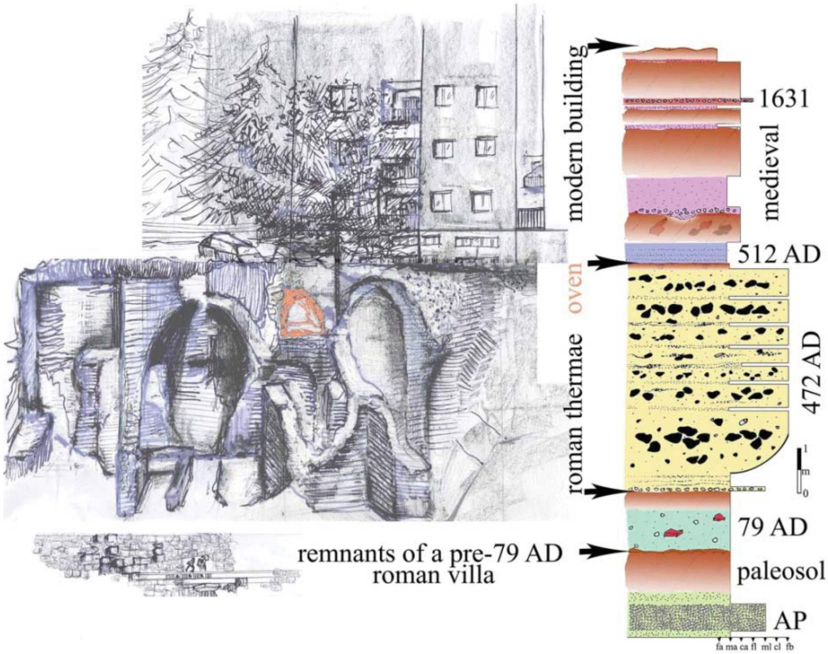

Figure 2. Sketch showing the superposition of buildings buried in volcanic deposits, labeled on the right, at Pollena Trocchia excavation. On the right, stratigraphic sketch showing the complete sequence excavated. Note the modern buildings at the top of the volcanic sequence.

4. Conclusion

The most significant finding from the reconstructed sequence of volcanic events in the Neapolitan area is the human resilience to the continuously destroyed area by numerous volcanic eruptions.

5. Acknowledgement

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NDSHA
Reliable Paradigm for Seismic Hazard Assessment

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Abstract. Probabilistic Seismic Hazard Assessment (PSHA) fatal drawbacks call for a new paradigm to evaluate seismic hazard. The Neo-Deterministic Seismic Hazard Assessment (NDSHA) was proposed some twenty year ago and is found to reliably and realistically simulate a wide suite of earthquake ground motions that may impact civil populations as well as their heritage buildings, and may represent a suitable new paradigm. Earthquakes cannot be predicted with ultimate precision, but algorithms exist for intermediate-term middle-range prediction of main shocks above a pre-assigned threshold, like CN. The proper integration of seismological (NDSHA) and geodetic (GPS) information supplies a reliable contribution to the reduction of the space extent of predictions of earthquakes and defines a new paradigm for time-dependent hazard scenarios.

Keywords: Earthquakes, seismic hazard, NDSHA

1. Introduction

Most of the fatal drawbacks of Probabilistic Seismic Hazard Assessment (PSHA) have been discussed by many authors and call for a new paradigm (different from PSHA) to evaluate seismic hazard (for a recent review see Jia [1] and references therein). The Neo-Deterministic Seismic Hazard Assessment (NDSHA) method, proposed some twenty year ago, is found to reliably and realistically simulate a wide suite of earthquake ground motions that may impact civil populations as well as their heritage buildings.

2. Method

The scenario-based NDSHA's modeling technique is developed from fundamental physical knowledge of: (i) the seismic source process; (ii) the propagation of

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earthquake waves; and (iii) their combined interactions with site effects. Thus, NDSHA effectively accounts for the tensor nature of earthquake ground motions: (a) formally described as the tensor product of the earthquake source functions and the Greens Functions of the transmitting (pathway) medium: and (b) more informally described as mathematical arrays of numbers or functions (indices) that transform according to certain rules under a change of coordinates. Importantly, NDSHA uses all available information about the space distribution of large magnitude earthquake phenomena, including: (a) Maximum Credible Earthquake (MCE) which is based on seismic history and seismotectonics; and (b) geological and geophysical data. Moreover it does not rely on scalar empirical ground motion attenuation models, as these are often both: (a) Weakly constrained by available observations; and (b) fundamentally unable to account for the tensor nature of earthquake ground motion.

3. Examples of NDSHA Applications

Standard NDSHA is estimated as the envelope ground shaking from the largest observed or credible earthquakes, and does not consider temporal features of earthquakes occurrence. Hence it provides robust and safely conservative hazard estimates for engineering design and mitigation decision strategies; but without requiring (often faulty) *assumptions* about the *probabilistic* model of earthquake occurrence. No need to invoke the chimeric, physically rootless return period. If specific applications may benefit from temporal information, including a gross estimate of the average occurrence time, the definition of the Gutenberg-Richter (GR) relation is performed according to the multi-scale seismicity model and occurrence rate is associated to each NDSHA modeled source.

Observations from recent destructive earthquakes in Italy, e.g. Emilia 2012, Central Italy 2009 and 2016-2017 seismic crises, and Nepal 2015, have confirmed the validity of NDSHA's approach and application ([2], [3]). Recently, NDSHA has been applied to schools (http://www.xeris.it/CaseStudies/index.html) and to tangible cultural heritage (https://www.veneto.beniculturali.it/prevenzione-sismica-area-veneta). The widespread application of NDSHA may enhance earthquake safety and resilience of civil populations in all earthquake-prone regions. This is especially relevant in those *tectonically active* areas where the historic earthquake record is too short to have yet experienced (due to a relatively prolonged quiescence) the full range of *large*, *major* and *great earthquake* events, which may potentially occur ([4], [5], [6], [7], [8] and references therein, [9]).

4. NDSHA, Intermediate-Term Middle-Range Earthquake Prediction and GPS

Earthquakes cannot be predicted with ultimate precision, but algorithms exist for intermediate-term middle-range prediction of main shocks above a preassigned threshold, based on seismicity patterns, like CN and M8 ([10], [11],

[12]). Accordingly with [13]), the proper integration of seismological and geodetic information, clearly supplies a reliable contribution to the reduction of the space extent of predictions of earthquakes (e.g. the 2016-2017 seismic crisis in Central Italy and the 2012 Emilia sequence) and defines a new paradigm for time dependent hazard scenarios. In this framework, GPS data are not used to estimate the standard 2D velocity and strain field in the area, but to reconstruct the stations velocity and strain pattern along transects, which are properly oriented according to the a priori information about the known tectonic setting. Overall, the analysis of the available geodetic data indicates that it is possible to highlight the velocity variation and the related strain accumulation within the area alarmed by CN.

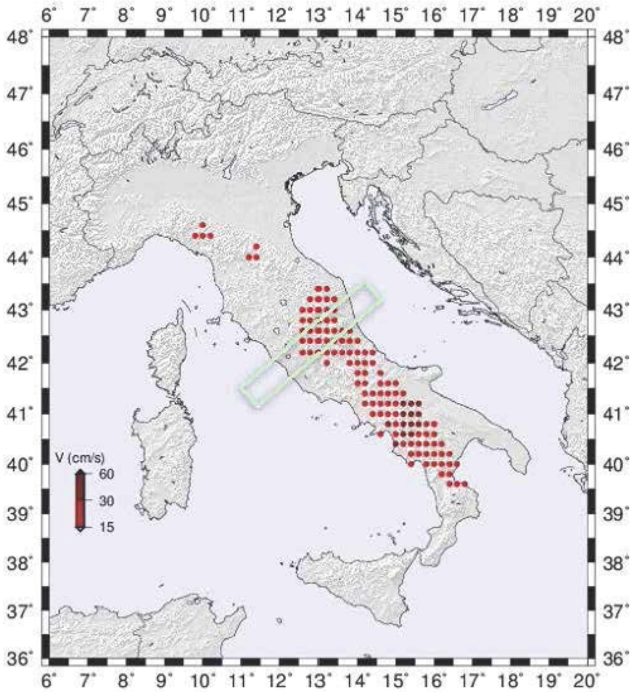

Fig. 1. Hazard scenario of CN Central Italy Region, expressed in terms of Peak Ground Velocity (PGV), and its intersection with the rectangular area covered by the RAN-DPC stations along the Amatrice transect: The rectangular area encloses the seismic hazard scenario simultaneously defined/alerted by CN and GPS data, that extends for about only 5000 km^2.

5. Conclusions

The integrated routine monitoring, CN and GPS, could be more widely applied in the near future, since dense permanent GNSS networks could be established using low-cost GNSS receivers. An example of the possible significant reduction of the size of the CN alarmed areas, by the integrated monitoring, CN and GPS, is given in Fig. 1. The map shows the NDSHA ground motion scenario at bedrock for alarmed Central Italy CN region, expressed here in terms of PGV (Peak Ground Velocity), and the rectangular area covered by the GPS stations, where large anomalies in the velocity and strain pattern are observed. Remarkably, the seismic hazard scenario, which refers to the area simultaneously defined/alerted based on CN and GPS data, extends for about only 5000 km^2. By the way, the PGV values observed by Rete Accelerometrica NazionaleDipartimento Protezione Civile (RANDPC) at Amatrice (up to 31 cm/s) and Norcia (up to 56 cm/s) fit very nicely the values predicted by NDSHA ground motion scenarios (3060 cm/s).

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Time-Dependent Neo-Deterministic Seismic Hazard Scenarios: Recent Achievements in Italy

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Abstract. The development of reliable tools aimed at forecasting earthquake occurrence and related ground shaking is a challenging scientific task, due to the societal relevance and intrinsic complexity of seismic phenomenon. The problem requires rigorous formalization and testing of any forecasting tool, first in retrospect, and then in an experimental real-time forecasting mode. Judging the performance of experimental forecasting implies a careful application of statistics to data of limited size and different accuracy. Long lasting practice and results obtained in two decades of rigorous prospective testing of fully formalized algorithms CN and M8S in Italy and elsewhere support the feasibility of earthquake forecasting based on the analysis of seismicity patterns at the intermediate-term middle-range scales. The synergic analysis of seismicity patterns along with geodetic velocity and strain patterns from GPS observations may allow for constraining better the alerted area. Based on routinely updated space-time formally defined forecasts, an integrated procedure has been developed for the definition of time-dependent seismic hazard scenarios through realistic modelling of ground motion by the Neo-Deterministic Seismic Hazard Assessment (NDSHA) approach. This scenario-based methodology permits to construct, both at regional and local scales, actual scenarios of ground motion at the times when a strong event is likely to occur within the alerted area. This work summarises recent advances and results of prospective testing the integrated NDSHA scenarios by reviewing outcomes from their consolidated application in Italy and elsewhere. The results obtained so far support the validity of the time-dependent scenarios that may allow assigning priorities for a broad spectrum of timely and effective risk mitigation actions.

Keywords: Earthquakes, seismic hazard scenarios, experiment testing

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1. Introduction

Forecasting earthquakes and related ground shaking is an intrisically complex problem. Testing a forecasting method for its reliability implies a careful application of statistics to data of limited size and different accuracy. Observations and physical models suggest that several processes in the Earth's lithosphere are predictable, although after substantial averaging and up to a limit of epstemic uncertainty. Accordingly, a successful forecasting of earthquakes requires a holistic approach, where the earthquake forecast/prediction is posed as a successive, step-by-step, narrowing of the magnitude range, region under investigation, and time of expectation, all within the limits imposed by physics and data uncertainties [1]. The reduction of uncertainties pertaining to the location (where) and time (when) of an expected strong earthquake requires the use of additional information, which may be eventually provided by different observables (e.g. GPS, gravity, geochemical and other geophysical evidences), as well as by relatively lower magnitude seismicity data from high quality local catalogs.

Different descriptions of seismic hazards, either static or time-dependent, may be appropriate for mitigation of earthquake-related risks, including possible cascading effects on environment and infrastructures. However, rigorous and objective verification of seismic hazard estimates against the real seismic activity is a necessary precondition for any responsible seismic risk assessment. Relying on untested seismic hazard estimates can turn out quite expensive: Under-predicting earthquake risks can lead to fatalities and significant economic losses [2] and over-predicting risks can produce unnecessary investment in excessive and costly safety measures.

2. Intermediate-Term Middle-Range Earthquake Forecasting

Italy is the only country worldwide where the two independent and globally tested CN and M8S algorithms have been simultaneously applied during the last two decades. A detailed description of these algorithms and their rigorous prospective testing in Italy is provided in the works of Peresan and co-workers [3,4].

CN and M8S algorithms permit to deal with multiple sets of seismic transients (including changes in the frequency-magnitude distribution and clustering of epicentres) and allow identifying Time of Increased Probability (TIP) for a region where a strong event is likely to occur. Forecasts are binary, i.e. "alarm" or "no alarm": The diagnosis of a TIP means that the probability of occurrence of a strong earthquake is higher than usual, while no-alarm of TIP implies that the probability of a strong earthquake is lower than usual, about ten times lower than in the case of alarm associated to TIP [5]. The forecast/prediction rules are clearly specified so that if an earthquake with magnitude above a predefined threshold $M \geq M_0$ (i.e. so-called "target event") occurs it can be readily judged whether it falls within or outside the anticipated space-time-magnitude volume, or whether it has been correctly predicted or not. The predefined rules make "falsifiable" both CN and M8S algorithms. Anyway, only by systematically recording for a sufficiently long time span the number of successful predictions and failures along with the number and duration of alarms, the performance of a method can be assessed [6]. That is precisely the scope of prospective application of CN and M8S in Italy and- elsewhere.

The real-time prediction experiment is ongoing since 2003 and aims at truly prospective testing of the forecasts by the M8S and CN algorithms. These predictions are regularly updated and their complete archive is made available on-line (www.mitp.ru/en/cn/CN-Italy.html). Although this information, as a rule, is not aiming at red alerts, it is accessible to professionals via a password only in order to prevent its improper use. The obtained results have already permitted a preliminary assessment of the significance of the issued predictions, as shown below and elsewhere [7].

2.1 Algorithm M8S in Italy

The algorithm M8S analyses seismicity within a set of overlapping Circles of Investigation (CIs) having a common radius proportional to the magnitude of target events [3]. M8S forecasts for Italy are performed for three different magnitude ranges, namely M5.5+, M6.0+, and M6.5+, where M_0+ indicates the magnitude range: $M_0 \leq M_0 < M_0+0.5$. The predictions are updated every six months and the algorithm forecasted about 60% of the target earthquakes (17 out of 30) that occurred within the areas alerted for the relevant magnitude range, with about 30% of the overall space-time volume of alarms, which accounts for actual distribution of seismic loci (Table 1). The confidence level of M5.5+ predictions since 2002 has been estimated to be above 99% (that is, the probability of obtaining similar results by random guessing is below 1%) and no estimation is yet possible for other magnitude levels due to the extremely small number of target events. Further details about M8S results are provided in Peresan and co-workers [5].

Table 1. Space-time volume of alarms (STV) for M8S application in Italy, for three magnitude ranges defined by M6.5+, M6.0+ and M5.5+. N is the total number of target events and n is the number of predicted earthquakes. The confidence level of forward predictions for M5.5+ is above 99%.

Experiment	M6.5+		M6.0+		M5.5+	
	STV (%)	n/N	STV (%)	n/N	STV (%)	n/N
Retrospective (1972-2001)	35	2/2	39	1/2	38	9/14
Forward (2002-2018)	22	0/1	29	0/3	14	5/9
All together (1972-2018)	30	2/3	35	1/5	29	14/23

2.2 Algorithm CN in Italy

The algorithm CN analyses the seismic activity inside a set of four predefined regions (polygons), outlined according to the seismotectonic zoning [4]. CN predictions are regularly updated every two months since 1998. So far CN forecasted 22 out of the 26 target earthquakes, which occurred within the monitored zones of Italy, including

Adria region, with about 30% of the considered space-time volume occupied by alarms (Table 2). The confidence level of CN forecasts is very high; that is the probability of receiving similar results by random guessing is below 1%. A detailed discussion about CN results, including a list of target events, is available in [4].

2.3 Adequate Assessment of Prediction Results

We stress that the adequate assessment of the predictive capability of a method is a fundamental step in the earthquake forecast/prediction research and requires a correct application of appropriate statistical tools, respectful of their basic assumptions and data quantity/quality. Molchan and co-workers [7] exemplify how the basic elements of hypothesis testing can be misused: (1) by overlooking the definitions and rules of an algorithm's application, including declustering procedure and definition of target events; (2) by splitting the overall statistics for the entire region of application into sub-samples with insufficient number of target events which automatically degrade the statistical significance of the forecast/prediction results; and (3) by other typical methodological errors to be avoided in the statistical hypothesis testing [8].

Table 2. Space-time volume of alarms (STV) for CN application in Italy and its surroundings. N is the total number of target events and n is the number of predicted earthquakes. During the period 1954-1963 only Central and Southern regions were analysed. Forward predictions for the Adria region began in 2005.

Experiment	Space-time volume of alarm, STV (%)	n/N	Confidence level (%)
Retrospective* (1954 – 1963)	41	3/3	93
Retrospective (1964 – 1997)	26	10/12	>99
Forward** (1998 – 2018)	33	9/11	>99
All together (1954 – 2018)	30	22/26	>99

* Central and Southern Regions only
** Adria is considered since 2005

An in-depth comprehensive discussion on methodologies for assessing earthquake prediction results in Italy and surroundings can be found elsewhere [7]. We follow the fundamental rules of the statistical hypothesis testing in assessing the significance and efficiency achieved by CN and M8S algorithms in the ongoing real-time experimental application.

3. Time-Dependent Seismic Hazard Scenarios

The neo-deterministic approach NDSHA allows defining the seismic hazard from the envelope of the values of ground motion parameters (like acceleration, velocity or displacement) by considering scenario earthquakes consistent with seismic history and seismotectonics [9]. Realistic synthetic seismograms can be computed at any site by the modal summation technique, starting from the available information about regional structural models and seismic sources. Hence NDSHA does not require resorting to empirical ground motion prediction equations (GMPE) and makes it feasible to:

- Derive maps for any parameter of ground motion of interest, which can be extracted from synthetic seismograms;
- Fill in the gap in the available observations by considering a wide set of scenarios and parametric analyses;

- Incorporate the available geological and geophysical information, including pattern recognition of earthquake prone areas [5], earthquakes occurrence rates [10] and the space-time information provided by formally defined and tested forecasts, like those from CN and M8S [4,9].

Based on the routinely updated space-time information provided by CN and M8S forecasts, an integrated procedure has been developed that allows for the operational definition of time-dependent NDSHA scenarios. The method combines pattern recognition algorithms designed for the space-time identification of strong earthquakes (including CN and M8S), with the algorithms for realistic modeling of ground motion. Accordingly, a set of neo-deterministic scenarios of ground motion at bedrock, which refers to the time interval when a strong event is likely to occur within the alerted area, are defined by means of full waveform modeling, both at regional and local scales. In Italy the time-dependent ground motion scenarios, associated with CN and M8S alarmed areas, are routinely updated every two months since 2006 [9]. So far, five large earthquakes struck the Italian territory: Amatrice, Visso and Norcia (2016); L'Aquila (2009); and Emilia (2012), and in all these cases the time-depedent NDSHA maps well anticipated the observed ground shaking [4]. Some results from real-time testing of the integrated NDSHA scenarios are exemplified in the following, focusing on the sequence of destructive earthquakes which struck the Central Italy starting on August 24, 2016.

4. Towards Integration With Information From Space Geodesy

A novel scheme, able to optimally exploit the information content of the available data, has been recently proposed for the synergic use of seismological and geodetic information [11], in order to delineate, as precisely as possible, the regions where to concentrate prevention actions and seismic risk mitigation planning.

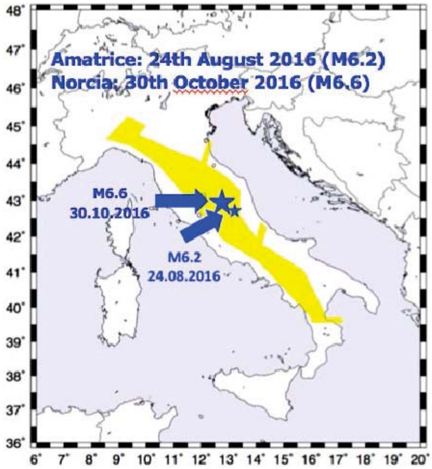
The algorithms CN and M8S allow for the identification of the region and time interval where a strong event is likely to occur based on multiple sets of seismic transients. This information, as a rule not aiming at red alert, may allow analysis of other observables to be properly focalized. An improved but not ultimate precision can be achieved reducing as much as possible the space-time volume of the alarms, by jointly considering seismological and geodetic information. A pioneering step was made in the framework of the project SISMA funded by the Italian Space Agency about ten years ago [12]. Differently from the standard approach, the geodetic information coming from Global Navigation Satellite Systems (GNSS) and Synthetic Aperture Radar (SAR) is not used to estimate the standard 2D velocity and strain fields in the area, but to reconstruct the velocity and strain patterns along transects oriented according to the *a priori* known tectonic setting, provided by the real information content of available data. Considering properly defined transects within the region(s) alarmed by the CN algorithm, the velocity variation and the related strain accumulation can be highlighted, with due consideration of the uncertainties involved in GNSS data.

Tools have been developed to allow for a systematic analysis of the velocity variations together with their accuracy along a number of transects, located along strike and across strike, according to the tectonic and seismological information. A retrospective analysis (including stability tests) has been carried out on GPS data preceding the 2012 Emilia earthquake and the 2016 Central Italy seismic crisis, which started with the Amatrice earthquake. The analysis permitted identifying reliable anomalies in the strain rate distribution in space, without detecting any time dependence in more than 10 years preceding the occurrence of the studied events [11]. Some counter examples have been considered as well (e.g. transects traversing CN not-alarmed areas), but these did not show any spatial acceleration localized trend comparable to the ones well-defined along the Emilia and Amatrice transects.

5. Reality Check: The 2016 Central Italy Earthquakes

The time-dependent ground shaking scenarios associated with CN alerted regions turned out to be well consistent with the recorded one [13]. Specifically, CN Central Region (Fig. 1a) was alerted for an earthquake with M≥5.6 at the time when the Amatrice earthquake occurred, on August 24, 2016. CN forecasts were updated on September 1 (just after the Amatrice earthquake), indicating a persistent alarm in the Central Region, and on October 30 this alarm was confirmed by the M6.6 Norcia earthquake. The predicted acceleration was 0.3-0.6 g, in good agreement with the values recorded for
the M6.2 Amatrice earthquake (up to 0.45 g), and with the even stronger ground shaking recorded for the M6.6 Norcia earthquake (up to 0.6 g). Besides these two main events, the M6.1 Visso earthquake also caused a shaking exceeding 0.3 g at several sites. Remarkably, the observed ground shaking was significantly higher at several sites than the PSHA maps predicted (0.250-0.275 g), even when grossly adjusted for soil type corrections [14].

GPS retrospective data analysis, in the time range from beginning of January 2005 to middle of August 2016, evidenced a well localised, long term peak of the velocity gradient along the Amatrice transect (Fig. 2), properly oriented across the region alarmed by the CN algorithm for the time interval (Fig. 1a). This gradient peak (geodetic signature), localised between Rieti and Amatrice, is stable over time and cannot be explained simply by the overall tectonic extension across the Central Italy Apennines, as in the case of Raiano and Camerino data [11].



(a) (b)

Figure 1. Synergic analysis of seismological and geodetic information: (a) CN Central Region (yellow) alarmed for an earthquake with M≥5.6, in the time interval 1.11.2012-1.11.2016 [4]; (b) the Amatrice transect and its intersection with the scenario of CN Central Italy Region. The seismic hazard scenario simultaneously defined/alerted by CN and GPS data extends only for about 5000 km^2 [11].

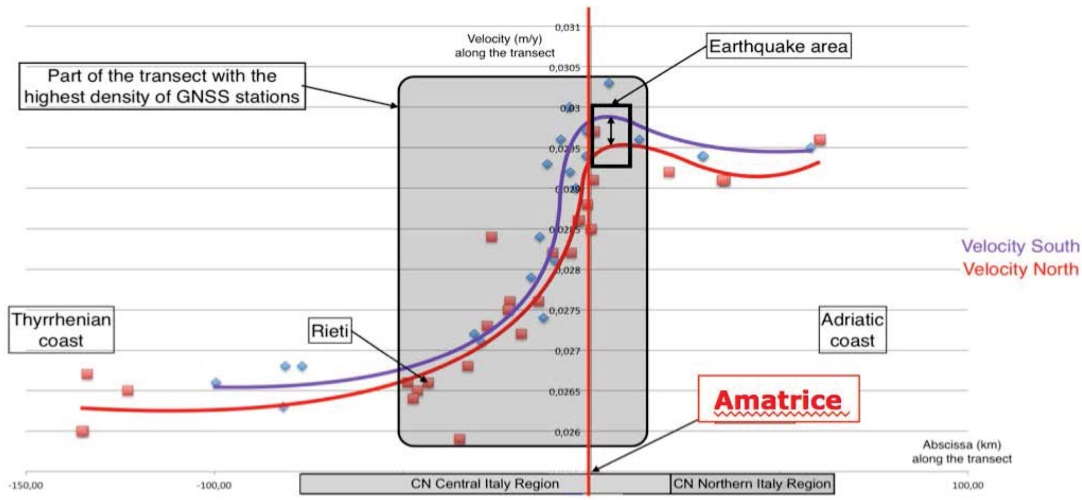


Figure 2. Velocity pattern along the Amatrice transect across Apennines. Velocity South and Velocity North indicate the velocity patterns as derived by the GPS stations respectively located south and north with respect to the axis of the transect passing through Amatrice. Intersections of the axis of transect with CN regions are indicated at the bottom [11].

Seismic Hazard Assessment of Apennine Tectonic Events at Naples

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Abstract. Realistic seismograms of Appenine tectonic events have been computed for the urban area of Naples by a hybrid technique based on the mode summation and the finite difference methods used in the Neo Deterministic Seismic Hazard Assessment (NDSHA). The use of such sophisticated algorithms is justified by the knowledge of the geological setting and physical properties of soils, and of shear wave velocities obtained from the nonlinear inversion of Rayleigh wave group velocities. Ground motion has been computed for the 1980 Irpinia earthquake (Ms=6.9) along the representative cross sections of the 6 geological zones recognized in the urban area of Naples. Moreover, seismograms have been computed in the historical center for the 1688 scenario earthquake (MW=6.98±0.12). Focal mechanisms and depth of the source have been assumed according to the earthquake that occurred on December 29, 2013 (Mw=5.2) in the northern segment of the 1688 fault. Recordings of the event at the station SMN, in the historical center of Naples, have been fitted by assigning Vs to lithotypes based on noise cross-correlation measurements. Then the computed response spectra have been compared with the Italian seismic building code.

Keywords: Ground motion evaluation, V_S measurements, response spectra

1. Introduction

The City of Naples, located between the volcanic complexes of Campi Flegrei and Somma-Vesuvius (Fig. 1), is characterized by a high seismic risk because of the high population density and the remarkable cultural and architectural heritage. Following the CPTI15 earthquake catalogue [1], the maximum felt intensity at Naples is VIII (MCS) and was caused by the strongest central-southern Apennine earthquakes, that is the 1456 and 1688 (Sannio) earthquakes. The 1980 Irpinia earthquake (M_w= 6.9) is the last strong event with the intensity VII-VIII (MCS). Beside tectonic earthquakes, Naples has also experienced shaking with much lower intensities from volcanic earthquakes located in the nearby fields of Campi Flegrei and Ischia, to the west and

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southwest, and Somma-Vesuvius to the east of the city, but this is not considered in this work.

A realistic estimate of the expected ground motion can be performed by using the Neo-Deterministic Seismic Hazard Assessment (NDSHA) method which takes into account seismic sources and propagation and local site effects by using the physical principles of wave generation and propagation in complex media [2]. This is of importance since the Italian building code NTC2018 [3] requires the computation of seismograms and complete synthetic seismograms are also needed for laboratory experiments of structure resistance to shaking. In fact, an earthquake recording is often used as a shaking input that may not be realistically representative for the building site.

The definition of shear wave velocities (V_S) with depth is a basic step for a realistic estimation of the expected ground motion as the V_S contrast between the bedrock and the overlying unconsolidated sediments is mostly responsible of the amplification of site effects. Borehole measurements may not be representative of a site and particularly in volcanic settings where V_S depends on the degree of local textural conditions and hardening. Seismic experiments that are able to reach great depths are in most cases prohibitive in a densely urbanized area like Naples, and an alternative is the approach based on the non-linear inversion of the average group velocity dispersion curve of the fundamental-mode surface waves obtained from the cross-correlation between synchronous noise recordings at two receivers. Noise cross-correlation experiments between two receivers have been successfully performed in the historical center of Naples [4].

This paper focuses on the seismic microzoning of Naples for the Apennine tectonic events. Ground motion parameters have been computed in the urban area of Naples for the 1980 earthquake, and in the historical center for the 1688 earthquake. The detailed information available on the mechanical properties of the sub-soil and its geometry has allowed the computation of quite realistic ground motion by the hybrid technique [5] as used in the NDSHA approach. In the hybrid method, modal summation is applied along the 1-D anelastic model that represents the average path between the assumed source and the local laterally heterogeneous (2-D) structure beneath the area of interest. A double-couple point source of seismic waves is assumed, described by the strike, dip of the causative fault, its rake, and the depth of focus. The seismograms are computed for frequencies up to 10 Hz and are numerically propagated through the laterally varying local structure by a finite difference method. Synthetic seismograms of the vertical, transverse, and radial components of ground motion are computed at a predefined set of points (receivers) at the surface. Site amplification effects are estimated in terms of spectral amplification, defined as the response spectrum at a site in the laterally heterogeneous (2-D) structural model, and normalized to the response spectrum computed from a 1-D reference model.

2. Seismic Response of Naples for the 1980 Earthquake

The 1980 Irpinia earthquake (M_W= 6.9) was the first strong event instrumentally recorded close to Naples at the seismic station of Torre del Greco, located on a lava flow on the flanks of Somma-Vesuvius, and these recorded seismograms were reasonably well fitted by synthetic seismograms. A detailed geological and seismic study based on several stratigraphies and shear wave velocity profiles, both down- and cross-hole tests, and inversion of Rayleigh group velocities allowed for the definition of 6 homogeneous zones in the urban area of Naples [6,7]. The geological setting of Naples is characterized by pyroclastic materials, soil and rock, erupted from both Campi Flegrei and Somma-Vesuvius, that often underwent morphological changes in the past due to the influence of the meteoric and marine agents and by the urban settlements. The seismic basement is represented by the tuff horizon at the depth of about 20 m in the historical center, and deepens in the eastern and western sectors of the city. The historical center (zone 5) is important because of its concentration of monuments and is characterized by the presence of several man-made cavities whose effect on seismic ground motion is negligible [6].

The seismic ground motion for the 1980 earthquake was computed at Naples along the 2-D sections within each of the 6 recognized geological zones by considering different V_S profiles. The computed average and maximum response spectra are shown in Fig. 2.

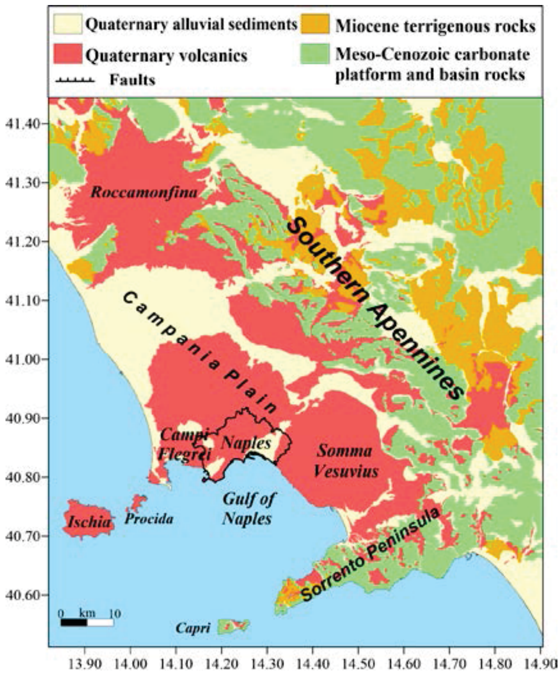


Figure 1. Location of Naples on the simplified geological map of Campania.

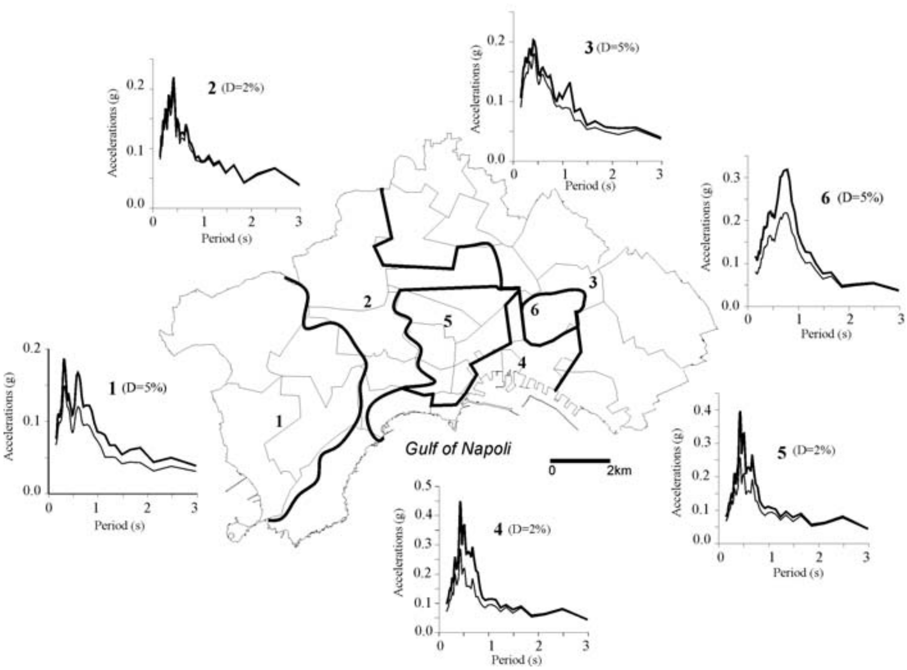


Figure 2. Average (thin line) and maximum (thick line) response spectra of the radial component of ground motion computed for each geological zone of Naples for the 1980 earthquake.

Simulations of ground motions were also performed with the same approach for the strongest earthquakes at Naples of 1456 and 1688 [8]. The physical parameters of the travelled lithotypes were assigned on the basis of the geotechnical, borehole, and FTAN measurements performed in other neighbouring sites and related to very shallow depths.

3. V_S models from Noise Cross-Correlation in the Historical Center

Recently, an innovative approach has been used for measuring V_S with depth that employs ambient noise cross-correlation (NC) between two receivers (estimated Green's function of the medium), frequency-time analysis (FTAN), and non-linear inversion with Hedgehog method [4, and references therein].

As an example, we herein report the results obtained along three alignments at the historical center of Naples (Fig. 3). The experiments were carried out by employing 2 Kinemetrics Q330 stations, one of which (SMN) is permanently installed in the underground for seismic monitoring (www.ogsism.unina.it). For each station pair the synchronous noise recordings are analyzed and daily and monthly cross-correlated and iteratively band-pass filtered (Butterworth filters) to enhance the dispersive wave train. As an example, shown in Fig. 3b is the monthly stacked NCs (vertical component) computed for the SMN-NAS path in the band pass 4-7 Hz.

The fundamental-mode Rayleigh surface waves were extracted with the FTAN method (Fig. 3c) and then V_S models with depth were obtained (Fig. 3d). For the geological interpretation, the chosen solutions below the paths (Fig. 3a) were compared with a stratigraphy in a deep well (up to 465 m depth) drilled in 1859 nearby the Royal Palace. The V_S models match very well the depth of the Neapolitan Yellow Tuff (NYT) deposit and the depth of the whitish tuff deposit, which results very compact (V_S > 1000 m/s on average at ~ 70 m of depth below the sea level). These results are important for the definition of the seismic basement, which is a key for trustworthy microzoning studies.

4. Seismic Response for the 1688 Earthquake

The 1688 earthquake is representative of the Sannio-Matese seismicity and can be considered the strongest earthquake scenario to simulate the ground motion at Naples. Simulation of ground motion at the historical center was performed with the hybrid method by assuming normal and transcurrent faults, and varying source depth [8]. An earthquake occurred on December 29, 2013 (Mw=5.2) in the northern segment of the 1688 fault. Recordings of such event at the station SMN, in the historical center of Naples, were fitted along a N-S section [9], where V_S were assigned to lithotypes based on noise cross-correlation measurements [4]. Then, keeping the mechanisms and depth of the moderate 2013 event, the seismograms were computed for the 1688 earthquake (M_W= 6.98±0.12) by assuming the epicenter coordinates given by CPTI15 catalogue [1]. The causative fault of the 1688 earthquake is located at 50-60 km from Naples.

Following the Italian seismic building code [3], the response spectra were assigned to soil typologies based on V_{S30} values. The subsoil of the historical center of Naples can be classified as B and C soil types. Moreover, the building code considers response spectra relative to limit states of usage (SLO), of damage (SLD), of life safeguard (SLV), and of collapse prevention (SLC). Although historical buildings are made of tuff stones, synthetic response spectra have been evaluated for higher damping of 5% to be compared with the elastic response spectra of the Italian seismic code (Fig. 4). It turns out that a seismic event like the 1688 earthquake (M_W= 6.9-7.1) is predicted by the seismic code for SLV and SLC limit states, but only for sites with the maximum thickness of soil cover.

5. Conclusions

Realistic seismograms have been computed for Naples based on advanced seismological methodologies and sound information on the physical properties of wave travelling paths. The results obtained in the historical center of Naples with the non-linear inversion of group velocity dispersion data of the fundamental-mode Rayleigh waves, extracted with the FTAN method from the noise cross-correlation between two receivers, show that the procedure is a powerful instrument to obtain V_S vs. depth profiles in highly urbanized areas. The results of this study show that a preventive definition of the seismic hazard in urban areas like Naples can be obtained and used for retrofitting of buildings and thus mitigating seismic risk.

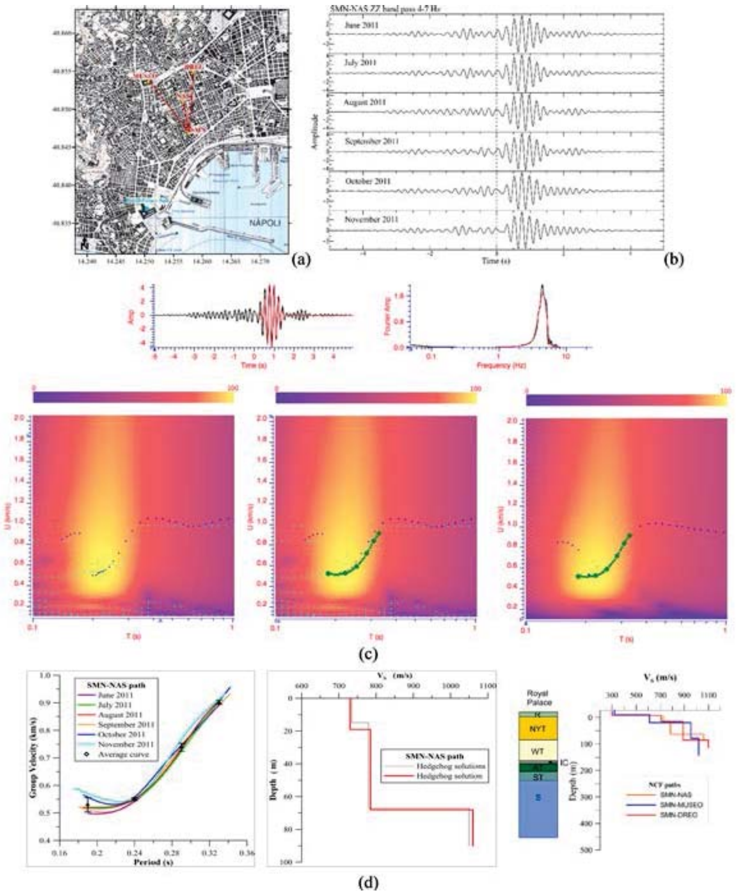
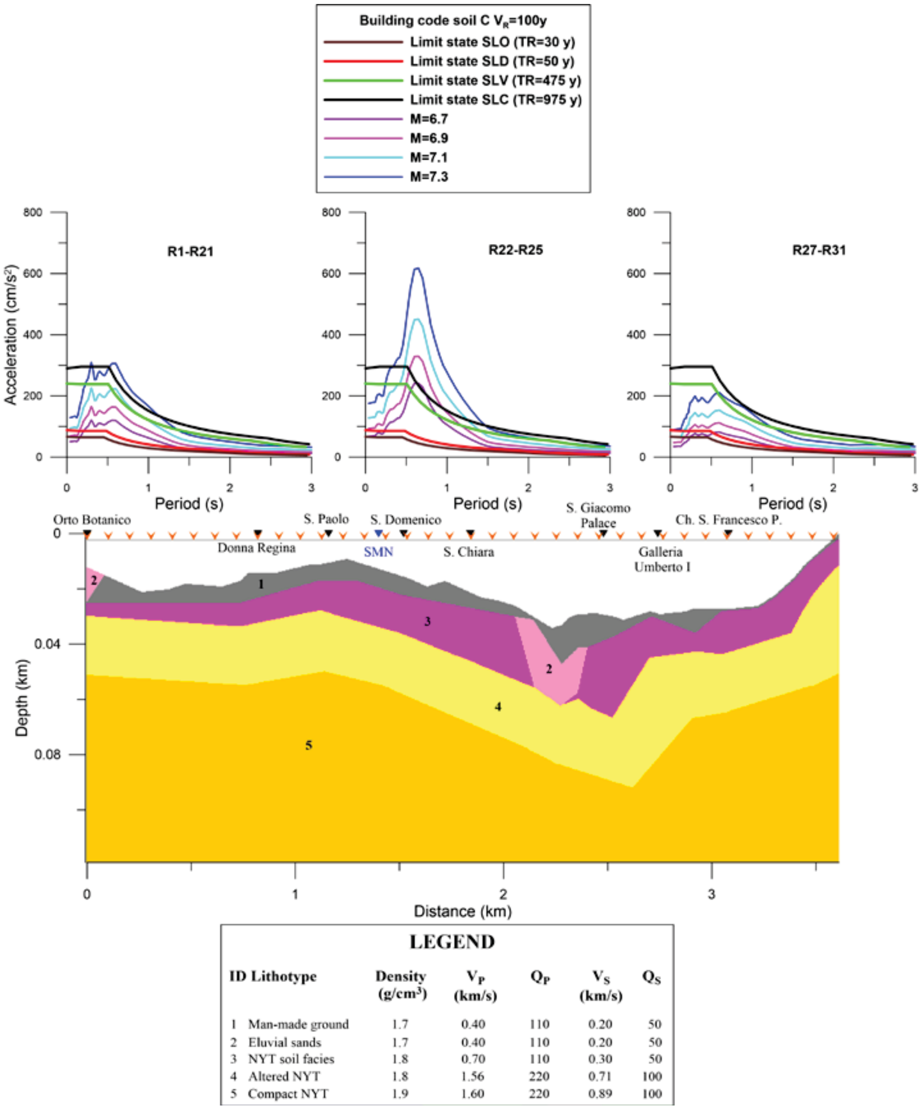


Figure 3. (a) Locations of paths. (b) Monthly NC computed for the SMN-NAS path. (c) FTAN analysis on the NC monthly stacked (August 2011 in (b)): FTAN map of the causal part of the signal in the top (black line); a raw group velocity curve is chosen by the analyst (green dots) by picking the energy maxima on the FTAN map (black dots). Then the phase-matched filtering is performed on the chosen period-band to remove noise; the FTAN image of the cleaned waveform is computed and the cleaned group velocity curve is obtained. The fundamental mode waveform and its Fourier spectrum amplitude are shown (red line) in the top together with the original correspondent ones (black line). (d) From left to right: Average dispersion curve with error bar; Vs models obtained from the inversion of the average curve and the chosen solution (red line); V_S models below the investigated paths and the stratigraphy of the deep drilling at Plebiscito square. Legend: R = man-made material and recent pyroclastic deposits; NYT = Neapolitan Yellow Tuff; WT = Whitish tuff; IC = Campanian Ignimbrite; AT = Ancient Tuffs; ST = Tuffs and sedimentary rocks; S = Sedimentary rocks.



ID	Lithotype	Density (g/cm³)	V_P (km/s)	Q_P	V_S (km/s)	Q_S
1	Man-made ground	1.7	0.40	110	0.20	50
2	Eluvial sands	1.7	0.40	110	0.20	50
3	NYT soil facies	1.8	0.70	110	0.30	50
4	Altered NYT	1.8	1.56	220	0.71	100
5	Compact NYT	1.9	1.60	220	0.89	100

Figure 4. Computed response spectra for the 1688 earthquake, scaled for M_W magnitudes of 6.9, 7.1 and 7.3, and compared with the Italian seismic building code [3] for Naples.

6. Acknowledgements

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Seismic Hazard Assessment and Risk Mitigation at Ischia Island (Naples, Southern Italy): A Paradigm for Seismic Risk Management in Italy

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Abstract. The island of Ischia is located in the metropolitan area of Naples and is an active volcanic area that is dormant since 1302, and where a devastating earthquake occurred in 1883, which completely destroyed the small town of Casamicciola and killed about 2600 people. Recently, a small but very shallow earthquake (August 21, 2017, M=4.0) occurred in the Casamicciola area and claimed two victims and destroyed many edifices, in a very localized area, just above the source, within the town. The location of the recent earthquake is likely the same as the 1883 seismic event and of other severe events occurring in the period 1828-1881 and in previous centuries. The study of past destructive earthquakes which appeared clustered with time intervals of several years or decades, indicates that other destructive earthquakes are likely to occur in the following years or decades. Based on the seismic history and past macroseismic data and compared with observations from the present earthquake and using numerical simulation models, the analysis demonstrates that the current seismic hazard maps for the area give largely underestimated accelerations and suggests an approach aimed at both managing the very high and imminent risk in the area and providing reliable estimates of maximum accelerations which can be experienced in the future. We show how the Neo-Deterministic Seismic Hazard Assessment (NDSHA) approach provides a hazard map for the area that is consistent with macroseismic studies and present earthquake faults evidences, thus correcting the macroscopic problems of the current official hazard map based on the Probabilistic Seismic Hazard Assessment (PHSA). Furthermore, in view of the likely occurrence of new and even more destructive earthquakes in the fol-

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lowing years, we suggest a practical approach for timely planning and securing of the most hazardous areas of the island where the masonry structures should be strengthened to resist the maximum expected seismic loads.

Keywords: Seismicity, Ischia Island, seismic risk

1. Introduction

Italy is prone to seismic risk, not due to the extreme severity of earthquake magnitudes, but because most seismic areas are densely populated [1]. Another important problem is that in most seismic areas the masonry edifices of high historical and architectural value are present, and protecting ancient towns and populations from earthquakes, which often produce casualties and destruction even for moderate magnitude earthquakes, is significant and still unsolved. Because of the absence of extreme earthquake magnitudes, the seismic risk mitigation in Italy could be made very effective by consolidation of edifices to make them resistant to the expected seismic loads. Two problems make it difficult, however, to accomplish this goal: the first one is the high cost required to secure all the edifices lying in seismic areas, and the second is that, although the hazard maps for the Italian territory are based on a quite accurate and very long historical information, most of the recent earthquakes caused seismic accelerations significantly larger than those expected according to the current seismic regulations.

In addition to Aquila 2009 and Emilia 2012 events and the Central Italy seismic crisis that started in 2016 (e,g, [2-5], a striking example of such problems, reproduced on a very small scale, is represented by the Ischia island earthquake which occurred on August 21, 2017 with magnitude Ml=4.0 (Fig.1). This low magnitude earthquake claimed 2 victims, produced 42 injuries, and required evacuations of 2500 individuals. The earthquake was very shallow (2 km of depth) and the seismic accelerations were locally very strong, although the affected area was very small (about two km^2). The seismicity of the island is historically always concentrated in the same area affected by the last earthquake (the town of Casamicciola,Table 1), and the evident problems of the hazard map show some peculiarities that make this an ideal laboratory to implement and solve, at a small scale, the same problems constituting the larger issue of seismic risk in the whole of Italy.

In this paper we review the main features of the Ischia island seismicity and analyze the major problems enlightened by the last earthquake. We then propose a solution capable of addressing and solving the two significant issues evidenced by this earthquake, which are somewhat representative of the Italian situation.

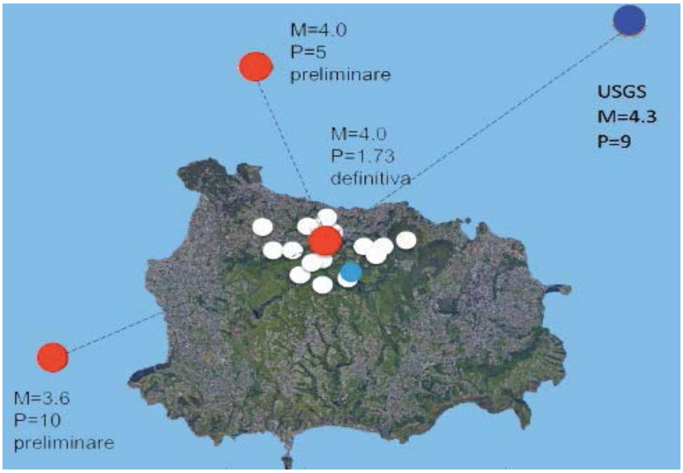


Figure 1. Recent seismicity at Ischia island since 1993 (M>1.0). The large red circle represents the locations of the August 21, 2017 earthquake whose location and magnitude has been changed 3 times by INGV. The true location, corrected on 25/08/2018, is marked by a cross. The final depth and magnitude are 1.7 km and 4.0, respectively. The location in blue is the one given by USGS and was assigned to the depth of 9 km and magnitude of M=4.3.

Table 1. List of the largest historical earthquakes at Ischia island [6].

Year	Location	I_{MAX} (MCS)
1275	Casamicciola	IX-X
1302	Eastern part of island	VIII
1557	Campagnano	VII-VIII
1762	Casamicciola	VII
1767	Eastern part of island	VII-VIII
1769	Casamicciola	VIII
1828	Casamicciola	VIII-IX
1841	Casamicciola	VII
1863	Casamicciola	VII
1867	Casamicciola	VI-VII
1881	Casamicciola	IX
1883	Casamicciola	XI

2. Seismicity of Ischia Island

The island of Ischia has often been struck in the past by strong and destructive earthquakes that involved a very limited area, which, in the limits of our understanding of most ancient reports, appears to be more or less always the same. Table 1 reports the historical seismicity occurring in the area, which, with several exceptions pertaining to the eastern sector of the island, appears almost totally concentrated in the Casamicciola town area. Such a seismicity, from previous hypotheses and mainly based on the 1883 earthquake studies [7], definitively validated by the contemporary observations from the 21/8/2017 earthquake, appears to be caused by the differential movements of the Epomeo horst which moves up and down in response to a magmatic reservoir located at a depth of about 3 km [7,8] . For some reasons, probably linked to the depth of the 'ductile' temperature limit [7,8], the differential motion of the Epomeo horst causes seismicity only on the Northwestern faults, located just below the town of Casamicciola. Figure 2, redrawn from the INGV report [9], shows the likely geometry of the main fault causing the earthquakes in this area.

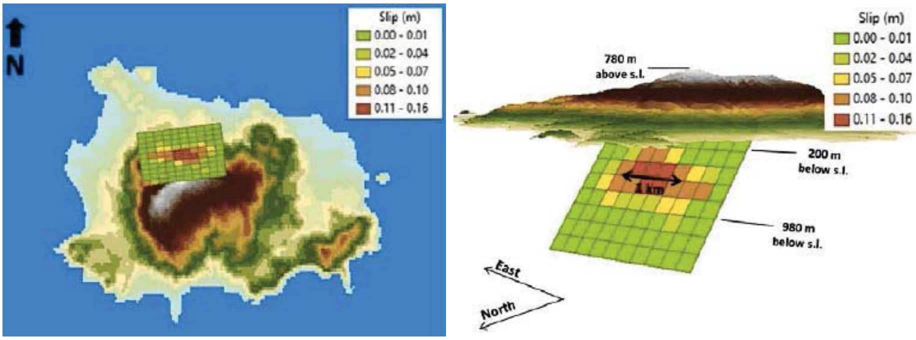


Fig.2. Reconstruction of a variable slip fault model for the August 21, 2017 earthquake [9].

It is important to note that the proposed fault model with an opposite dip (towards S-SW) for the main fault [8] is in contrast with fault traces observed [10], clearly indicating normal faulting traces dipping N-NE. In the light of recent observations of the August 21, 2017 M=4.0 earthquake, the highly destructive character of the Casamicciola earthquakes can be ascribed essentially to the very shallow depth of the source (less than 2 km): considerable accelerations are generated even by events of modest magnitudes. Although the magnitude estimated by 'fast' methods like coda duration may be largely uncertain, for this recent earthquake the magnitude estimates range from Mw=3.9 [9] to Mb=4.3 (USGS), up to a magnitude 4.4, estimated from the geodetic seismic moment on the fault required to explain the InSAR ground deformation data [9]. Hence, besides the uncertainty in the given magnitude range (3.9-4.4), about twice the standard error affecting magnitudes at global scale (e.g. [11]), the magnitude of the event has been modest, though very damaging in a very limited area. The 2017 earthquake claimed two victims, whereas the one in 1883 caused more than 2400 casualties and the complete destruction of the town of Casamicciola. Figure 3 reports the reconstruction of macroseismic intensities associated to the 1883 earthquake [7], where the violet area represents the zone where intensities up to XI (MCS) were reported in 1883 and considerable edifice collapse has been observed after the 2017 earthquake. Figure 4 shows the ground accelerations recorded at the Casamicciola observatory (INGV station IOCA, equipped with velocimeter and accelerometer). The peak accelerations recorded at Casamicciola were 0.29 g (horizontal) and 0.22 g (vertical).

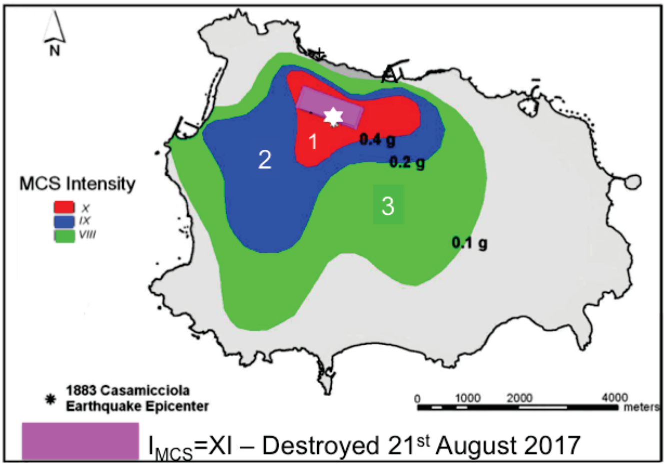


Figure 3. Isoseismal map for the 1883 event [7]. The area 1, in red, is bounded by the intensity X, the area 2, in blue, by the intensity IX, and the area 3, in green, by the intensity VIII. Also shown are the levels of ground accelerations deduced for each intensity degree by empirical laws. The violet area represents the zone where the intensity XI was experienced in 1883, and which has been destroyed by the August 21, 2017 earthquake.

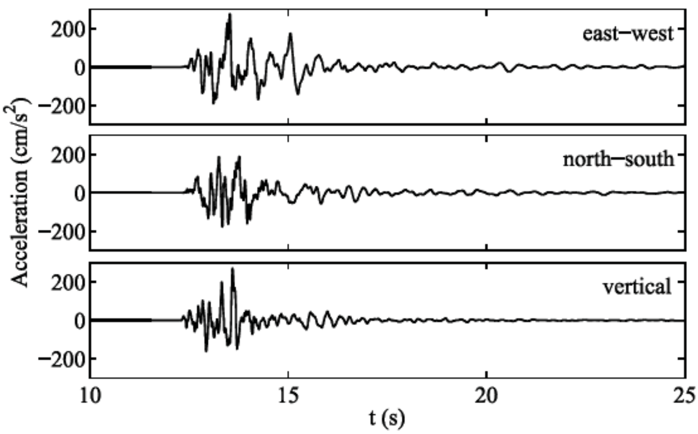


Figure 4. Ground accelerations recorded by the accelerometer installed at the closed Osservatorio Geofisico in the town of Casamicciola (about 1 km from the epicentre). The maximum horizontal acceleration detected was 0.29g and maximum vertical acceleration detected exceeded 0.2g.

It is interesting to compare these intensity maps and peak acceleration with the official seismic hazard map for the area, reported in Fig. 5. We note that in the official hazard map the estimated horizontal accelerations progressively decrease from East to West, because the seismic risk in the island is only considered for earthquakes that occurred on the mainland. Moreover, the estimated PSHA (for 475 years "return period", i.e. 10% probability of being exceeded in 50 years) in correspondence of Casamicciola is computed by multiplying the value in the figure, estimated on hard rock, by the multiplier 1.2, which takes into account the average local site response. The resulting value is 0.18g, so that the observed horizontal peak acceleration is about 57% higher than that forecasted by the hazard map. The maximum vertical acceleration exceeded 0.20 g, more than twice the PSHA estimated value of 0.09 g. The evident total inadequacy of the PSHA seismic hazard map for Ischia poses even larger problems in view of the historical observation that destructive earthquakes on the island have often occurred in clusters, within time intervals of years and decades. The last cluster before the 2017 earthquake started in 1828, with an earthquake slightly larger than the one of 2017, and continued with 5 more events of maximum intensity equal to or larger than VII. The last two earthquakes occurred in 1881 and 1883 and caused about 250 and more than 2500 casualties, respectively. The 1883 earthquake destroyed completely the town of Casamicciola.

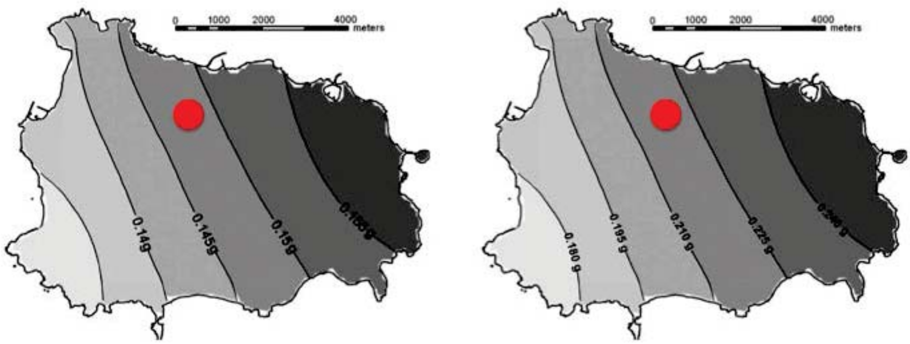


Figure 5. PSHA expected accelerations at Ischia island [12]. Left: Peak horizontal accelerations on bedrock. Right: expected accelerations for soil class C, which corresponds to the maximum amplification factor of 1.5. For Casamicciola, the regulation prescribes soil class B with the multiplication factor of 1.2.

3. Urgent Planning for Securing Urban Areas

Given that the past seismicity shows the occurrence of clustered destructive events, the August 21, 2017 earthquake makes it clear that two urgent steps should be undertaken: (1) securing the constructions that are mostly masonry in the urban areas most prone to experiencing large seismic intensities; and (2) re-elaborating a seismic hazard map for Ischia island, which realistically takes into account the maximum (spectral) accelerations that can be produced by local earthquakes and that it can be used in the design of new constructions and possibly in the retrofitting of existing ones.

An elaboration of a plan for securing edifices in the most hazardous areas is a priority in order to avoid collapses of large numbers of old, masonry edifices, in case of earthquakes stronger than the one of August 21, 2017. This is crucial in view of past experiences which show that higher magnitude earthquakes tend to occur in clusters and on time intervals of several decades. Securing the present edifices is also crucial because Ischia is a renowned location for international tourism, and its population during the summer months may increase 10 times. In the following we, therefore, present a plan for securing the urban areas for the edifices to resist the earthquakes like the one of 1883, which, to our knowledge, is the maximum local earthquake recorded on the island. For such an earthquake, we do not have a precise estimation of the magnitude, but we have an accurate isoseismal map [13]. Regarding its magnitude, we can make an inference based on its maximum intensity that is related to the maximum intensity and estimated magnitude of the August 21, 2017 earthquake. Comparing the maximum intensity of the 2017 earthquake with the 1883 earthquake and assuming the magnitude M=4.0 for the recent event, the magnitude of the 1883 event is estimated to be between M=5 and M=5.5. Whereas a magnitude estimation for the 1883 earthquake results useful for estimating possible ground accelerations and hence hazard maps, an urgent plan for securing edifices in the most risky areas should rely on intensities only, because these already include the effects of source, travel paths, and site effects [14]. The procedure we propose is to take advantage from the well-established observations worldwide that relate masonry edifice types, seismic intensities, and structural damages. Table 2 reports the International classification of masonry edifices [15], whereas Table 3 shows the level of damage suffered by each class of edifices as a function of the intensity [15].

We must note that the intensities shown in Table 3 are values of IEMS98, because they are calibrated internationally with this scale, whereas in Italy is much more common to use the MCS scale. Approximately, the following relations hold: IMM ~ (5/6) IMCS and IMM ~ IMSK ~ IEMS-92, where IEMS-92 is the intensity scale defined by the European Seismological Commission in 1992, IMM is the modified Mercalli scale, and IMSK is the Medvedev, Sponheuer, Karnik scale [16]. However, given the approximations implicit in our methodology, slight differences in the two intensity scales are not relevant in this first approximation.

Table 2. Definition of vulnerability classes for edifices: combination of vertical and horizontal structural features [15].

Horizontal structures	Vertical structures			
	Poor masonry	Medium masonry	Good masonry	Reinforced concrete
Archway system or mix	A	A	A	
Wooden ceiling with or without chain	A	A	B	
Ceiling in I-beams with or without chains	B	B	C	
Ceiling in reinforced concrete	B	C	C	C
Reinforced buildings	C	D	D	D
Anti-seismic original buildings	D	D	D	D

Table 3. Observed damage levels in several worldwide earthquakes of different edifice classes [15].

Damage intensity EMS98	0 None	1 low	2 Medium	3 Serious	4 Very serious (partial collapse)	5 Total collapse
VII			Many B, few C	Many A, few B	Few A	
VIII			Many C, few D	Many B, few C	Many A, few B	Some A
IX			Many D, few E	Many C, few D	Many B, few C	Many A, few B
X			Many E, few F	Many D, few E	Many C, few D	Most A, many B, few C
XI			Many F	Many E, few F	Most of C, many D, few E	Almost all A, most B, many C , few D

From Table 3 we can infer for each intensity level what are the classes of edifices suffering only slight damage with negligible probability of collapse. It is easy to evidence, for instance, that in zones experiencing intensity up to X, only edifices belonging to class D are negligibly affected by collapse. In zones with intensities lower than IX, the edifices of class C are only marginally affected by collapse. In zones with intensities lower than VIII, the class B edifices only rarely collapse. It is then natural to plan a strengthening of all the edifices lying in the areas affected in 1883 for intensities VIII and higher. In areas delimited by the intensity of degree X, all the edifices must be of class D or higher. Therefore, all the edifices A, B, and C must be structurally reinforced to belong to class D. In areas delimited by the intensity IX, all the class A and B edifices must be reinforced to belong to class C, and in the areas delimited by the intensity VIII the class A edifices must be reinforced to be class B at least. In order to maintain a higher caution, we suggest that in the areas VIII the class A edifices be reinforced to become class C, and that the owners of class B edifices be incentivized, although not compelled, to reinforce their edifices to become class C at least.

4. Towards a New Reliable Seismic Hazard Map

Considering the faults of the actual, official hazard map for the area, which strongly underestimated the accelerations observed for the August 21, 2017 earthquake, it is important to define a new hazard map with realistic and reliable predictions of maximum accelerations. The official seismic hazard maps used for Italy are based on the PSHA method (Probabilistic Seismic Hazard Assessment). However, this method has several problems, well described by many authors [17 and reference therein]. In particular, it is known to underestimate peak accelerations at close distances from the seismogenic faults, and it completely fails in the case when a given fault does not cause any earthquake in the time interval during which the historical catalogue is reliable. A more powerful method, which is gaining progressively more favor with the improvement of the specific knowledge about active faults, is the Neo-Deterministic Seismic Hazard Assessment (NDSHA) [18,19]. NDSHA computations for the Italian territory have been already obtained in a variety of cases and several ground shaking maps for Italy have been published, based on the computation of synthetic seismograms for different hypotheses about the properties of the source and of the regional structural models [18,19]. Investigations of the uncertainties of the definition of sources with historical seismicity demonstrate [17] that the unique 1,000-year long Italian earthquake catalogue, acting as the experimental set, is within errors almost everywhere matched or enveloped by the sources identified within the seismogenic nodes defined by morphostructural zonation and pattern recognition techniques [20, 21], if their magnitude is incremented by 0.5, or twice the global standard deviation of magnitude [11]. The ground shaking map of horizontal accelerations is reproduced in Fig. 6a. The maximum computed acceleration in the grid point closer to the Ischia island ranges between 0.3-0.6g, which is significantly higher than (i.e. well enveloping) the maximum acceleration observed for the August 21, 2017 seismic event. Figure 6b shows the comparison of the observed response spectra with those obtained from the signals used to generate the map of Fig. 6a, and three more synthetic response spectra obtained at Ischia for three specific sources for which high-frequency synthetic seismograms have been generated. Source n. 3, located near Ischia and characterized by M=5.1, is the one responsible for the Maximum Credible Seismic Input (MCSI, [22]) obtained at the island, shown by the grey band in Figure 6b.

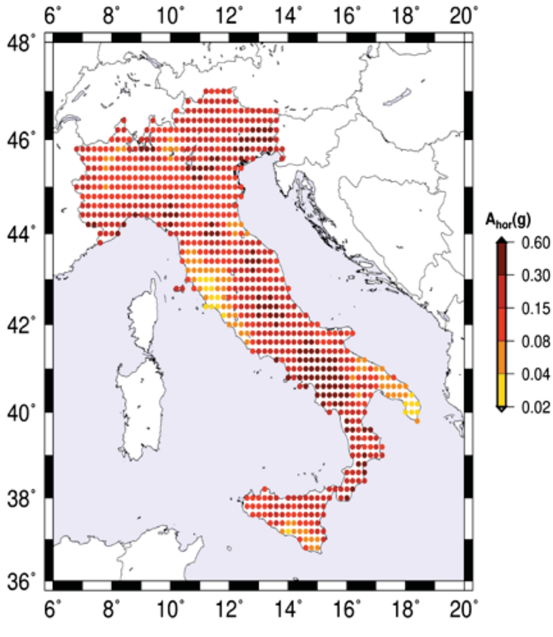
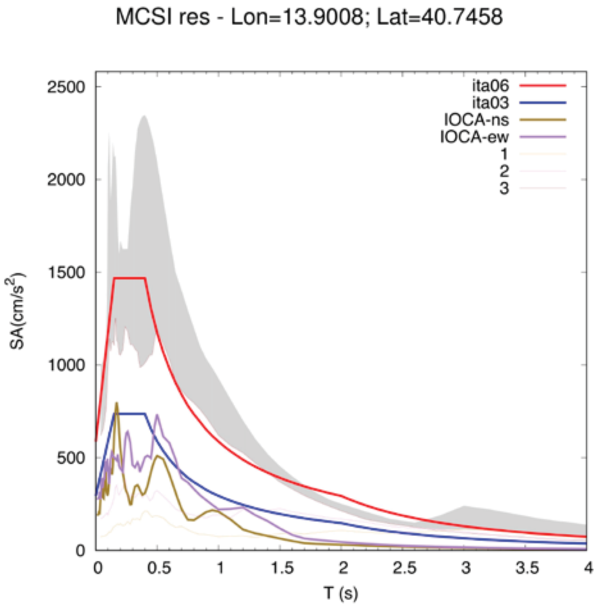


Figure 6. (a) Design Ground Acceleration computed with NDSHA approach [17]. Note that the grid node very close to Ischia island is assigned a ground acceleration 0.3<a<0.6.



	source	profile	M_w	edi (km)	depth (km)	strike (°)	dip (°)	rake (°)	sre (°)	slon (°E)	slat (°N)
1	sz 0928 bb	-	7.0	37.8	15.0	254	47	158	10	14.3	40.9
2	sz 0928 bb	-	6.7	24.0	10.0	254	47	158	29	14.1	40.9
3	sz 0928 bb	-	5.9	5.1	10.0	254	47	158	253	13.9	40.7

Figure 6. (b) Comparison between observed and synthetic response spectra. IOCA spectra are obtained from the records of the NS and EW components of the August 21, 2017 seismic event. ita06 and ita03 represent the spectrum normalized to the class of DGA (0.3-0.6g) expected at the nearest grid point to Ischia according to the NDSHA map of Fig. 6a (see also [18 and 19]). 1 and 2 are the median spectra obtained from hundred realizations of the rupturing process for two sources located in inland Campania, while 3 represents the median spectrum for the scenario of a M=5.1 earthquake located in Ischia. The latter is the dominating contribution to the Maximum Credible Seismic Input (gray band) in Ischia, calculated according to Fig. 4 of reference [22].

5. Discussion and Conclusions

The case of Ischia island is a paradigm for the mitigation of seismic risk in Italy, because the earthquakes occur always in a limited area below the town of Casamicciola and at very shallow depths (less than about 2 km). The main peculiarity of these earthquakes, which poses markedly different problems, with respect to the Apennine or Alpine chains, is that for reasons not yet understood the larger earthquakes (M>3) occur in clusters whose typical duration intervals are of several decades (about 5 decades for the last cluster, from 1828 to 1883). For instance, the devastating earthquake occurring at Casamicciola in 1883 caused 2500 casualties and was preceded 2 years before (1881) by a slightly lower magnitude event, and caused more than 250 casualties. Seven earthquakes with IMCS ≥ VII occurred in that time interval. Such feature makes it very crucial and urgent to strengthen the edifices which can likely collapse in the case of a maximum credible earthquake (MCE), which may likely slightly exceed the earthquake of 1883.

In this work, we proposed two lines of actions for quickly securing the urban areas most affected by the 1883 scenario, and for elaborating a reliable hazard map to be used to design new edifices which can resist the maximum expected ground accelerations. As the most urgent action, we propose to consolidate the edifices lying in the areas affected by IMCS ≥ VIII during the 1883 earthquake, in order to have, in each intensity area, only the class of edifices which are normally non collapsing with that seismic load. We stress that by securing the most risky area, which is very limited, will produce an affordable cost and high relevance for civil safety, in the range of 50-100 M€. As to the elaboration of a new and reliable hazard map able to correctly estimate the maximum expected earthquake magnitudes, the most promising method is NDSHA, since it has demonstrated to overcome the strong underestimation of ground accelerations obtained by the present map based on PSHA. A very accurate seismic hazard map should, however, take into account also the local seismogenic structure, associated with the town of Casamicciola, which likely generated all the significant historical earthquakes on the island. This is a task which is perfectly in line with the capabilities of the NDSHA methodology, and we have shown some examples of preliminary computation of possible accelerations by this local source.

We want to highlight that the problem of the island of Ischia should provide a striking example of a relatively small scale of what should be accomplished for the entire Italian territory. By initiating this process on this island is, however, much more urgent, because we know from the historical seismicity that larger earthquakes like the one of 2017 generally occur in swarms, with inter-event times of a several years and durations of several decades. Ischia is a renewed international tourism brand, and can become a good case study on which to test, calibrate reliable seismic mitigation procedures, and put in place risk mitigation actions that be extended to the national scale.

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GLOBAL VOLCANIC SIMULATOR
Assessment of Multiple Hazards of Cities on Volcanoes

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Abstract. Global Volcanic Simulator is a physical–chemical–mathematical–computer model useful for assessing multiple hazards from volcanic eruptions and consists of the sub-models of the characteristic parts of volcanoes (magma chamber where magma accumulates and differentiates before erupting, volcanic conduit along which magma ascends to the surface, conduit surroundings, atmosphere above the surface of the volcano). For each volcanic eruption scenario, the simulator models are assembled by a scheduler and this scheduling is dynamic, since during an eruption different models of the same characteristic part of the volcano must be employed to account for the relevant volcanic processes. Each sub-model is properly verified and validated before being incorporated into the simulator, and many simulation scenarios must be used for multi-hazard assessment to ensure that the hazards associated with the environment surrounding a volcano are known with minimal uncertainties. This work summarizes the generalized model used in the simulator and the results of some simulations of magma chamber dynamics, magma ascent in volcanic conduits, and distribution of volcanic material in the atmosphere from a collapsing volcanic column at Vesuvius. The general multicomponent, multiphase, and three-dimensional transient model and more simpler models incorporated into the Global Volcanic Simulator are necessary for properly assessing multiple hazards of cities threatened by volcanic eruptions.

Keywords: Global Volcanic Simulator, Vesuvius, Vesuvio, Campi Flegrei, Phlegraean Fuelds, volcanoes, multiphase modeling, computer simulation, hazard assessment

1. Introduction

Volcanoes are fractures in the Earth's crust that allow magma, or partially molten silicate materials containing dissolved gases, to escape from the mantle. The Earth's composition is different in different parts of the crust and mantle and a wide variety of eruption modes is possible because of the complicated

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interrelationships between the chemical and physical properties of these materials. The magma accumulating below a volcano in a mushy region called magma reservoir or magma chamber[1] changes composition from the assimilation with magma from deeper regions of the mantle and as it rises due to buoyancy its dissolved gases (largely water and carbon dioxide) exsolve and can generate great volumes of gases that upon exiting from a volcanic conduit produce high rising volcanic columns of gas and ash. When magma slowly degases during its ascent to the surface it produces slowly moving lava flows on the surface of the volcano. Magmas with large contents of dissolved gases fragment instead in the conduit and the resulting volcanic cloud or column reaches the stratosphere and then propagates laterally, transporting the material over the continents and possibly affecting the Earth's climate. As an eruption proceeds and heavier magma from the mantle is drawn toward the surface, the eruption column can collapse and produce ground-hugging pyroclastic flows which can move in excess of several hundred kilometers per hour and at high temperatures. The pyroclastic flow phase of an eruption is extremely dangerous and no living being can survive if caught in its wake [1].

The earth scientists studying volcanoes have been successful in mapping their locations or answering the "where" question [2], have been marginally successful in understanding "how" the eruptions develop, and have been unsuccessful in predicting "when" the eruptions will occur [3]. This lack of prediction presents problems for the cities on or close to the volcanoes, because without knowing the "when" of eruptions it is impossible to plan well in advance the evacuations of hundreds of thousands or millions of people that could be affected by the eruptions [4]. An alternative is to cohabit with volcanoes, but then it is necessary to produce resilient and sustainable habitats for the people in order to minimize the effects of eruptions. This interdisciplinary and transdisciplinary undertaking is, however, difficult to achieve, because it requires collaborations of actors with different interests and development of appropriate volcanic eruption scenarios in order to properly protect these habitats [5].

Volcanic earthquakes are caused by the fracturing of rocks from the changes of magma's composition and physical properties during its ascent through the mantle and lithosphere. Lava flows moving along the surface of a volcano are produced from the degassed magma exiting from the volcanic vent, and ash fall and pyroclastic flows are produced from the eruption column. Large pieces of rocks from the destruction of the volcanic edifice can also be produced and can reach the distances of tens of kilometers from the vent. Lahars are mixtures of water, ash, and gravel that travel along the valleys of the volcano and are produced from the condensation of water vapor in the eruption column. A single volcanic hazard or in combination with other hazards, such as ash fall, ejection of large pieces of rocks, and ground motions from earthquakes, can produce collapses of buildings in the built environment and severely damage the infrastructure. Pyroclastic flows hug the ground at high temperatures and cause asphyxiation

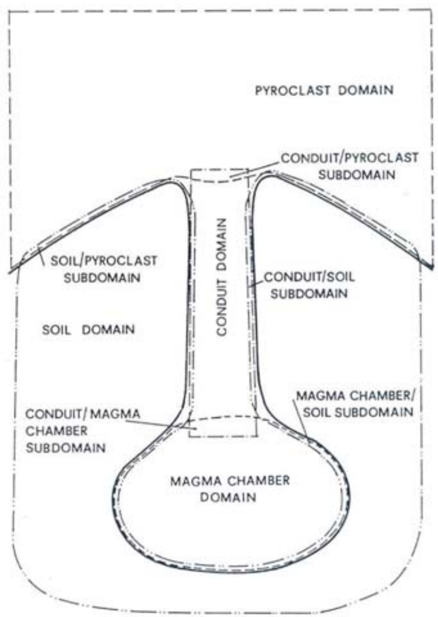
[1] Magma chamber contain partially molten rocks of different compositions and possibly gas bubbles from the exsolved gases.

problems and burns for living beings, and produce distributed loading forces and moments on structures [1, 6].

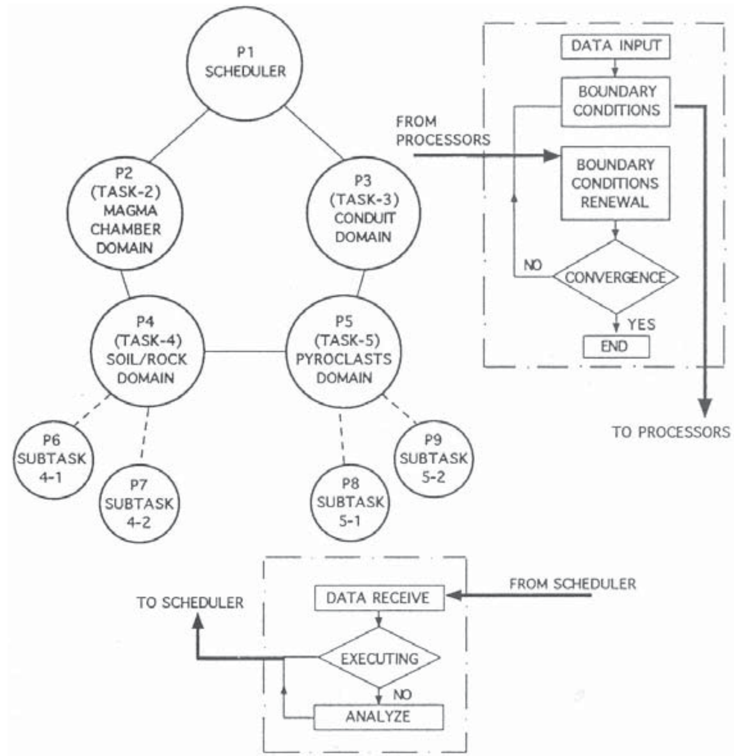
Assessments of multiple hazards of cities on active volcanoes require, therefore, the utilization of tools that can model different volcanic processes from the beginning to the end of eruptions. This requires accounting for chemical composition, storage and feeding characteristics of magma within the volcano, structure of volcanic edifice that may contain a variety of different fractured systems and aquifers, and condition of the built environment on the slopes of the volcano. Many of these parameters may, however, be poorly constrained and a large number of simulations is required: (1) to ascertain that the modeling equations are solved correctly, and (2) to assess the chemical and physical uncertainties associated with the models. The first task of *verification* must proceed the second task of *validation* and no single hazard assessment simulation can produce satisfactory results [7].

Building resilient and sustainable cities on volcanoes is, therefore, a complex undertaking where the simulation of different scenarios of volcanic eruptions must be performed by the tools that can adequately model the relevant volcanic processes. The premise of Global Volcanic Simulator [8, 9] is to accomplish this task and this integrative computer model is continuously being upgraded to ensure its usefulness. The current simulator can solve numerically the multidimensional forms of multicomponent and multiphase mass, momentum, energy, and entropy transport equations for each characteristic part of a volcano (magma chamber, volcanic conduit, surroundings of conduit and magma chamber, environment above the volcanic edifice) with the appropriate constitutive equations that best describe the material response (thermo-fluid and elasto-plastic deformations) of each part [1, 10, 11]. The coupling or boundary conditions for each part are being managed by a scheduler to ensure that each model of the simulator is being provided with the necessary boundary conditions to initiate its computational cycle. When a modeling part of the simulator needs boundary conditions for the execution of its next computational cycle and these conditions are not available before other parts execute their calculations, the scheduler places on hold the execution of this part until its boundary conditions become available (Fig. 1).

In the following, we will first summarize a generalized model of multiphase and multicomponent mixtures used in the simulator to produce models for different parts of the volcanic system. Some of these parts can be modeled with simple models whereas others require very complex modeling strategies in order to properly account for the variety of volcanic processes occurring during an eruption. The simple models presented pertain to the long-term (hundreds to thousands of years) magma supply and discharge from magma chambers and short-term (days to months) magma ascent along the conduits. Modeling of eruption columns requires the use of complex three-dimensional multiphase and multicomponent models. The details of the physical–chemical–mathematical equations used in the simulator for modeling volcanic processes can be found elsewhere [1, 10] and are not described herein. Each model employed requires verification and valida-



(a) Schematic illustration of the decomposition of volcano into different parts or domains.



(b) Computer implementation for the interaction and scheduling computations within the domains.

Figure 1. Global Volcanic Simulator architecture. Subdomains exchange boundary conditions between domains and the entire computation is performed in a multiprocessor environment on one or more computers connected in a network [8, 9, 12].

tion, in the sense that its physical–chemical–mathematical equations are solved with an acceptable numerical accuracy by conducting grid-size and time-step refinements, and use of most effective modeling strategy.

2. Generalized Multiphase and Multicomponent Material Transport Model

2.1 Eulerian Form of Material Transport Laws

The physical laws governing the transport of mass, momentum, and energy of multicomponent and multiphase Eulerian phases can be established through formal averaging procedures involving the well–established single–phase macroscopic transport model of matter [10]. The averaging procedure acts like a filter which eliminates detailed tracking of matter particles while allowing for their gross motions and interactions. The volume averaging is most useful, for it not only furnishes the desired mass, momentum, energy, and entropy transport laws for each phase of a multiphase mixture, but also provides an additional set of transport equations that account for the structural properties of the mixture, such as the size of the averaging region and the information associated with the averaging process. A structural model of multiphase mixtures also eliminates the complications associated with turbulence modeling based on the Reynolds averaging procedures of single–phase flows and parallels that of large eddy simulation where only the local turbulence scales are averaged while the large scales are computed.

Structural properties of multiphase mixture include particle inertia, rotation, and dilatancy (expansion–contraction effects), and can be directly associated with turbulence production and dissipation. The structural effects of multiphase mixtures are intimately tied with the microphysical processes at the centimeter and smaller scales where the turbulent energy is dissipated and thus contribute to the global plume dynamics where this energy is produced.

When the pyroclastic dispersion models do not account for a systematic coupling between different turbulence scales they fail in their predictive capabilities for modeling long–duration and high–rising volcanic plumes. Turbulence is ubiquitous in volcanic plumes and no serious attention has been paid to date to the effects of large turbulence Reynolds numbers on energy dissipation, coupling between small and large scales of turbulence, effects of Stokes number or particle size, particle loading, volume fraction, particle settling parameter, and the relative importance of viscous, inertia, and buoyancy forces [11].

In the structured model of multiphase mixtures, a macroscopic averaging volume U contains all phases of the mixture and the local thermodynamic properties F^α of phase α appear as *volume–averaged* variables

$$< F^\alpha >= \frac{1}{U_\alpha} \int_{U_\alpha} F^\alpha \, dU \tag{1}$$

where U_α is the volume of phase α in U.

The *density–weighted average* F_α, *partial average* $\bar{F}_\alpha$, and *phase average* $\bar{\bar{F}}_\alpha$ are defined as

$$F_\alpha = \frac{< \rho^\alpha F^\alpha >}{< \rho^\alpha >} = \frac{1}{\bar{\rho}_\alpha} \frac{U_\alpha}{U} < \rho^\alpha F^\alpha > \tag{2}$$

$$\bar{F}_\alpha = \frac{U_\alpha}{U} < F^\alpha >, \qquad \bar{\bar{F}}_\alpha =< F^\alpha > \tag{3}$$

The *partial density of phase* α denotes the mass of phase α per unit volume of mixture and is defined by

$$\bar{\rho}_\alpha = \frac{U_\alpha}{U} < \rho^\alpha >= \phi_\alpha \bar{\bar{\rho}}_\alpha, \quad \bar{\rho} = \sum_{\alpha=1}^{\gamma} \bar{\rho}_\alpha \tag{4}$$

where ϕ_α is the *volume fraction* (U_α/U), $\bar{\bar{\rho}}_\alpha$ is the volume–averaged mass density of phase α in the averaging volume, and $\bar{\rho}$ is the *density of the multiphase mixture.*

The *velocity of phase* α, $\mathbf{v}_\alpha$, and the *mixture velocity*, $\mathbf{v}$, are defined as

$$\mathbf{v}_\alpha = \frac{1}{\bar{\rho}_\alpha} \frac{U_\alpha}{U} < \rho^\alpha \mathbf{v}^\alpha >, \qquad \mathbf{v} = \frac{1}{\bar{\rho}} \sum_{\alpha=1}^{\gamma} \bar{\rho}_\alpha \mathbf{v}_\alpha \tag{5}$$

and the *diffusion velocity* of phase α, $\mathbf{u}_\alpha$, is the velocity relative to the center of mass and satisfies

$$\mathbf{u}_\alpha = \mathbf{v}_\alpha - \mathbf{v}, \qquad \sum_{\alpha=1}^{\gamma} \bar{\rho}_\alpha \mathbf{u}_\alpha = 0 \tag{6}$$

By employing the above definitions, the averaging procedure produces the following expression for the *balance of mass of phase* α

$$\grave{\bar{\rho}}_\alpha + \bar{\rho}_\alpha \boldsymbol{\nabla} \cdot \mathbf{v}_\alpha = \hat{c}_\alpha = -\frac{1}{U} \int_{a^\Lambda} m^\alpha da \tag{7}$$

where the backward prime affixed to a phase variable denotes the *material derivative* following that phase. The mass generation rate per unit volume of the mixture $\hat{c}_\alpha$ arises from the phase change processes, a^Λ denotes the interfacial area of phase α in U, m^α is the local mass transfer rate across the interface, and $\hat{c}_\alpha$ is equal to zero if there is no mass transfer across the interfaces.

The conservation of mass for a *multiphase mixture* is obtained by summing from $\alpha = 1$ to $\alpha = \gamma$ in Eq. (7). This produces

$$\frac{\partial \bar{\rho}}{\partial t} + \boldsymbol{\nabla} \cdot \bar{\rho} \mathbf{v} = 0 \quad \text{or} \quad \dot{\bar{\rho}} + \bar{\rho} \boldsymbol{\nabla} \cdot \mathbf{v} = 0, \quad \sum_{\alpha=1}^{\gamma} \hat{c}_\alpha = 0 \tag{8}$$

where the third equation accounts for the mass conservation property of the mixture and the dot over the mixture density signifies the *material derivative* following the motion of the mixture as a whole.

The *linear momentum of phase* α is expressed by

$$\bar{\rho}_\alpha \grave{\mathbf{v}}_\alpha = \boldsymbol{\nabla}\cdot\bar{\mathbf{T}}_\alpha + \bar{\rho}_\alpha \mathbf{b}_\alpha + \hat{\mathbf{p}}_\alpha \tag{9}$$

where $\bar{\mathbf{T}}_\alpha$ is the stress tensor and $\mathbf{b}_\alpha$ is the body force per unit mass. $\hat{\mathbf{p}}_\alpha$ is the momentum source per unit volume and arises from phase changes and structural effects of the mixture because of the finite size of the averaging volume U.

The *angular momentum of phase* α expresses the non-symmetry of the stress tensor

$$\mathbf{M}_\alpha = \bar{\mathbf{T}}_\alpha - \bar{\mathbf{T}}_\alpha^T \tag{10}$$

where the superscript T denotes transpose. This asymmetry can be produced by particle spins, couple stresses, and body moments.

The *conservation of energy of phase* α takes the following form

$$\bar{\rho}_\alpha \grave{\varepsilon}_\alpha = \mathrm{tr}(\bar{\mathbf{T}}_\alpha^T\cdot(\boldsymbol{\nabla}\mathbf{v}_\alpha)) - \boldsymbol{\nabla}\cdot\bar{\mathbf{q}}_\alpha + \bar{\rho}_\alpha r_\alpha + \hat{\epsilon}_\alpha \tag{11}$$

where ε_α is the internal energy, tr denotes the trace operation, r_α is the energy generation rate per unit mass, and $\hat{\epsilon}_\alpha$ accounts for both the energy transfer rate per unit volume between the phases and the structural properties of the mixture.

The *entropy inequality of phase* α satisfies

$$\bar{\rho}_\alpha \grave{s}_\alpha + \boldsymbol{\nabla}\cdot\left(\frac{\bar{\mathbf{q}}_\alpha}{\bar{\bar{\theta}}_\alpha}\right) - \frac{\bar{\rho}_\alpha r_\alpha}{\bar{\bar{\theta}}_\alpha} + \hat{c}_\alpha s_\alpha + \hat{s}_\alpha \geq 0 \tag{12}$$

where s_α is the entropy, $\bar{\bar{\theta}}_\alpha$ is the *phase averaged temperature*, and $\hat{s}_\alpha$ is the *entropy source of phase* α that is not necessarily positive semidefinite.

The phasic conservation of mass, linear and angular momenta, energy, and entropy Eqs. (7, 9-12) are similar to the corresponding equations of single–phase multicomponent mixtures and reduce to the latter if the interfacial effects of the mixture are negligible. Every physically consistent theory of multiphase mixtures should have such a *consistency property* in order to reproduce at least the most simple and known physical phenomena.

The motion of each phase relative to the center of mass is accounted for by taking moments of the phasic conservation of mass and momentum equations *relative to the center of mass.* These operations produce the *balance of equilibrated inertia*

$$\bar{\rho}_\alpha \grave{i}_\alpha = -\hat{c}_\alpha(i_\alpha - \hat{i}_\alpha) + 2\bar{\rho}_\alpha i_\alpha \frac{\grave{\phi}_\alpha}{\phi_\alpha} - \boldsymbol{\nabla}\cdot\left(\mathbf{U}_\alpha \frac{\grave{\phi}_\alpha}{\phi_\alpha}\right) \tag{13}$$

and *balance of equilibrated moments*

$$\begin{aligned}\bar{\rho}_\alpha \overline{i_\alpha \frac{\grave{\phi}_\alpha}{\phi_\alpha}}^{\grave{}} &= -\hat{c}_\alpha \frac{\grave{\phi}_\alpha}{\phi_\alpha}(i_\alpha - \hat{i}_\alpha) + \bar{S}_\alpha + \boldsymbol{\nabla}\cdot\bar{\boldsymbol{\lambda}}_\alpha - \bar{\rho}_\alpha i_\alpha \frac{\grave{\phi}_\alpha}{\phi_\alpha}\boldsymbol{\nabla}\cdot\mathbf{v}_\alpha \\ &+ \bar{\rho}_\alpha i_\alpha \left(\frac{\grave{\phi}_\alpha}{\phi_\alpha}\right)^2 - \left(\frac{\grave{\phi}_\alpha}{\phi_\alpha}\right)\boldsymbol{\nabla}\cdot\left(\mathbf{U}_\alpha \frac{\grave{\phi}_\alpha}{\phi_\alpha}\right)\end{aligned} \tag{14}$$

where the *isotropic inertia of phase* α is defined as

$$i_\alpha = \frac{1}{\bar{\rho}_\alpha}\frac{1}{U}\int_{U_\alpha} \rho^\alpha \boldsymbol{\xi}\cdot\boldsymbol{\xi}\, dU \tag{15}$$

with $\boldsymbol{\xi}$ is the position vector relative to the center of mass. In the equilibrated inertia equation, $\hat{i}_\alpha$ represents the source of inertia due to phase change, whereas $\mathbf{U}_\alpha$ accounts for triple correlations of $\boldsymbol{\xi}$ which are associated with the non-uniformities within the averaging volume. The moment of surface forces acting on the surface of volume U_α in U is represented in the equilibrated moments equation by $\bar{S}_\alpha$, whereas $\bar{\boldsymbol{\lambda}}_\alpha$ in this expression represents the volume–averaged moment of the stress tensor $\bar{\mathbf{T}}_\alpha$.

The above multiphase material transport equations are the result of replacing continuous distribution of forces in the averaging volume by the resultant forces and couples acting on this volume. When the forces acting on the surface of U_α are averaged, the result is an average force which is represented by the surface traction force $\bar{\mathbf{T}}_\alpha\cdot\mathbf{n}_\alpha$ and a resultant couple represented by $\bar{\mathbf{S}}_\alpha$. Similarly, the average stress tensor $\bar{\mathbf{T}}_\alpha$ and intrinsic stress moment $\bar{\boldsymbol{\lambda}}_\alpha$ replace the local variation of stress tensor within U_α. These results are consistent with particle mechanics where the forces acting on a collection of particles can be replaced by a resultant force and a resultant couple. The structural properties of the mixture are thus accounted for by i_α, $\mathbf{U}_\alpha$, $\bar{\mathbf{S}}_\alpha$, and $\bar{\boldsymbol{\lambda}}_\alpha$, and may also appear in the phasic variables $\bar{\mathbf{T}}_\alpha$, $\hat{\mathbf{p}}_\alpha$, $\bar{\mathbf{q}}_\alpha$, $\hat{i}_\alpha$, $\hat{\epsilon}_\alpha$, and $\hat{c}_\alpha$. These variables are required to satisfy certain constitutive principles and the second law of thermodynamics as represented by Eq. (12).

When some of the results of constitutive theory of mixtures of fluids [10] are used in the above transport equations, these expressions, expressed in the tensor index notation with indices i, j, and k, reduce to the following forms:

Conservation of Mass:

$$\frac{\partial\bar{\rho}_\alpha}{\partial t} + \frac{\partial\bar{\rho}_\alpha v_{\alpha j}}{\partial x_j} = \hat{c}_\alpha, \qquad \bar{\rho}_\alpha = \phi_\alpha\bar{\bar{\rho}}_\alpha \tag{16}$$

$$\frac{\partial\bar{\bar{\rho}}_\alpha}{\partial t} + \frac{\partial\bar{\bar{\rho}}_\alpha v_{\alpha j}}{\partial x_j} = \frac{\hat{c}_\alpha}{\phi_\alpha} - \bar{\bar{\rho}}_\alpha\varphi_\alpha, \qquad \varphi_\alpha = \frac{\grave{\phi}_\alpha}{\phi_\alpha} \tag{17}$$

Conservation of Momentum:

$$\begin{aligned}\frac{\partial\bar{\rho}_\alpha v_{\alpha i}}{\partial t} + \frac{\partial\bar{\rho}_\alpha v_{\alpha i}v_{\alpha j}}{\partial x_j} &= -\phi_\alpha p_{\alpha,i} - \frac{1}{2}\bar{\rho}_\alpha i_\alpha(\frac{\grave{\phi}_\alpha}{\phi_\alpha})^2_{,i} + (O_{\alpha\alpha}\phi_\alpha\frac{\grave{\phi}_\alpha}{\phi_\alpha})_{,i}\\ &+\hat{c}_\alpha v_{\alpha i} + \left[\lambda_{\alpha\alpha}\, D_{\alpha kk}\delta_{ij} + 2\,\mu_{\alpha\alpha}D_{\alpha ij} + 2\,\bar{\rho}_\alpha C_\alpha\phi_{\alpha,i}\phi_{\alpha,j}\right]_{,j}\\ &-\sum_\beta^{\gamma-1}\xi_{\alpha\beta}(v_{\beta i} - v_{\gamma i}) - \sum_\beta^{\gamma}\gamma_{\alpha\beta}\bar{\bar{\theta}}_{\beta,i} - \sum_\beta^{\gamma}\mathit{\Delta}_{\alpha\beta}\bar{\bar{\rho}}_{\beta,i} + \bar{\rho}_\alpha b_{\alpha i}\end{aligned} \tag{18}$$

where $D_{\alpha ij}$ is the deformation rate tensor, and an index following a comma in a subscripted variable denotes the partial derivative with respect to that index; for example, $p_{\alpha,i} = \partial p_\alpha / \partial x_i$. In Eq. (18), p_α is the thermodynamic pressure, $\lambda_{\alpha\alpha}$ and $\mu_{\alpha\alpha}$ are the bulk and shear viscosity coefficients, respectively, C_α and $O_{\alpha\alpha}$ are structural property coefficients, $\xi_{\alpha\beta}$ are viscous drag coefficients, $\gamma_{\alpha\beta}$ are Soret effect coefficients, and $\Delta_{\alpha\beta}$ are density gradient coefficients. The viscosity coefficients include both viscous and turbulent contributions and the latter can be modeled with the subgrid scale models. The stress term with the parameter C_α accounts for Mohr–Coulomb yield–type criteria of plastic deformation when the volume fraction gradients become high and the flow begins to creep as in pyroclastic flows during material sedimentation. In this situation, the pressure gradient becomes balanced by the gravity and compaction characteristics of particulates. This stress term thus accounts for the yield stress of the material and is independent of the rate of strain. It produces energy dissipation (see Eq. (20) below).

Conservation of Total Energy:

One can derive several useful forms for the energy equation. The one that we will need is the total energy equation for phase α, which is obtained by adding the scalar product of velocity and momentum Eq. (9) to the internal energy Eq. (11). By defining the total energy of phase α as being the sum of internal, kinetic, and compaction energies, i.e.

$$e_\alpha = \varepsilon_\alpha + \frac{1}{2} v_{\alpha i} v_{\alpha i} + C_\alpha \phi_{\alpha,i} \phi_{\alpha,i} \tag{19}$$

The conservation equation for total energy of phase α thus becomes,

$$\begin{aligned} \frac{\partial \bar{\rho}_\alpha e_\alpha}{\partial t} + \frac{\partial \bar{\rho}_\alpha e_\alpha v_{\alpha j}}{\partial x_j} &= -\bar{q}_{\alpha i,i} - \phi_\alpha (p_\alpha v_{\alpha i})_{,i} + (O_{\alpha\alpha} \phi_\alpha \varphi_\alpha v_{\alpha i})_{,i} \\ &+ \left[(\lambda_{\alpha\alpha} D_{\alpha kk} \delta_{ij} + 2\, \mu_{\alpha\alpha} D_{\alpha ij} + 2\, \bar{\rho}_\alpha C_\alpha \phi_{\alpha,i} \phi_{\alpha,j})\, v_{\alpha i} \right]_{,j} \\ &- v_{\alpha i} \sum_{\beta}^{\gamma-1} \xi_{\alpha\beta} (v_{\beta i} - v_{\gamma i}) - v_{\alpha i} \sum_{\beta}^{\gamma} \gamma_{\alpha\beta} \bar{\bar{\theta}}_{\beta,i} - v_{\alpha i} \sum_{\beta}^{\gamma} \Delta_{\alpha\beta} \bar{\bar{\rho}}_{\beta,i} \\ &+ \bar{\rho}_\alpha b_{\alpha i} v_{\alpha i} + \bar{\rho}_\alpha r_\alpha - \bar{q}_{s\alpha} + \hat{c}_\alpha (\hat{\bar{\epsilon}}_\alpha + \frac{1}{2} v_{\alpha i} v_{\alpha i} + C_\alpha \phi_{\alpha,i} \phi_{\alpha,i}) \\ &- \phi_\alpha \varphi_\alpha (p_\alpha - \beta_\alpha) - v_{\alpha i} \frac{1}{2} (\varphi_\alpha^2)_{,i}\, \bar{\rho}_\alpha i_\alpha \end{aligned} \tag{20}$$

In this equation $\bar{q}_{s\alpha}$ is the interfacial heat transfer rate per unit volume, whereas the *configuration pressure* β_α can be computed from the Helmholtz potential. This pressure arises from the changes in the packing of phase α and thus reflects the strength of contact forces between this and other phases. A reasonable choice for this pressure is the packing stress of material grains.

The total energy Eq. (20) shows how the energy of each phase is distributed between different processes. The convection of energy is balanced by heat transfer due to temperature gradients within the phases, temperature differences between the phases, phase changes releasing or requiring latent heat, viscous dissipation which produces heat from fluid friction within each phase and from the exchange of momenta between the phases, flow work associated with pressure and distribution of phases, energy generation from electromagnetic or other processes, and the work expended in distributing phase matter in different regions of vorticity. The larger the phase inertia and its volume fraction gradient, the more energy from large eddies must be expended or dissipated by the small eddies to maintain equilibrium. The strengths of contact forces between the phases and the phasic dilatation rates can both produce and dissipate energy within a mixture. The redistribution of particulate and non–particulate matter at small scales is thus governed by phase inertia, volume fraction (particle loading), and configuration pressure parameters.

Inertia Transport Equation:

$$\frac{\partial \bar{\rho}_\alpha i_\alpha}{\partial t} + \frac{\partial \bar{\rho}_\alpha i_\alpha v_{\alpha j}}{\partial x_j} = \hat{c}_\alpha \hat{i}_\alpha + 2\,\bar{\rho}_\alpha i_\alpha \varphi_\alpha - (\varphi_\alpha U_{\alpha m})_{,m} \tag{21}$$

Dilatation–Contraction Transport Equation:

$$\begin{aligned}\frac{\partial \bar{\rho}_\alpha \varphi_\alpha}{\partial t} + \frac{\partial \bar{\rho}_\alpha \varphi_\alpha v_{\alpha j}}{\partial x_j} &= \hat{c}_\alpha \varphi_\alpha - D_{\alpha kk}(\bar{\rho}_\alpha \varphi_\alpha + \frac{\phi_\alpha}{i_\alpha} O_{\alpha\alpha}) \\ &\quad + \frac{1}{i_\alpha} \sum_{\beta}^{\gamma} (\kappa_{\alpha\beta} i_\beta + H_{\alpha\beta} \phi_\beta \varphi_\beta) - \bar{\rho}_\alpha \varphi_\alpha^2\end{aligned} \tag{22}$$

The inertia and dilatation–contraction transport equations account for small scale effects in the flow, which have been averaged out through the averaging procedure of local mass, momentum, and energy transport laws. In our model, the microstructural effects survive through phase inertia, volume fraction, and configuration pressure, and provide a feedback to the mean flow. The phase inertia can be viewed as a measure of turbulent intensity and $U_{\alpha m}$ as proportional to the gradient of this intensity.

Since the phase inertia moderates both the production of turbulent kinetic energy and turbulent dissipation rate, the inertia transport Eq. (21) can be split into two interacting parts that model this turbulence. The size of the averaging volume can be, therefore, interpreted as the filter width, with the microstructural parameters defining its characteristics. The resulting structural model is thus analogous to large eddy simulation models where the small scales are averaged out and modeled and the large ones are computed. It is also considerably simpler than the multiphase flow turbulence models based on the single–phase flow Reynolds averaging where there are too many poorly constrained modeling parameters.

To close the above equations we also need a constitutive equation for the heat flux rate, which in linearized form can be written as

$$\bar{q}_{\alpha i} = -\sum_{\beta}^{\gamma} \kappa_{\alpha\beta}\bar{\bar{\theta}}_{\beta,i} - \sum_{\beta}^{\gamma} \nu_{\alpha\beta}\bar{\bar{\rho}}_{\beta,i} - \sum_{\beta}^{\gamma-1} \varsigma_{\alpha\beta}(v_{\beta i} - v_{\gamma i}) - \sum_{\beta}^{\gamma} \Gamma_{\alpha\beta}\phi_{\beta,i} \quad (23)$$

where the first term on the right represents the Fourier effect (heat flow due to temperature gradients) and the second term is the Dufour effect (heat flow due to mass transfer). Except for the temperature gradient term in this equation, all other terms can, in general, be neglected. Equation (12) places restrictions on the phenomenological coefficients of constitutive equations and requires that the following conditions be satisfied

$$\kappa_{\alpha\alpha} \geq 0; \qquad H_{\alpha\alpha} \geq 0; \qquad O_{\alpha\alpha} \leq 0; \qquad \lambda_{\alpha\alpha} + \frac{2}{3}\mu_{\alpha\alpha} \geq 0;$$
$$\xi_{\alpha\alpha} \geq 0; \qquad \xi_{\alpha\beta} \leq 0, \qquad \alpha \neq \beta \neq \gamma \quad (24)$$

The interfacial heat transfer can be modeled as

$$\bar{q}_{s\alpha} = \bar{h}_{\alpha}(\bar{\bar{\theta}}_{\alpha} - \bar{\bar{\theta}}_{g}) \quad (25)$$

where $\bar{\bar{\theta}}_g$ is the temperature of the gas phase and $\bar{h}_\alpha$ is the heat transfer coefficient. The phase change energy flux $\hat{c}_\alpha\hat{\bar{\varepsilon}}_\alpha$ is related to the mass supply $\hat{c}_\alpha$ and average energy of interfaces of phase α. Similarly, the source of inertia $\hat{c}_\alpha\hat{\bar{i}}_\alpha$ is related to the mass supply and average inertia of interfaces of phase α. Modeling of $\hat{c}_\alpha$ depends on the composition and chemical reactions of the constituents of phase α, and, in order to account for these effects, we must extend the single–component multiphase flow theory to one involving many components. This extension is discussed in the following section.

2.2 Multiphase–Multicomponent Flows

While it is possible to assign unique properties to each chemical constituent or component in a mixture, we will not follow this approach in order to keep the model as simple as possible. In our approximation, we only modify the conservation of mass equation of each phase to account for the diffusion of each constituent and retain the previously–derived phasic conservation equations for momentum, energy, inertia, and dilatation–contraction transport.

If $\omega_{a\alpha}$ is the mass fraction of constituent a in phase α, Eqs. (7) and (8) can be used to show

$$\frac{\partial\bar{\rho}_\alpha\omega_{a\alpha}}{\partial t} + \frac{\partial\bar{\rho}_\alpha\omega_{a\alpha}v_{\alpha j}}{\partial x_j} = \hat{c}_{a\alpha} - \frac{\partial J_{a\alpha j}}{\partial x_j}; \quad a = 1,\cdots,s \quad (26)$$

$$\frac{\partial\bar{\bar{\rho}}_\alpha\omega_{a\alpha}}{\partial t} + \frac{\partial\bar{\bar{\rho}}_\alpha\omega_{a\alpha}v_{\alpha j}}{\partial x_j} = \frac{\hat{c}_{a\alpha}}{\phi_\alpha} - \bar{\bar{\rho}}_\alpha\varphi_\alpha - \frac{1}{\phi_\alpha}\frac{\partial J_{a\alpha j}}{\partial x_j}; \quad a = 1,\cdots,s \quad (27)$$

where $\hat{c}_{a\alpha}$ is the net mass generation rate per unit volume and $\mathbf{J}_{\mathbf{a}\alpha}$ is the *mass diffusion flux* of constituent a in phase α. $\hat{c}_{a\alpha}$ accounts for the combined effects of nucleation, condensation, evaporation, aggregation, fragmentation, and chemical reactions. The constituent mass generation rate is equal to zero if no constituent is produced or consumed, while its mass flux can be produced with or without chemical reactions. Conservation of mass of each chemical constituent then requires

$$\sum_{a=1}^{s} \omega_{a\alpha} = 1, \quad \alpha = 1, \cdots, \gamma; \quad \sum_{a=1}^{s} \hat{c}_{a\alpha} = \hat{c}_{\alpha}, \quad \sum_{\alpha=1}^{\gamma} \hat{c}_{\alpha} = 0 \tag{28}$$

The diffusion flux $\mathbf{J}_{\mathbf{a}\alpha}$ accounts for the diffusion of component a relative to the mean flow of phase α and, according to the kinetic theory [13], is proportional to the mass fraction gradient

$$\mathbf{J}_{a\alpha} = -\mathbf{K}_{\mathbf{a}\alpha} \cdot \boldsymbol{\nabla} \omega_{\mathbf{a}\alpha} \tag{29}$$

where $\mathbf{K}_{\mathbf{a}\alpha}$ is the *mass diffusion tensor* that accounts for the effects of turbulence.

The Eulerian formalism is useful for modeling the continuous gas phase and large number of fine particulate phases of the mixture because these strongly interact with each other through collisions and turbulence. The centimeter-size and larger particles are affected much less by the gas and small particulate motions and tend to follow the ballistic trajectories. Their motions are more effectively described by the Lagrangian kinetic equations which we will not present in this work, but are available in the simulator for simultaneously modeling the continuous and discrete phases.

2.3 Generalized Model Implementation

The generalized multiphase and multicomponent transport theory model discussed above can be simplified by neglecting certain processes through the appropriate use of *nondimensional analysis* [1] or by averaging over one or more spatial dimensions when the variations of physical variables in these dimensions are not as significant as in other spatial dimensions. Opening of volcanic conduits and magma ascent in conduits can sometimes satisfy these requirements and are often better approximations of physical phenomena than the more complex models where the specifications of some parameters becomes highly uncertain. The choice of appropriate models in the Global Volcanic Simulator requires considerable similarity with modeling strategies, because the mere use of models propagated through computer codes and without understanding their limitations does not produce an understanding of the modeled processes.

3. Global Volcanic Simulator Models

Global Volcanic Simulator employs different models based on the generalized model discussed above [1, 10, 14] to model the material transport in the volcanic system, where each part of this system (magma chamber, conduit, atmosphere) employs the relevant thermal, fluid mechanics, and mechanical constitutive equations to account for fluid- and solid-like material behaviors. The generalized model can account for very complex volcanic processes occurring in volcanic columns and magma chambers, and can be simplified to simpler situations involving steady-state, one-dimensional, or lumped parameter situations, as illustrated by the following models of magma chamber dynamics, opening of volcanic conduit, magma ascent in conduit, and distribution of pyroclasts in the atmosphere above the volcano.

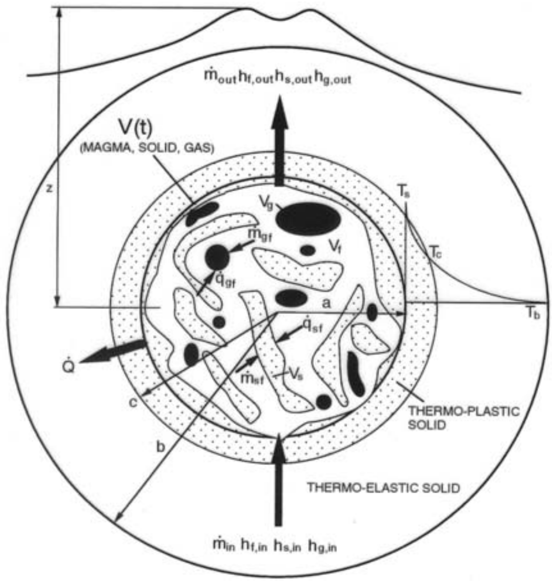
3.1 Magma Chamber Dynamics

The *magma chamber model* depicted in Fig. 2a considers the inner region of the chamber as a mixture of magma, solids, and gases, and the surrounding regions as thermoplastic and thermoelastic solids. This model allows for simulating the long-term subplinian and plinian activity of a volcano by accounting for magma supply from the mantle and opening of volcanic conduit when the pressure in the chamber exceeds the yield strength of the overlying rocks. An application of this model to Vesuvius (Fig. 2b,c), with magma chamber volume of about 10 km^3 and located at 5 km below the surface, shows the semi-cyclic eruptions of this volcano and suggests that the next eruption has a high probability of being plinian and not subplinian as assumed in the Vesuvius Evacuation Plan [4].

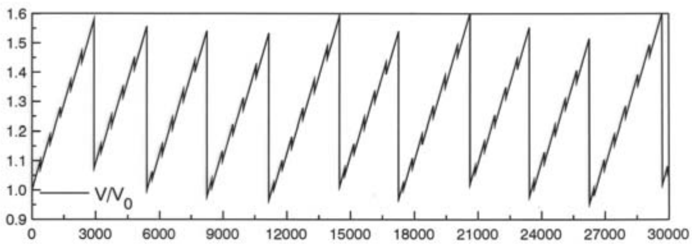
3.2 Magma Ascent in Conduits

The *conduit opening model* shown in Fig. 3a considers magma ascent along a one-dimensional fracture. Here magma rises because of buoyancy and its pressure decrease causes the exsolution of dissolved gases. Its ascent is controled by the Froude, Reynolds, and Magma Porosity numbers, where the small Reynolds and Magma Porosity numbers inhibit the ascent velocity through the conduit because of the small permeability of magma reservoir and high shearing stresses (from large magma viscosity), suggesting that an eruption will not occur until a certain critical amount of melt is available in the magma reservoir.

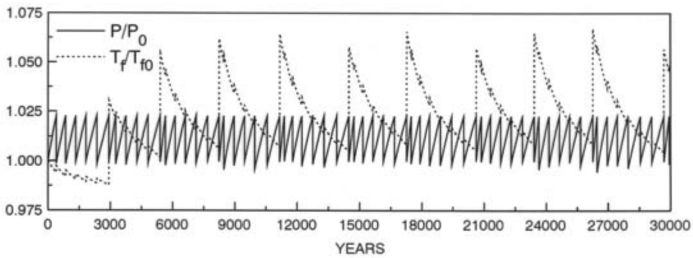
When the rising magma in a conduit begins exsolving gases (Fig. 3b) it is necessary to employ a different model that utilizes single phase flow in one part of the conduit and multiphase flow with gaseous phases in the more superficial part of the conduit. This more complicated model allows for the determination of pressure, temperature, velocities of phases, void fractions, and mass fractions at the conduit exit, which serve as the boundary conditions for the volcanic column model described below. Such a model accounts for magma fragmentation in a conduit and suggests that for very viscous magmas the magma pressure in a conduit can fall significantly below the lithostatic pressure of surrounding rocks and cause water from the aquifers to enter into the conduit. The resulting magma–water interaction produces a violent phreatomagmatic eruption capable of decapitating the entire cone of a volcano [1], as happened during the 1631 eruption of Vesuvius [16].



(a) Magma chamber with inner region consisting of melt, solids, and exsolved gases, and outer regions consisting of thermoplasic and thermoelastic solids.

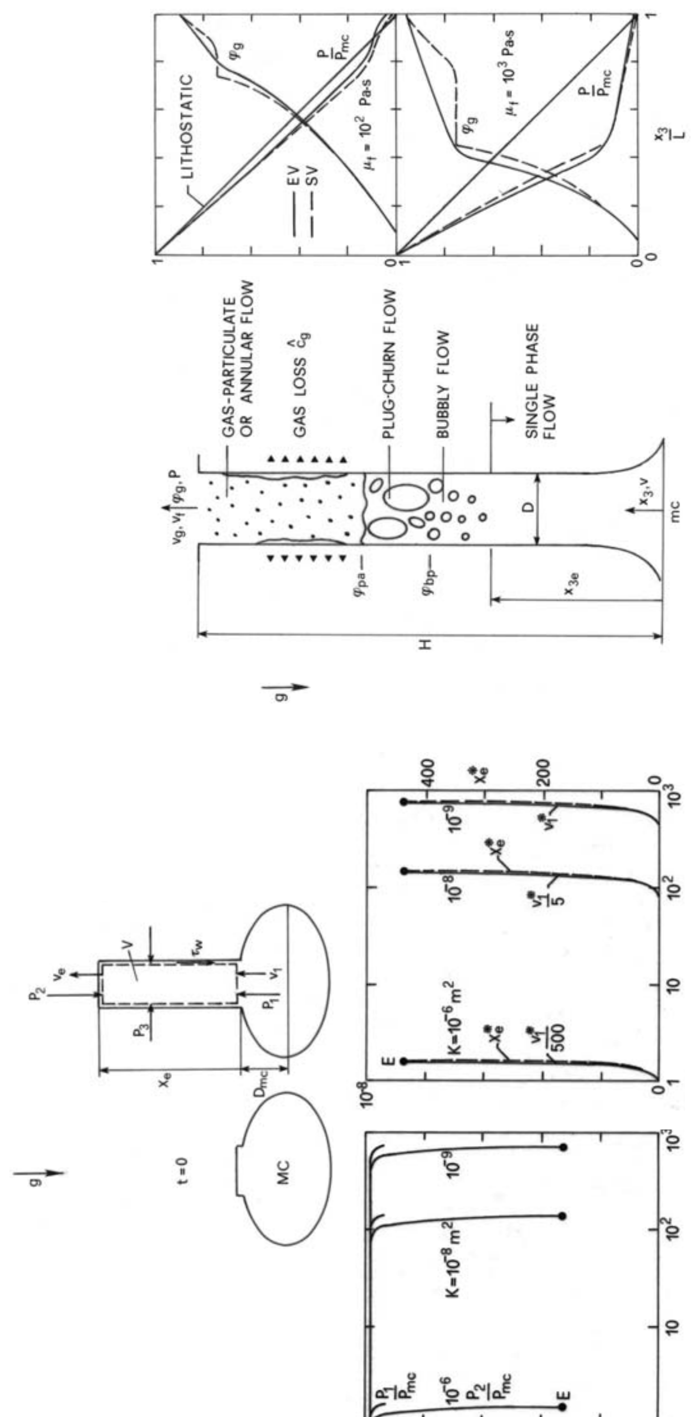


(b) Variation of magma chamber volume V with time.



(c) Variations of magma chamber pressure P and temperature T_f with time.

Figure 2. Plinian eruptions of Vesuvius occur every few thousand years and subplinian eruptions occur every few centuries, as inferred from the studies of historical eruptions [15].



(a) One-dimensional single phase flow model of opening of volcanic conduit and distributions of magma front pressure P_2, velocity v_1, and distance x_e with time as a function of magma chamber permeability K. Ponts E are termination points of calculation, because the dissolved gases begin exsolving and the model becomes invalid.

(b) One-dimensional two-phase flow model of magma ascent in a conduit and vertical pressure P and gas volume fraction φ_g distributions, where P_{mc} and μ_f are magma chamber pressure and magma viscosity, respectively.

Figure 3. Opening of volcanic conduit and and magma ascent along the conduit.

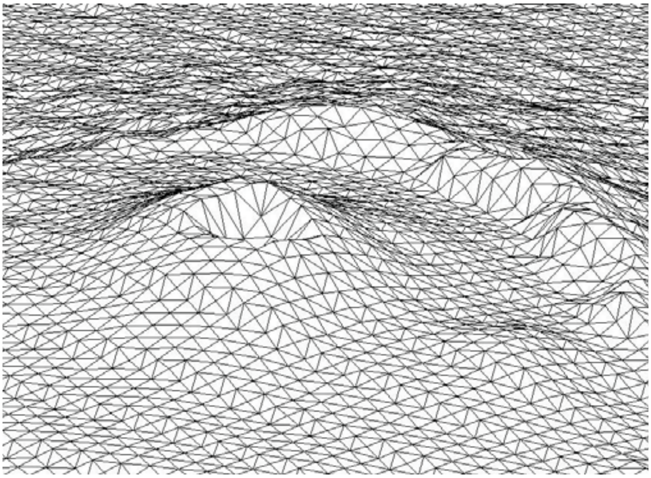
3.3 Collapsing Volcanic Column

Time-dependent and three-dimensional simulation of a volcanic column is a very complex undertaking because the column consists of gaseous phases (air, water vapor, carbon dioxide), solid phases (different sizes of pyroclasts ranging from micron-size ash particulates to cm-size pieces of rock from the volcanic edifice), and nucleating and growing liquid water droplets (produced from the condensation of water vapor exsolved from magma during its ascent to the surface). Modeling of the condensation process in the atmosphere requires the consideration of microphysics of the process, which is currently incompletely understood as in weather predictions [11], and its neglect in the column is permissible when the column does not rapidly rises toward the tropopause where the air temperature reaches –60°C. This occurs when the column collapses in the troposphere close to the vent and produces pyroclastic flows that tend to hug the ground for tens of minutes before producing secondary columns that lift hot ash high into the atmosphere. The behavior of eruption column depends on the chemical and physical properties of the erupted material that during an eruption changes, since with time magmas with heavier compositions are erupted [1–3].

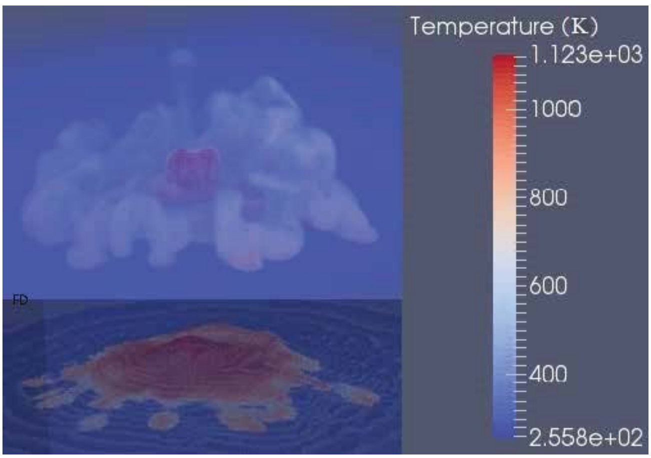
For assessing multiple hazards of an eruption with the built environment in the proximity of the volcano, multiple simulations must be performed with different volcano topographies and without and with this environment, and in the latter situation with sufficient grid resolutions that resolve significant human structures. Here, we will summarize the results of a simulation for Vesuvius that illustrates the necessity of defining the *exclusion area* around this volcano [5].

The topography of the volcano was produced from the 5 m resolution UTM data available from Istituto Geografico Militare Italiano and Fig. 4a shows a triangular grid of the topography around the cone of Vesuvius and Somma caldera used in calculations. The computational grid in the simulation includes the base area of 200 km^2 and the height of the troposphere, so that the collapsed volcanic column is fully contained in this volume during the entire duration of simulation. Figure 4b shows the temperature distribution of pyroclastic flows following the collapse of volcanic column and points to a very complex structure that does not only depend on the topography, but also by the thermo–fluid mechanics processes in the eruptive cloud, produced from the interactions of secondary columns above the pyroclastic flows.

The secondary columns above the pyroclastic flows are produced from the vertical buoyancy forces in the flows and cause continuous changes in the global column and limit the propagation distances of flows that are different in different directions. The hugging of the flows close to the central cone of the volcano suggests that the *exclusion nucleus* of this volcano has a limited extend of several kilometers from the vent and that outside of this area it should be possible to produce resilient and sustainable areas where the population can cohabit with the volcano. The redefinition of danger zones around Vesuvius and Phlegraean Campi Flegrei into exclusion nuclei, resilience belts, and sustainability areas is the key feature of VESUVIUS–CAMPIFLEGREI PENTALOGUE [5].



(a) Triangular grid of Somma–Vesuvius topography.



(b) Temperature distribution of pyroclastic flows on the surface and above the surface of volcano following the collapse of volcanic column.

Figure 4. Topography of Somma–Vesuvius and pyroclastic flows produced from the collapse of a plinian eruption column of Vesuvius.

4. Discussion

The main phase of a large-scale explosive eruption can last for several days and simulation of such an eruption is a very complex undertaking. This is because large computational resources are required to ensure that the physical–chemical–mathematical equations of the model are solved correctly (verification) and that

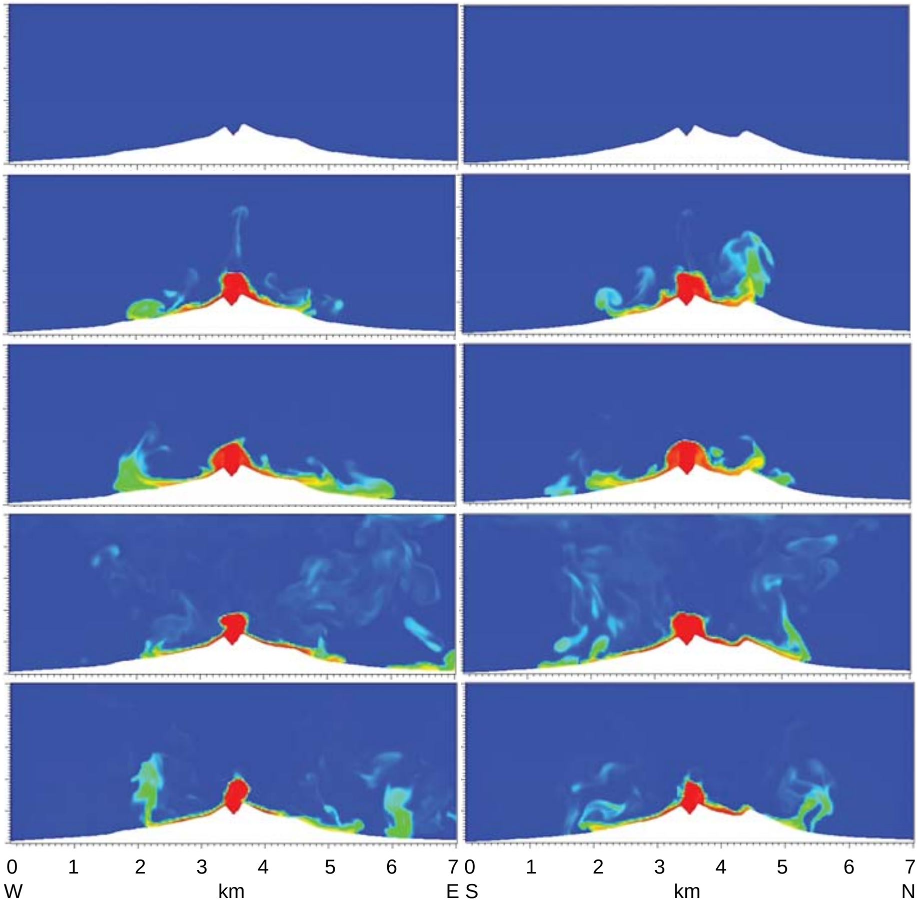


Figure 5. Temperature distributions along the WE and SN directions during the first minutes of an eruption of Vesuvius. The eruption produces column collapse and the pyroclastic flows propagate in different directions dependent of the topography and interactions of secondary columns produced on pyroclastic flows. The red color denotes temperature of about 1100 K and the blue color temperature of the atmosphere of about 300 K.

the model accounts for all relevant volcanic processes which can occur during the eruption (validation). For determining the effects of the eruptions on the built environment surrounding a volcano it is necessary to perform many simulations of different eruption scenarios to assess all possible hazards and their consequences that could be involved during the eruptions. And for producing resilient and sustainable habitats close to a volcano, these scenarios must also include those associated with the re-organization of the built environment, so that this environment can resist the eruptions with minimal socio-economic and cultural losses [5, 17]. Reliable assessments of hazards and consequences of volcanic eruptions are necessary for ascertaining the vulnerability, risk, resilience, and sustainability of a city in the proximity of a volcano [18], but currently such assessments do not exist, because it is apparently easier to promote evacuation plans whose reliabilities are highly questionable and detrimental for producing resilience and sustainability of cities close to volcanoes [4].

The current development of Global Volcanic Simulator is aimed at simulating from start to finish not only the plinian eruptions of Vesuvius, but also the plinian and super eruptions of Campi Flegrei, in order to map as precisely as possible the exclusion, resilience, and sustainability areas of these volcanoes [5]. For Vesuvius discussed in this work, the exclusion and other areas are not uniformly distributed around the volcano, because of both the asymmetry of the volcanic edifice and the perturbing effects on the volcanic column caused by both the rotation of the Earth and local and global weather conditions. As shown in Fig. 5, even in the absence of such perturbations the topography of the volcano is sufficient to dramatically affect the propagation of pyroclastic flows, since Mt. Somma to the north of Vesuvius represents a significant barrier that slows down their propagations while Valle del Inferno between the cone of Vesuvius and Mt. Somma allows for an effective channeling of flows in the directions toward Pompei to the east and San Giuseppe Vesuviano and Naples to the west.

A plinian eruption produces a volcanic column that rapidly rises into the stratosphere and then distributes the ash over a wide area, and its partial and total collapses can affect the built environment around the volcano much more severely than the fall of cold ash from high rising volcanic plumes. The secondary *phoenix columns* produced on the pyroclastic flows are the result of competitions between different forces, since close to the volcanic vent the radial inertial forces dominate the vertical buoyancy forces, whereas farther away from the vent the opposite is true. The buoyancy forces can lift the material from the flows and transport it into the colder regions of the atmosphere where it cools and falls as ash to the ground at low temperatures. Simulations of complete eruptions are, therefore, necessary to understand the detailed behavior of these flows, because they propagate in waves and each wave can reach different distance from the vent [1].

The ability to simulate volcanic eruptions from the beginning to the end is crucial for reliably assessing the hazards from ash fall, pyroclastic flows, and lahars, since this provides the forces, moments, temperatures, and concentrations of materials at different times and locations in the environments surrounding the volcanos. This data, together with possible displacements, velocities, and accelerations of ground motions of built environments in the proximities of volcanoes, provide the necessary information for building the appropriate structures that can resist and protect the populations from eruption products. Building resilient and sustainable habitats around volcanoes requires integrations of several fields of science and collaboration of populations exposed to the hazards, which is, however, difficult to achieve in practice and in particular for large cities where there are many actors with different interests [9, 17].

5. Conclusions

A reliable Global Volcanic Simulator is a very useful tool for assessing multiple hazards from volcanoes, and in particular those in the Neapolitan area where there are several million people exposed to these hazards. If we want to build or make the existing cities close to volcanoes resilient and sustainable we must be able to produce reliable eruption scenarios for use in the urban planning of the territories, so that the populations can cohabit with the volcanoes in security and prosperity. The simulator discussed in this paper incorporates chemical and physical models of different parts of the volcano, and the current version can simulate magma chamber evolution, opening of volcanic conduits, steady-state and transient magma ascent in volcanic conduits with and without magma fragmentation, interaction of water in underground aquifers with magma in conduits, and dispersion of erupted materials in the atmosphere. Each model of the simulator is first verified and validated before being integrated with other models, and this integration is accomplished by a scheduler which ensures that the boundary conditions for all characteristic parts of the simulator work as effectively as possible, depending on the available computational resources. The current and future work on Global Volcanic Simulator is directed at both improving the current models, implementation of new models for simulating complete eruptions, and definitions of exclusion nuclei, resilience belts, and sustainability areas for the Neapolitan volcanoes.

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Robustness and Progressive Collapse of New and Existing City Structures

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Abstract. Natural and man-made disasters are responsible for extensive human and socio-economic losses. Robustness is the capacity of a structure to avoid a major collapse due to minor damage from accidental actions. The lack of robustness gives rise to the progressive collapse mechanism, which is the failure of either a large percentage or the entire construction originated by the propagation of local damages. In the present paper the robustness assessment of new and existing steel structures within city centres is performed through specific applications with the aim to avoid progressive (or disproportionate) collapses. First, a general synopsis on the methodologies used for evaluating the structural robustness under earthquake is given. This is followed with a new deterministic method, framed within the Performance Based Design, to calculate the robustness indices corresponding to specified targets, providing a multi-level performance matrix. Finally, this methodology has been applied to two study cases, namely two new steel framed structures and an existing multi-story steel building.

Keywords: Robustness, progressive collapse, steel structures, moment resisting frames, performance-based design, pushover analysis, performance matrix

1. Introduction

In the recent decades, natural and man-made disasters are known to be the source of extensive human and socio-economic losses, particularly in modern societies and city structures. In this framework, the concepts of robustness and resilience of urban areas have gathered the attention of the scientific research world.

In the Structural Engineering field, the robustness is the capacity of a structure to avoid a major collapse due to minor damages triggered by accidental or malicious actions, or to show insensitivity to local failure. More specifically, a robust structure is able to redistribute loads when a load-bearing member suffers a loss of strength or stiffness, but exhibits a ductile, rather than brittle, failure mode. A robust structure is not over-designed, but it has the ability to resist damage through global structural behaviour and failure modes. In this case, the localised structural failure can be miti-

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gated by the capability of the structure to redistribute the load elsewhere. Eurocode 1 Part 1-7 [1] defines robustness as "the ability of a structure to withstand events like fire, explosions, impact or the consequences of human error without being damaged to an extent disproportionate to the original cause", thus linking explicitly this concept to the disproportionate collapse one.

The progressive collapse mechanism is the failure of either a large percentage or the entire construction, which is originated by the propagation of local damages so that the structural system cannot withstand the main structural loads. Vehicular collision, accidental overload, aircraft impact, design/construction error, fire, gas explosions, bomb explosions, hazardous materials and so on are possible abnormal loads triggering collapse similar to that of a row of dominos. The term progressive refers to the type of the structural collapse behaviour. The progressive collapse can be propagated horizontally, starting from a structural bay to those adjacent to it, or vertically, when the collapse of a column interests the story above it, leading to the so-called "pancake" collapse. A disproportionate collapse is that judged by the observer to be incongruent from the initial damage cause. This is merely a judgement made on observations of the damage consequences resulting from the originating events and does not describe the structural behaviour features. For example, a collapse may be progressive but not necessarily disproportionate, if it is blocked after it develops through a number of structural bays. On the other hand, a collapse may be disproportionate but not necessarily progressive if, for example, the collapse is limited in its extents to a single structural bay, but the structural bays are large.

New and existing city structures can be exposed during their life to extreme actions deriving from either artificial or natural risks not considered in the design phase. Such risks are earthquakes in non-seismic areas, unforeseeable fires, exceptional storms, heavy snow, explosions, terrorist attacks and so on. The capacity of structures to resist these actions is identified as "robustness". In particular, the most common meaning of robustness in the field of Structural Engineering is the capacity of structures not to suffer damage disproportional to the exposure generating the starting damage. This definition, incorporated within several codes, such as the recent Italian technical standards [2, 3], is not accomplished by effective criteria either in measuring robustness or determining whether the structure robustness level is acceptable or not. Therefore, the first step of the research within this field is to establish a reliable methodology for evaluating the performance of structures subjected to exceptional actions. For this purpose, a new procedure for robustness assessment has been conceived and applied first to new steel structures in a semi-probabilistic manner, and then deterministically to evaluate the seismic resistance of an existing gravity-load designed steel building. Such a method, framed within a performance-based approach, allows for the achievement of direct and indirect damages of buildings starting from their capacity curves evaluated through the pushover analyses. Finally, the robustness matrices have been determined for each analysed structure according to the predetermined performance targets.

2. Robustness and Progressive Collapse

Robustness is one of the main prerequisites of a structure to survive without failure over a time period [4]. In general, no specific definition of robustness exists. In the past decades the robustness of structures was evaluated under two different points of view, namely under exceptional and normally random conditions. According to the first perspective, a structure can be declared as robust when either collapse is not sudden or the resistance is not substantially lost although the deformations exceed the serviceability level. Instead, from the second perspective, a robust system can withstand occasional or frequent changes of environmental conditions without noticeable effects on its serviceability limit state behaviour.

The robustness assessment is of increasing interest in the structural design field. A robust structural design is made by solving an optimization problem. Commonly, all variable parameters are considered as random quantities, used to evaluate structural robustness in probabilistic way. The corresponding optimization problem for achieving robustness generally aims at achieving both an optimum mean and a minimum variance of the structural response with respect to input variations.

The robustness of structures is accomplished when their response is proportioned to different types of applied actions, i.e. loads exceeding the design ones, accidental loads or damage to members. In particular, the structural robustness can be achieved by [5]: (a) either preventing the action or increasing the occurrence probability; (b) protecting the building; (c) reducing the sensitivity to disproportionate collapse. This last case must be considered in the design process and designers must certify that the removal of any structural building component does not produce a total collapse. Furthermore, any resulting local damage must be confined within the stories above and below that interested by the component removal.

When civil structures are not robust, the final failure state is disproportionately greater than that originating the collapse. So, the so-called progressive collapse, defined as “the spread of an initial local failure from element to element resulting, eventually, in the collapse of an entire structure or a disproportionately large part of it” [6], is attained. Thus, in structures susceptible to progressive collapse, small events can have catastrophic consequences. According to this, the degree of “progressivity” of a collapse can be defined as the collapsed volume (or area) over the same quantity directly destroyed by the event.

The progressive collapse concept can be illustrated by the famous failure of the Ronan Point building in London in 1968. This precast concrete bearing walls building, 22 stories high, suffered a gas explosion in a corner at the 18^{th} floor, which produced, by means of a chain reaction, the collapse of the corner bay of the building from top to bottom (Fig. 1a).

More recently, the terrorist attacks on World Trade Center buildings in New York on September 11, 2001 represents a clear example of progressive collapse. A Boeing 767 crashed into the tower at high speed, causing structural damage near the impact point and producing an intense fire within the building (Fig. 1b). As a result of the combination of impact damages and fire damages, both buildings collapsed with a progressive failure due to the weight and impact of the collapsing upper parts of the towers.

(a) (b)

Figure 1. Structural progressive collapses: the cases of the Ronan Point building in London (1968) (a), and of the World Trade Center towers in New York (2011) (b).

In general, three alternative approaches to reduce the susceptibility of structures to disproportionate collapse can be distinguished:

- Redundancy or alternate load paths, so that if one component fails, alternative distribution of actions are available and a general collapse does not occur.
- Local resistance, which reduces susceptibility to progressive collapse by providing critical components offering additional resistance.
- Interconnection or continuity, which is a tool of improving redundancy or local resistance or both through a high constraint level among structural members.

The emphasis on redundancy over all alternatives in some recent codes and standards may not lead to buildings that are less susceptible to disproportionate collapse as a result of deliberate attacks.

3. Robustness Assessment Methodologies

3.1 Probabilistic method

The most effective probabilistic method for robustness assessment is based on the work developed by the Joint Committee on Structural Safety [7], represented by the event tree shown in Fig. 2.

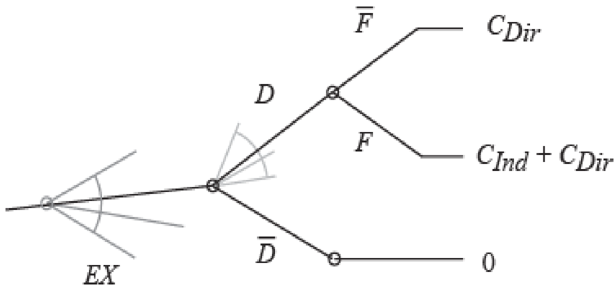


Figure 2. Robustness quantification through an event tree.

First, modelling of exposures (*EX*) is done, where they have the capacity to damage structural parts [8]. They include extreme values of design loads, deterioration processes, and also human errors during the whole structure life. When exposures occur, the structural system components can be either undamaged ($\overline{D}$) or damaged (D) according to several damage states which can lead to the failure (F) or not ($\overline{F}$). Consequences are classified as either direct (C_{Dir}) or indirect (C_{Ind}). The first ones are represented from damage to structural system parts. The second ones are due to either loss or failure of the system functionality and can be attributed to the lack of robustness. Consequences are generally represented as inconveniences to system users, injuries, fatalities, and/or monetary costs. In order to make a comparison among these effects, they can be combined into a scalar measure of consequences, often called utility (or disutility in case of negative consequences).

With the event tree defined in Fig. 2, it is possible to compute the system risk due to each possible event scenario. This is done by multiplying the consequence of each scenario by its probability of occurrence and then integrating over all of the random variables in the event tree. The risk corresponding to each branch is:

$$R_{Dir} = \int_x \int_y C_{Dir} P\left(\overline{F} \mid D = y\right) P\left(D = y \mid EX_{BD} = x\right) P\left(EX_{BD} = x\right) dydx \tag{1}$$

$$R_{Ind} = \int_x \int_y C_{Ind} P\left(F \mid D = y\right) P\left(D = y \mid EX_{BD} = x\right) P\left(EX_{BD} = x\right) dydx \tag{2}$$

A system is considered to be robust if the indirect risks do not contribute significantly to the total risk. Consequently, the following index of robustness I_{Rob} is proposed; it measures the fraction of total risk resulting from direct consequences:

$$I_{Rob} = \frac{R_{Dir}}{R_{Dir} + R_{Ind}} \tag{3}$$

The index can assume values between zero and one depending upon the source of risk. If the system is completely robust and there are no risks due to indirect consequences, then $I_{\text{Rob}} = 1$. On the other hand, if all risks are due to indirect consequences, then $I_{\text{Rob}} = 0$.

3.2 Deterministic Method

A deterministic procedure to define the structure robustness is needed aiming at evaluating how much this reserve should be exploited in order to preserve the structural integrity [9].

With reference to an ideal action system *A*, producing a global damage pattern *D* on the structure represented by means of the resistance *R* - damage *D* curve, known as Structural Performance Curve (SPC), the robustness index I_r can be defined. It is calculated as the ratio between the maximum "direct" energy absorbed by the structural system, which is associated to the direct damage, and the total energy, associated to direct and indirect damages, absorbed by the structure as a consequence of being exposed to a given action (Fig. 3).

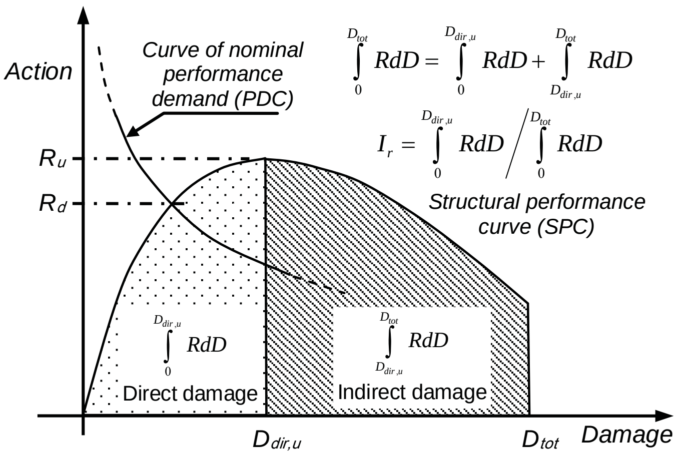


Figure 3. Definition of direct and indirect damages.

The following relationship is given:

$$I_r = \frac{\int_0^{D_{dir,u}} RdD}{\int_0^{D_{tot}} RdD} \tag{4}$$

For the purposes of practical calculations, eq. (4) can be also computed in approximate way as:

$$I_r = \frac{\int_0^{D_{dir,u}} RdD}{\int_0^{D_{tot}} RdD} \cong \gamma \frac{D_{dir,u}}{D_{tot}} \frac{R_u}{R_d} \tag{5}$$

where R_u and R_d are the structural ultimate resistance and the design resistance for a given nominal curve of performance demand (PDC), respectively (Fig. 3), and γ, ranging in most cases from 1.1 to 1.3, is a coefficient depending on the shape of the SPC.

If one observes that the ratio $D_{dir,u}/D_{tot}$ represents the ratio between the maximum direct damage tolerated by the structure ($D_{dir,u}$) and the actual damage suffered due to the loading event (D_{tot}), then a structural integrity index can be conventionally defined as $I_{si} = D_{dir,u}/D_{tot}$. Hence:

$$I_r \cong \gamma \frac{D_{dir,u}}{D_{tot}} \frac{R_u}{R_d} = \gamma I_{si} \frac{R_u}{R_d} \tag{6}$$

For a given PDC, three circumstances are possible:

(1) The SPC is below the PDC, which means $I_r < 1$ and $I_{si} < 1$; in this case $D_{tot} = D_{dir,u} + D_{ind}$, and hence:

$$\int_0^{D_{tot}} RdD = \int_0^{D_{dir,u}} RdD + \int_{D_{dir,u}}^{D_{tot}} RdD \tag{7}$$

(2) The SPC meets the PDC so as $D_{dir,u} = D_{tot}$, which means $I_r = I_{si} = 1$; in this case at the intersection of the nominal PDC with the SPC $dA/dD = 0$, hence:

$$\int_0^{D_{tot}} RdD = \int_0^{D_{dir,u}} RdD \tag{8}$$

(3) The SPC is such that $D_{dir,u} > D_{tot}$, which means $I_r > 1$ and $I_{si} > 1$; in this case $D_{tot} = D_{dir,d}$ and at the intersection of the nominal PDC with the SPC $dA/dD > 0$, hence:

$$\int_0^{D_{tot}} RdD = \int_0^{D_{dir,d}} RdD \tag{9}$$

The circumstance $I_r > 1$ allows for possible changes of the PDC due to unexpected or accidental actions to be tolerated with a lower risk to undergo indirect damage.

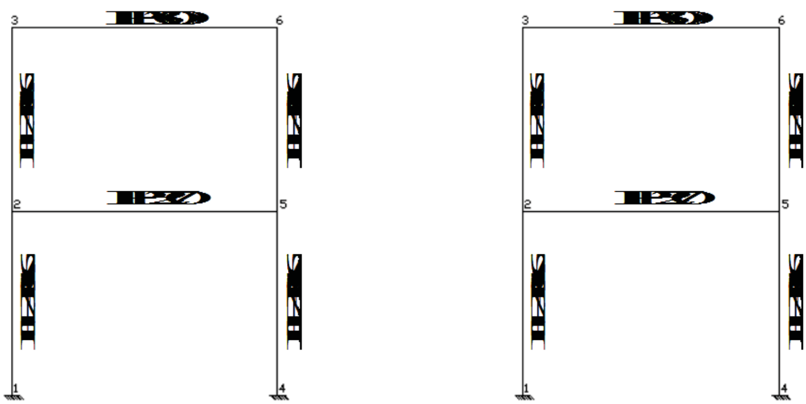
If the commonly accepted performance levels for construction design are assumed, an ideal concept of Robustness-Based Design (RBD) is defined. In this case, the structural design is carried out according to predetermined levels of robustness, each of them corresponding to a value of the robustness index I_r. As a result, a typical multi-level performance matrix is implemented (Table 1).

Table 1. Performance matrix accounting for robustness levels.

	Nominal design capacity			Robustness capacity			
PERFORMANCE LEVEL	**FO**	**O**	**LS**	**R1**	**R2**	**…**	**CP**
Frequent event	×	Maximum objective					
Occasional event	■	×	Intermediate objective				
Rare event	▲	■	×	Minimum objective			
Very rare or catastrophic event		▲	■	×	×	×	×

4. Analysis of New Structures

Two different types of new steel structures [10, 11] have been analysed aiming at evaluating their robustness under exceptional earthquakes having a return period of 2475 years and an exceedance probability of 2% [2]. These structures have been located in the historical centre of Naples on a soil type B. They are composed of frames made of S275JR steel profiles spaced 5 m apart from each other, and subjected to permanent and accidental loads of 5.15 kNm^{-2} and 2 kNm^{-2}, respectively. The first structure is a plane frame with a single bay developed on two levels with inter-storey height of 3.5 m. The second plane frame has three levels (H=3.00 m at the 1st and 2nd floors and H=3.50 m at the 3rd floor) with three bays. Both structures have been designed according to both the old [12] and the new [2] Italian seismic codes. In Fig. 4 the steel profiles obtained from the design phases deriving from application of used codes are provided [13].



(a) (b)

Fig. 4. 2-storeys frame designed according to M. D. 96 (a), and M. D. 08 (b).

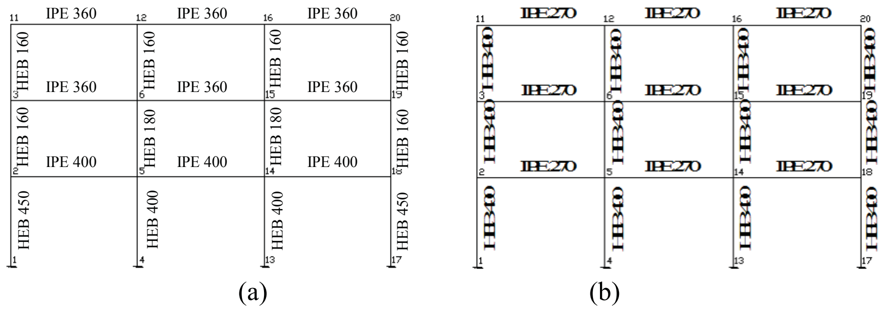


Figure 5. 3-storeys frame designed according to M. D. 96 (a) and M. D. 08 (b).

For these structures, the randomness of both materials (variation coefficients *COV* of 3%-5%-7%) and vertical loads (variation coefficients *COV* of 10%-20%-30%) has been considered in the framework of a semi-probabilistic analysis approach. Therefore, the combinations of the above *COVs* lead to nine analysis cases, which have been performed on each of the four examined structures.

The robustness assessment under earthquakes has been performed by means of pushover analyses on the FEM models of the inspected structures, which have been implemented by means of the SAP2000 non-linear analysis program [14]. For each of the nine analysis cases, two different lateral load distributions (constant and inverted triangular types) have been considered, leading globally towards seventy-two pushover curves (eighteen curves for each frame). Such curves have been transformed into the Acceleration-Displacement Response Spectra (ADRS) plane in order to be compared with the demand spectrum given by the considered exceptional earthquake. Therefore, according to eq. (4) and Fig. 3, the robustness index has been determined for each studied structure, leading to the mean values of Table 2.

Table 2. Mean robustness indices of the study frames.

Frame	M. D. 96	M. D. 08
2-storeys	0.34	4.21
3-storeys	0.40	3.55

The results show that the steel frames designed according to the old prescriptions [12] are not robust, since they have a soft-storey mechanism at the 2^{nd} floor under lateral forces. On the other hand, the frames designed according to the new seismic provisions [2, 3] are extremely robust, because they show a global collapse mechanism, while the new code provides a safer design of new steel structures. In addition, by considering the characteristic curves of examined structures, intended as the ones having the probability of being minored of 5%, six different target displacements can be identified as a function of both the yielding Sd_y and the ultimate Sd_u spectral displacements of these curves. Such targets are called as Fully Operational (FO=1/3 Sd_y), Operational (O = 2/3 Sd_y), Life Safety (LS= Sd_y), Robustness 1 ($R1$ = 1/3 Sd_u +2/3 Sd_y), Robustness 2 ($R2$ = 2/3 Sd_u +1/3 Sd_y), and Prevention of Collapse (PC = Sd_u = displacement corresponding to the maximum acceleration). For the sake of example, the characteristic pushover curve of the two-storeys frame designed according to M.D. 08, together with the above targets, is reported in Fig. 6.

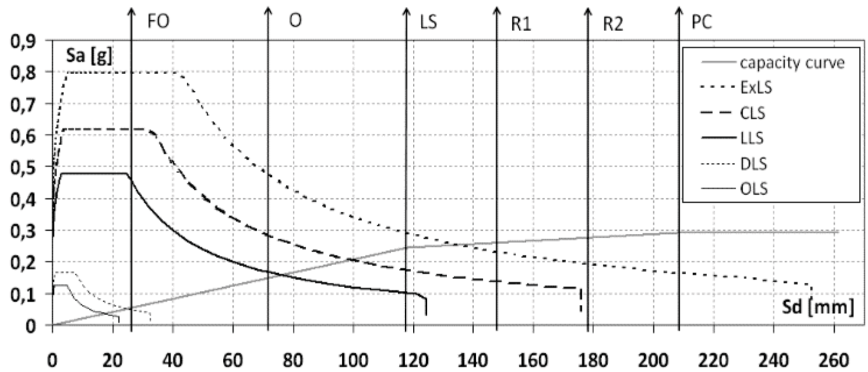


Figure 6. Characteristic pushover curve of the 2-storeys frame designed according to M. D. 08.

Therefore, considering the five different seismic demand spectra contemplated [2, 3] and represented by the four ordinary earthquakes (Damage Limit State – DLS; Operational Limit State – OLS; Life Safety Limit State – LLS; Collapse Limit State – CLS) plus the exceptional one (Exceptional Limit State - ExLS) having the probability of exceedance of 2% associated to the above target displacements, a robustness matrix can be built for each frame. For the sake of representation, such matrices are reported for the 2-storeys frame only (Tables 3 and 4).

It appears that the old Italian code [12] provides a very low level of robustness, whose indices are quite always below 1. Table 5 shows the ratio between the index values evaluated for the 2-storeys frame designed according to M. D. 08 and those achieved on the same structure projected by M. D. 96. It can be observed that in case of PC level, under the exceptional earthquake, the structure designed according to M.D. 08 has a robustness index 11 times greater than that designed according to M. D. 96.

Table 3. Robustness matrix of the 2-story frame designed according to M. D. 96.

Limit state	FO	O	LS	R1	R2	PC
OLS	0.46					
DLS	0.21	1.14				
LLS	0.02	0.11	0.27			
CLS		0.07	0.17	0.21		
ExLS			0.11	0.14	0.16	0.19

Table 4. Robustness matrix of the 2-story frame designed according to M.D. 08.

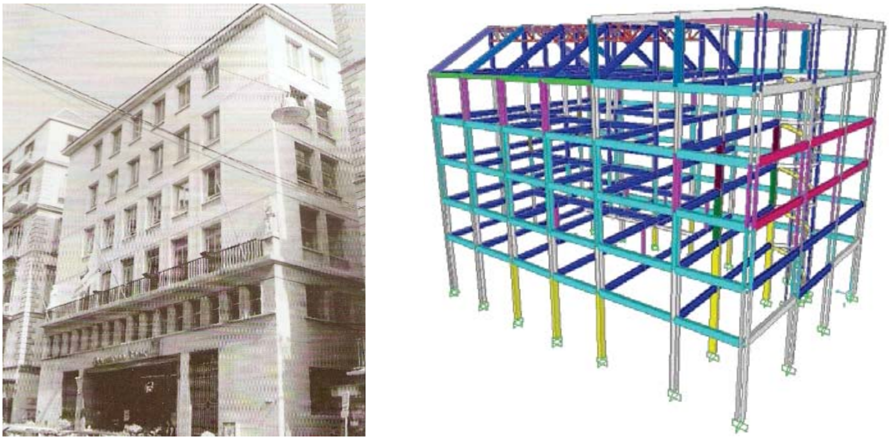
Limit state	FO	O	LS	R1	R2	PC
OLS	3.01					
DLS	1.47	9.17				
LLS	0.16	0.97	2.48			
CLS		0.57	1.46	2.20		
ExLS			0.80	1.20	1.63	2.09

Table 5. Robustness indices ratios between the 2-storeys frame designed according to M.D. 08 and the one designed according to M. D. 96.

Limit state	FO	O	LS	R1	R2	PC
OLS	6.54					
DLS	7.00	8.04				
LLS	8.00	8.82	9.18			
CLS		8.14	8.59	10.48		
ExLS			7.27	8.57	10.19	11.00

5. Analysis of an Existing Building

The existing building under study is the Deutsche Bank in S. Brigida street in Naples. It represents the first suspended steel structure built in Italy up to 1950s (Fig. 7a). The building is composed of seven transverse frames with welded joints and external columns supporting an upper truss. Two tie-beams are suspended from the truss and sustain the intermediate floors, so as to create a large area free from columns at the ground floor. Columns are made of two coupled channels with battened plates, whilst beams are made of coupled double T and double C profiles. The corrosion of structural elements, particularly at the roof level, as well as the lack of penetration in all the welds, represented the main dangers for the suspended building. Therefore, corrosion was eliminated and three systems were adopted for consolidation operations by the designers [15]. The goal of the current analysis was to evaluate the robustness towards earthquake of this building, designed to resist gravity loads only, after consolidation interventions. To this purpose, a refined FEM model has been set up by means of the SAP2000 analysis software [14] (Fig.7b).



(a) (b)

Figure 7. Real view (a) and 3D FEM model (b) of the Deutsche Bank building in Naples.

Loads and materials have been considered according to the technical report developed at the construction time [15]. Pushover analyses have been carried out in directions *x* and *y* according to the two lateral load distributions foreseen by the actual standard. Then, in the same way of the previous cases, different targets have been identified on the pushover curves (Fig. 8) and considering five earthquake spectra, the robustness matrices in the two plane directions have been determined (Tables 6 and 7).

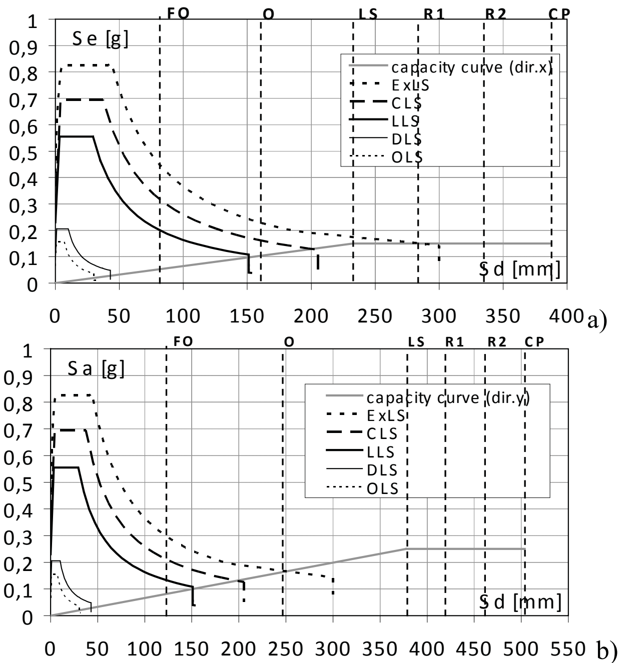


Figure 8. Pushover curve of the Deutsche Bank building in directions *x* (a) and *y* (b).

Table 6. Robustness matrix of the Deutsche Bank building (direction *x*).

Limit state	FO	O	LS	R1	R2	PC
OLS	6.70					
DLS	3.30	13.30				
LLS	0.27	1.07	2.33			
CLS		0.62	1.36	1.70		
ExLS			0.81	1.02	1.19	1.36

Table 7. Robustness matrix of the Deutsche Bank building (direction *y*).

Limit state	FO	O	LS	R1	R2	PC
OLS	14.00					
DLS	6.98	31.89				
LLS	0.56	2.56	6.30			
CLS		1.50	3.69	4.10		
ExLS			2.21	2.45	2.69	2.95

From the above tables it is apparent that also in the weak direction (*x*), intermediate objective are fulfilled with robustness levels greater than one. As a result, even if the building was not designed to support earthquakes, the consolidation interventions were effective in providing the structure with both resistance and robustness, the latter also under exceptional loading conditions.

6. Concluding Remarks

The application of the proposed method for robustness evaluation of steel buildings of city centres has been illustrated by means of some case studies, and framed within the Performance Based Design this method has been applied to both new and existing structures, aimed at estimating the robustness indices corresponding to specified targets and providing a multi-level performance matrix.

The analyses showed that the new structures, when designed according to the new Italian seismic code for exceptional earthquake actions, provide high indices of robustness and that their behaviour is characterized by a global collapse mechanism. On the contrary, the structures designed according to the old code have shown a deficient robustness level and their behaviour is characterized by a soft-story mechanism at the second floor.

Finally, an evaluated existing steel building, even if it was designed to resist gravity loads only, exhibits an acceptable robustness level even under the earthquake actions, thanks to the performed consolidation interventions.

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Parametric Estimation of Seismic Impact Scenarios and Expected Losses at Urban Scale

Case Study of Historical Center of Sant'Antimo in Napoli (Italy)

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Abstract. The study reported in this work aimed at analyzing a suburban sector of the historical center of Sant'Antimo, located in the province of Naples, in order to assess seismic vulnerability of the masonry building compounds. The conducted vulnerability analysis integrates vulnerability indexes with a GIS tool for the spatial identification of the most vulnerable structural units. Furthermore, the possible damage scenarios that are dependent on earthquake magnitudes and epicentral distances have been adopted for the quantification of losses in terms of collapsed and unusable buildings and human casualties.

Keywords: Masonry aggregates, vulnerability assessment, damage scenarios, loss estimation, GIS

1. Introduction

A large-scale seismic risk analysis is useful for assessing the susceptibility of a sample of buildings exceeding, in a specific period of time, a certain seismic event of an assigned intensity. Seismic risk can be understood as the product of three factors: Exposure, vulnerability, and hazard. The proposed method uses the seismic attenuation law [1] based on a parametric approach that estimates the effects of the seismic impact in terms of spatial damage distributions on a built area of Sant'Antimo, a town in the province of Naples.

2. Structural Characterization of Sant'Antimo's Subsector

Sant'Antimo, an Italian town with 33,905 inhabitants, is situated 16 km from the historical city of Naples [2] and the subsector studied is composed of 42 buildings erected in aggregate. According to the Building Typology Matrix (BTM) [3], two different

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typological classes can be distinguished in this subsector: Class M3.3 for masonry structures with composite steel and masonry slabs (in 36% of the cases) and class M3.4 for masonry structures with reinforced concrete floors and roof (in 64% of the cases) (Fig. 1).

(a) (b)

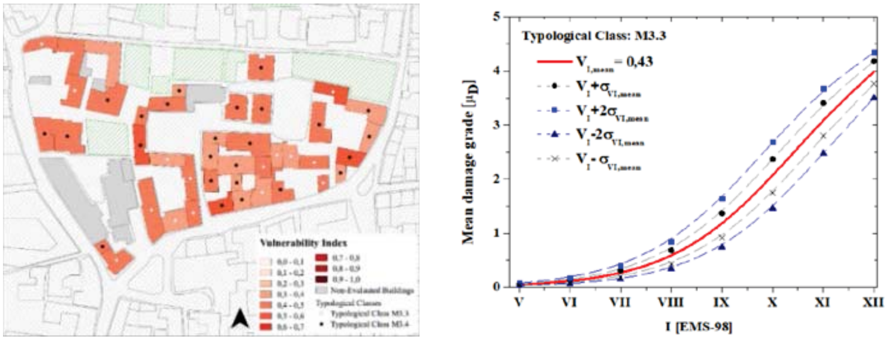
Figure 1. (a) Numbering classification. (b) Typological characterization of the subsector masonry building compounds.

3. Seismic Vulnerability Assessment

A quick seismic evaluation procedure for masonry aggregates has been proposed for the study area [4,5]. Conceptually, the methodology is based on the calculation for each structural unit (S.U.) of a vulnerability index, I_v, as the weighted sum of scores multiplied by the weights related to 15 parameters. Theses parameters are distributed into 4 classes (A, B, C, D) with each class having a score, S_i, with growing vulnerability. Each parameter is associated with a weight, W_i, that can range from 0.25 for the less important parameter to a maximum of 1.20 for the most important one. The vulnerability distribution on the study area is illustrated in Fig. 2a, whereas the mean vulnerability curve associated to the M3.3 typological class is shown in Fig. 2b.

4. Parametric Damage Scenarios and Loss Estimation

The seismic damage severity is addressed in this work on the basis of appropriate analyses, performed according to a proposed seismic attenuation law [6] that estimates the damage suffered by the earthquakes with different magnitudes and epicentral distances. The correlations obtained between moment magnitude, M_w, and macroseismic intensity, $I_{EMS\text{-}98}$[7], for different epicentral distances are summarized in Table 1.



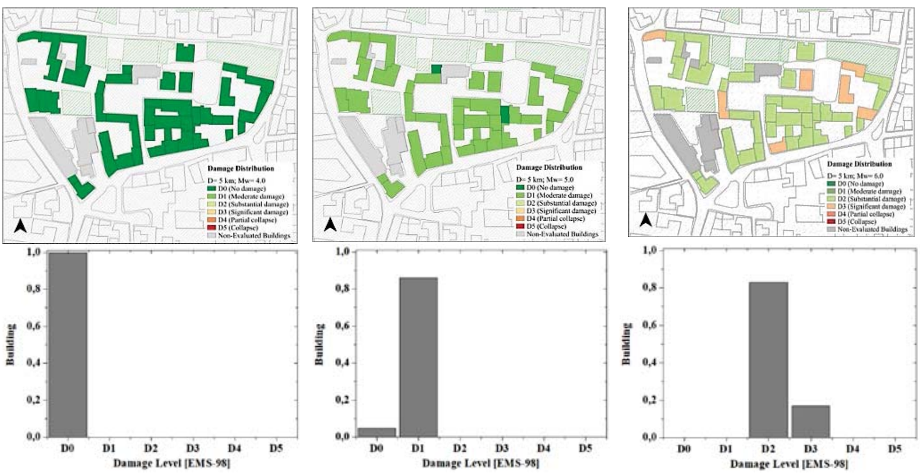
(a) (b)

Figure 2. (a) Spatial vulnerability distribution map on the investigated area. (b) Mean vulnerability curve for the M3.3 typological class.

Table 1. Correlation between moment magnitude, M_w, and macroseismic intensities, I_{EMS-98}, for different epicentral distances.

Epicentral distance, D [km]	M_w=4.0	M_w=5.0	M_w=6.0
	Macroseismic Intensity, I_{EMS-98}		
5	VII	VIII	X
15	V	VII	VIII
30	III	V	VII

On the basis of factors in the above table, the damage parameter, μ_D, representative of the damage levels of the EMS-98 scale, was estimated to produce nine damage maps and as an example the most severe damage cases are shown in Fig. 3.



D= 5 km; M_w= 4.0 D= 5 km; M_w= 5.0 D= 5 km; M_w= 6.0

Figure 3. Some seismic scenarios and the corresponding damage distributions.

From this figure is apparent that for a fixed distance from the seismogenic source the damage level depends significantly on the moment magnitude of the source and that this damage increases with the magnitude.

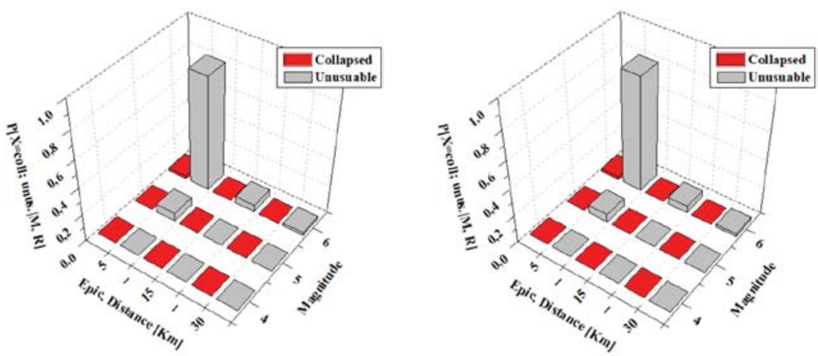
The consequences of the seismic events in terms of collapse and unusable buildings are evaluated in this work following the empirical correlations proposed for the Italian territory [8]. As shown in Table 2, the probability of unusable and collapsed buildings of studied buildings tends to decrease proportionally with the decrease of the moment magnitude and the increase of the epicentral distance. Shown in Table 3 are the estimated casualty rates (number of deaths and severely injured) and homelessness [9,10] and in Fig. 4 the graphical results.

Table 2. Estimation of collapsed and unusable buildings for the study area.

D [km]	Number of collapsed and unusable buildings					
	M_w=4.0		M_w=5.0		M_w=6.0	
	Collapsed	Unusable	Collapsed	Unusable	Collapsed	Unusable
5	-	-	-	2 (5%)	1 (2%)	35 (83%)
15	-	-	-	-	-	2 (5%)
30	-	-	-	-	-	1 (2%)

Table 3. Estimation of casualties and homeless for different combinations of moment magnitude and epicentral distances.

D [km]	Number of casualties and homeless people					
	M_w=4.0		M_w=5.0		M_w=6.0	
	Death	Homeless	Death	Homeless	Death	Homeless
5	-	-	-	8 (5%)	3 (2%)	127 (83%)
15	-	-	-	-	-	8 (5%)
30	-	-	-	-	-	3 (2%)



(a) (b)

Fig. 4. Loss scenarios: (a) Collapsed and unusable buildings. (b) Casualties rates.

5. Conclusions

In the paper a seismic damage forecast model has been proposed on a built area of Sant'Antimo, a town in the district of Naples. By defining a set of magnitudes (M_w) and epicentral distances (D), it has been possible to estimate the influence of these parameters on the inspected urban habitat and to estimate the associated damages caused by different earthquakes. The results obtained show that, as expected, for distances very close to the site of interest, the damage increases with increasing seismic intensity. In fact, for D=5 Km and M_w= 6, the most severe scenario (83% of unusable buildings, 2% of collapsed building) has been identified. In terms of human casualties and homeless the estimation suggests 3 deaths and 127 homeless. The study shows high seismic vulnerability of the study area and represents a useful tool for implementing emergency management predictive plans.

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Knowledge Levels Influence on the Retrofitting Cost Assessment of a School Building

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Abstract. Post-earthquake investigation and research on seismic risk analysis have shown that existing non-ductile reinforced concrete (RC) frame structures are much more susceptible to damage and collapse than the modern code-conforming ones. The assessment and retrofit of these non-ductile RC structures, built without adequate seismic detailing requirements, is a crucial research theme for engineers dealing with cost evaluation and characterization of retrofitting operations. In the assessment for an existing building many parameters can influence the cost, such as the knowledge level achieved through specific in-situ tests campaigns. The modification of the material properties values on the basis of proper confidence factors can have a large impact in the needed retrofitting operations and, therefore, in the resulting costs, and through the case study of an old RC school building located in the Avellino province it is shown how the influence of different knowledge levels can affect these parameters. A 3D model of the building is implemented by using the commercial software for structural calculation and a seismic vulnerability analysis is carried out on the building highlighting the deficiencies of both static and seismic loading conditions. Retrofitting operations are, therefore, applied in order to achieve a certain threshold of the seismic safety conditions for the inspected school building. The retrofit structural costs related to the in-elevation structure of the building (excluding roof and foundations) are calculated for each desired knowledge level and compared, considering also different budgets related to the diverse number of in-situ tests carried out in the three analysis cases. The results show that the costs associated with higher knowledge levels of retrofit operations produce higher seismic safety thresholds.

Keywords: Reinforced concrete, building retrofit, seismic safety.

1. Introduction

A school building located in Avellino province (Italy) is used as a case study to show the influence of different knowledge levels on cost assessment for a school building seismic retrofit. A 3D model of the building has been produced using the commercial software for structural calculation CDS 2018 [1] and an analysis of seismic vulnerability carried out on the building has highlighted the deficiencies in both static and seismic load conditions. Retrofitting operations [2,3] are applied in order to

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achieve a certain threshold of the seismic safety conditions for the inspected school building. First, the retrofit structural costs related to the in elevation structure of the building (excluding roof and foundations) are calculated for each desired knowledge and then they are compared to each other. Finally, the comparison among total intervention costs related to the three knowledge levels is performed considering different budgets related to the diverse number of in-situ tests carried out in the three analysis cases. The costs of in-situ tests reduce the costs of retrofit operations needed to achieve a certain threshold of seismic safety.

2. Seismic Assessment

The building complex that hosts the primary school of Pratola Serra (district of Avellino, Italy) was built in 1960s in various phases with a reinforced concrete frame structure and without adequate seismic detailing requirements. The building consists of one level below the ground, two levels above the ground and the roof. The school building area is around 980 m^2 at the 1st and 2nd floors, while it is around 810 m^2 at the 3rd and 4th floors. The choice of the number of tests on concrete and steel specimens through destructive and non-destructive tests is one of the most challenging and discussed topic in the codes all around the world and the in-situ tests are the first step in the seismic assessment. The Italian codes NTC 2008 [4] and NTC 2018 [5] and the European code EN 1998-3-Eurocode 8 part 3 [6] allow the achievement one of three knowledge levels as a function of both the information acquired on the building structural configuration and the number of tests on concrete and steel specimens to be performed. Depending on the knowledge level attained, a proper confidence factor (CF) should be applied to material properties values in order to obtain a proper design. In this context, it is worth noticing that the provisions of the current Italian code [4] are formally equivalent to those of the old codes [5] and its explanatory standard Circolare 2009 [7]. We report herein the results pertaining to the achievement of the knowledge level 2 (KL2), in order to use the static non-linear analysis as the vulnerability assessment procedure. In the real case study, the tests have been realized where possible and based on the specific conditions of the investigated building. Table 1 presents the cost minimization results for tests based on the default values for the case study involved.

Table 1. Minimization of costs for in-situ tests to achieve the KL2 knowledge level.

Intervention	Cost per unit (euro)	Unit per floor and total	Total cost (euro)
Concrete specimen extraction	58	(3+3+3+3)*2=24	1,397
Test on concrete specimen	171	(3+3+3+3)*2=24	4.113
Steel bar extraction	78	(3+3+3+3)*2=24	1,884
Test on steel bar	22	(3+3+3+3)*2=24	528
Ultrasonic test	50	(9+9+9+9)*2=72	3,600

Finally, it is possible to calculate the minimum total cost of the campaign of tests on the examined structure in order to achieve KL2. This cost of is equal to

11,522.00 euro. Coherently with the hypothesis of cost minimization for tests in order to achieve the predefined Knowledge Levels 1 (KL1) and 3 (KL3) are calculated. With reference to KL1, the total cost for the in-situ tests campaign is 6,882.00 euro, given 5,282.00 euro for destructive tests and 1,600.00 euro for non-destructive tests. With reference to KL3, the total cost for the in-situ tests campaign is 18,004.00 euro, given 13,204.00 euro for destructive tests and 4,800.00 euro for non-destructive tests. In the initial investigation stage and based on the material properties derived from real in-situ investigation leading towards the KL2 pushover analyses on the case study building have been done by following the indications of the older Italian seismic code [4]. The pushover curve is an essential tool for the application of the Capacity Spectrum Method [8] and allows for the determination of the building response from an earthquake spectral shape. The pushovers have been done by using both two different distributions of forces and possible eccentricities with respect to the mass centroid equal to 5% of the structure length in each direction. Figure 1a shows the pushover results in terms of base shear versus top displacement, whereas Fig. 1b shows the Life Safety limit state for the members satisfying (green) and not satisfying (red) the safety checks.

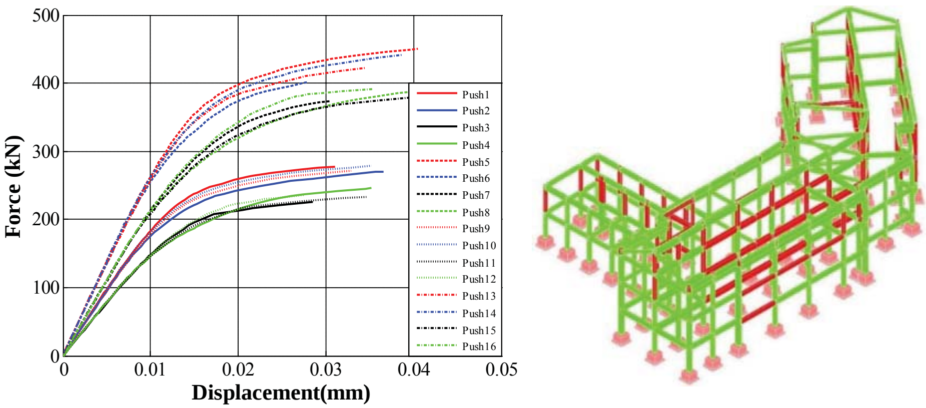

Figure 1. (a) Pushover curves for the case study building having material properties based on the KL2. (b) Member safety verifications for Life Safety limit state.

In order to determine if the building is safe or not under seismic actions, the used software (CDS 2018) [5] calculates the Seismic Risk Indicator (SRI), also called in the literature as the seismic safety factor [9], that is a very useful parameter to measure the structure vulnerability. SRI is defined as the ratio of Peak Ground Acceleration (PGA) capacity ($PGA_{LS\_Capacity}$) and PGA demand (PGA_{LS_Demand}), based on the seismic actions prescribed from the code at the Life Safety (LS) limit state of the building, i.e.

$$SRI = \frac{PGA_{LS\_Capacity}}{PGA_{LS\_Demand}} \quad (1)$$

$PGA_{LS\_Capacity}$ corresponds to the achievement of the first crisis inside the building related to LS limit state whereas PGA_{LS_Demand} is the PGA obtained from the elastic code spectrum for the specific site with reference to the LS limit state. With reference to the real case study, where KL2 is attained, the final value of the SRI is 0.26. Thus, the structure is strongly unsafe under seismic actions. Moreover, the verification associated with gravity actions is also not satisfied and it is clear that retrofit operations are needed for the inspected structure.

3. Seismic Retrofit

The main retrofit operations foreseen for the different structural members are: (a) the foundations, where a 60 cm thick slab has been realized; (b) all the unverified columns of the building have been RC jacketed with different thicknesses depending on their specific conditions; (c) all the deficient beams have been jacketed by steel members.; (d) RC shear walls have been realized along the external perimeter of the building at the first floor. After retrofit operations, analogously to what was done on the bare RC structure, pushover analyses have been carried out on the reinforced building according to the provisions of the Italian seismic code [4]. Figure 2a shows the pushover results in terms of base shear versus top displacement, whereas Fig. 2b shows the same results in terms of spectral acceleration over gravity acceleration versus top displacement. The sixteen pushover curves are grouped with the same colors already used in the analysis on the bare RC building. In this case, a SRI equal to 0.60 has been reached.

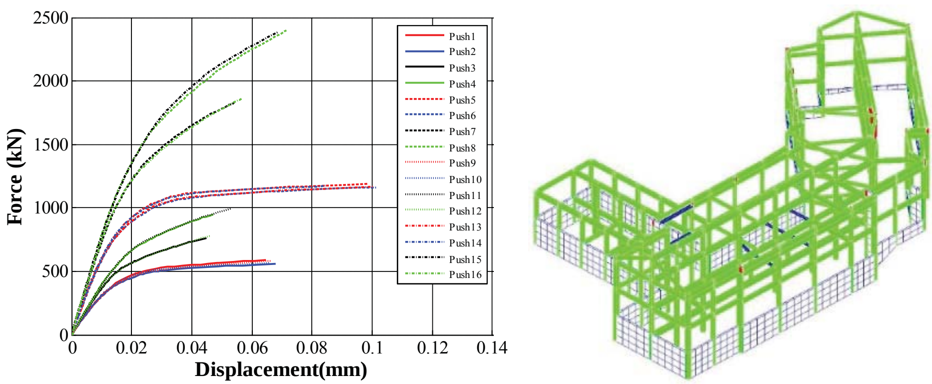

Figure 2. (a) Pushover curves for the case study building having material properties based on the KL2. (b) Member safety verifications at Life Safety limit state.

4. Cost Assessment

Here we summarize the costs associated with retrofitting interventions and related to the in-elevation structure of the building (excluding roof and foundations retrofit operations). The three main contributions to the total retrofit costs are related to columns, beams, and walls. The unit costs related to these operations must be multiplied for the quantities of each operation in order to have an overall estimation of the retrofit costs. The typologies of operations for columns, beams, and walls remain the same for all analyses of the parametric study, but the quantities depend on the selected knowledge level. Table 2 summarizes the costs related to in situ tests and retrofit operations on the basis of the attained KL.

Table 2. Evaluation of in-situ tests and retrofit operations costs on the basis of the attained knowledge level.

Knowledge level	SRI before retrofit operations	SRI after retrofit operations	In-situ tests cost (euro)	Retrofit operations costs (euro)	In-situ tests and retrofit operations costs (euro)
KL1	0.23	0.60	6,882	838,040	844,922
KL2	0.26	0.60	11,582	416,050	427.632
KL3	0.28	0.60	18,004	397,880	415.884

5. Conclusions

A school building located in the province of Avellino (Italy) was used as a case study to show the influence of different knowledge levels on the assessment of seismic retrofitting and upgrading costs. The seismic vulnerability analysis carried out on this building shows the deficiencies for both static and seismic load combinations. Therefore, retrofit interventions have been foreseen in order to achieve a level of the SRI equal to 0.60. This study has been repeated considering three different knowledge levels. The analysis results show that by spending more money on in-situ tests a saving in retrofit operations can be obtained. In particular, passing from the KL1 to KL2 knowledge level, independently from the SRI threshold chosen, there is a large cost saving, and by passing from KL2 to KL3 there is a small difference in costs.

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Life Cycle Assessment: A Case Study on the Environmental Comparison Between Steel and Glued Laminated Timber Structures

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Abstract. From the environmental point of view, more and more importance is devoted to the control of building products and in this framework the Life Cycle Assessment (LCA) is a reliable and widespread analysis method. We used this method to evaluate the impact on the environment and ecosystem of a given structure with assigned dimensions and made of either steel or glued laminated timber. First, the design of two structures was conducted according to the provisions of the new technical Italian code (NTC2018), and followed with the Impact 2002+ method used to assess the environmental impact of the designed structures. This analysis procedure takes into account fourteen impact categories, framed within environment, eco-systems and human resources, and related to four separate categories of damage. From the results obtained it is concluded that in the categories Human health and Ecosystem quality glued laminated timber is the most striking material, given the presence of dust or the fallout resulting from a progressive deforestation. On the contrary, steel is the most burdensome material in the categories Climate change and Resources, considering the heavy costs in terms of emissions and energy required, from the extraction of minerals to the formation of finished products.

Keywords: LCA, steel, glued laminated timber, environmental structure

1. Environmental and Structural Issues of the Case Study

The building under study was a residential structure of two floors (ground, and first) and having plan dimensions of 10x25 m^2 with the total height of the building from the foundations of 8 m. The building structure is a spatial frame with five bays in direction X and two bays in direction Y, and all having the length of 5 m. The seismic-resistant structure is represented by Concentric Bracing Frames arranged with the St. Andrew's cross configuration (CBF-X). The floors can be considered as

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diaphragms, since for both structures a reinforced concrete slab is present. The decks have adequate thicknesses to ensure both the maximum permeability of engineering plants and a reduced interference of structures in functional distributions, in line with the modern design requirements. In order to assess the impact only of the in-elevation structure in terms of environmental impact, the two case studies have the same structural component types (columns, beams and bracings) and finishing, as well as the type and geometry of foundations adequate for the acting loads. The materials considered were the S275 steel and GL24h glued laminated timber. Steel insures structural lightness combined with high performances in terms of strength and ductility, speed of assembly with dry solutions and ease of transportation, even without the aid of heavy machineries. Steel is also a "green" material, which is completely recyclable and does not alter its mechanical properties during the life cycle time. Any steel product at the end of its life cycle can be completely reused for an infinite number of times, as attested by the use of about 300 million tons of recycled steel per year and accounting for approximately 35% of the world's production. Such data, through continuous investments in both iron and steel technologies and awareness-raising campaigns towards the use of separate collection of waste and recycling systems, make steel the most recycled material of the world. Timber is the oldest natural building material used by man, due to the high availability, ease of processing and multiple uses and reuses that can be subjected to. In addition to the classic timber elements, used since the prehistory, the technological innovation has shifted towards the use of glued laminated timber components. This technology has allowed to overcome the limitations related to the maximum size and defects of timber elements, with use even in structures with large dimensions. By using relatively thin lamellae, it is also possible to control their moisture, which can be therefore adapted to that of the operative environmental conditions of the structure. For both chosen materials, the continuous recyclability is nowadays the best environmental prerogative, which increases their use and the production cycles. This promotes "sustainable development" through the complete recyclability, the high rate of reuse and recovery, and the compliance with the strictest environmental regulations of these building components.

Considering the design phase, both structural solutions are designed according to the current Italian Code NTC2018 [1] in order to ensure the highest standards of performance and earthquake safety. In the past, the pre-sizing of structural elements by means of computational methods derived from Structural Mechanics were employed, and later on, in order to evaluate the goodness of this preliminary design phase, both structures were modelled by the PRO_SAP analysis software [2] that idealize the frame members with one-dimensional elements and introduce the loads under the form of nodal and/or distributed actions. For evaluating the effects of seismic actions, and in accordance with the code, a linear dynamic analysis with a design spectrum resulting from a reference life, location of the site, characteristics of the subsoil (category C), and behaviour factor considered. Figure 1 shows the structural Finite Element Method (FEM) model used for steel and glued laminated timber structures.

2. LCA Analysis and Results

The Life Cycle Assessment (LCA) is a methodology that analyses all the stages of the life cycle of a product, evaluating energy and environmental factors attributable to processes or activities that lead to the production of that product [3]. In particular, LCA examines the stage of extraction of raw materials for production of basic materials, the formation of products, as well as the distribution, use and disposal of those products, and considering the possible recycling or landfill disposals.

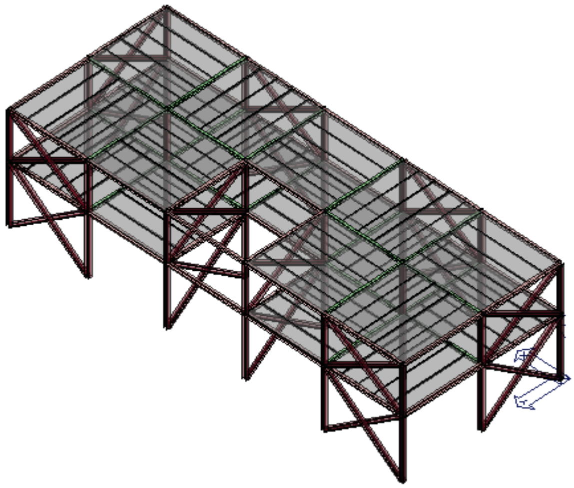

Figure1. Structural FEM model used for steel and glued laminated timber structures.

In order to ensure a correct evaluation of the process, standardized by the rules defined in ISO14040 [4] and ISO14044 [5] standards, it is necessary to evaluate all the phases characterising the LCA process, namely Goal and Scope, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and life cycle interpretation. Through the evaluation of these stages it is possible to reach the objective of establishing a comprehensive interaction framework with the environment, addressing design interventions towards a better environmental solution. Originally implemented by the Swiss Federal Institute of Technology in Lausanne, the Impact 2002+ method [6] is a solver for the application of the environmental assessment method. It is able to offer, among different approaches, the most reliable environmental solutions considering, at the same time, different midpoint categories, such as water acidification, land consumption and climate change extended to a time period. Analysing the interaction among these categories, the Impact 2002+ method identifies four environmental factor classes: Human health, Ecosystem, Climate, and Resources. As noted earlier, the used analysis approach aims at performing a complete environmental impact assessment of two equivalent structures, having the same use and finishes, and made of either steel or glued laminated timber. Adopting the evaluation criteria of the LCA analysis, the comparison is performed on the entire life cycle of structures, considering a time horizon of environmental footprint equivalent to 50 years. It is, however, important to precise that in the current analysis the comparison phase in terms of recycle of materials is omitted due to the inaccurate knowledge of the recycling of timber for structural use in Italy.

After analysing the impact of the two solutions, a comparison graph among different environmental damage categories is shown in Fig. 2. The use of adhesives and chemical solvents for the manufacturing phase and the considerable dust production severely penalizes glued laminated timber more than steel in the category Human health. In this context and when compared to the value of 100% assumed for the timber, the steel has an impact index equal to 25% only. In the Ecosystem quality category, even if both structures in the production phase are very dangerous for the environment, the steel has the best performance with a percentage of 52% only.

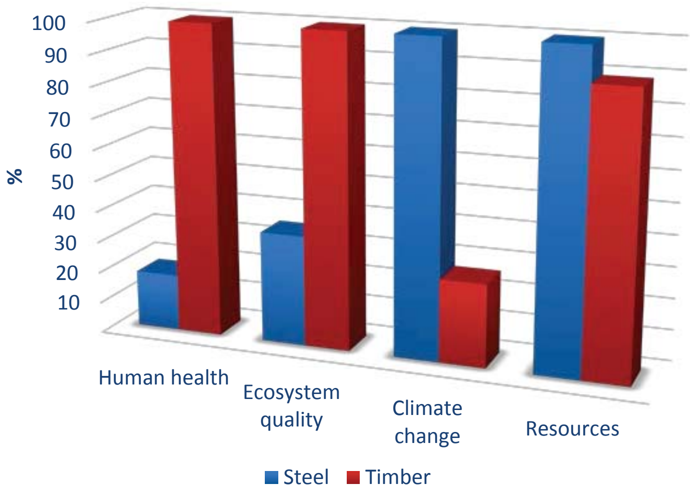

Figure 2. LCA comparison between steel and glued laminated timber structures.

In terms of resources used, it is easily recognised that timber is more eco-sustainable than steel, which is produced from waste materials requiring a lot of natural resources. In fact, even if steel is a recyclable material (up to 98%) and it does not lose its properties once recycled, over 45% of the European steel production is based on recovering and recycling of scraps, which are melted to create new steel products. In particular, in the European Community Italy occupies the first place for the production of steel in electric furnaces which use as a raw material essentially the ferrous scraps, and records the highest annual consumption of this material. In 2011 the Italian steel mills recycled nearly 20 million tons of ferrous scraps, of which about 70% came from the national collection, 18% was imported from other European countries, and the remaining 12% was from the underdeveloped countries. Based on these premises, evaluating the impact in terms of energy consumption in the Resources category, the glued laminated timber appears as the less impacting material, with a difference of about 39% compared to steel, where the high energy consumption resulting from the production phase is greater than that required by the timber.

Finally, in the Climate change category steel becomes the most impactful material, because, despite the technological improvement and evolution of used blast furnace systems, air emissions produce more effects on climate change than glued laminated timber.

In conclusion, it is seen from the above results that on the studied structure there is a substantial balance of environmental performances between steel and glued laminated timber. Nevertheless, if the comparison is made in quantitative terms, steel is slightly preferable in comparison to the glued laminated timber. However, considering the high benefits they provide from the energy point of view, these materials can be considered as the best alternatives to build structures with high energy saving.

3. Conclusions

The purpose of the present study was to assess the environmental impacts from steel and glued laminated timber used as construction materials for a two-story framed structure. Firstly, the structure has been designed with the two materials by considering the same boundary conditions, namely use, construction types, finishes, applied gravity loads and earthquake safety level, on the basis of the new technical Italian standard (NTC2018). Secondly, the environmental impacts of two structures during the phases of production of materials, erection and dismantling have been evaluated according to the Impact 2002+ method. Only due to the absence of reliable data about the percentages of recycled timber, a complete comparative analysis between the two solutions could not be provided. From the analysis performed it is determined that the production phase has an impact greater than that of the production and erection phases, because both structural typologies are made of semi-prefabricated components, which require to move the main resources in the production stage. Instead, from the comparison between two materials examined it is found that steel offers the best performances in the Human health and Ecosystem quality categories, whereas the glued laminated timber is preferable when the Climate change and Resources categories are of concern. Therefore, from the qualitative point of view, the two materials are basically equivalent in terms of environmental benefits provided to the study structure. Nevertheless, after a quantitative assessment of performances was completed, it is observed that steel is slightly preferable to glued laminated timber. Thus, for the investigated building the steel solution represents the most sustainable technique with less impact on the environment.

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Modal Parameters Identification on Environmental Tests of Ancient Bell Towers and Model Validation

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Abstract. The preliminary results of an ambient vibration-based investigation conducted on a large sample of historic masonry towers in the Marche region (Central Italy) are presented, with a focus on the San Ciriaco Belfry in Ancona (Italy). The assessment procedure includes full-scale ambient vibration testing, modal identification from ambient vibration responses, finite element modeling and dynamic-based identification of the uncertain structural parameters of the model. As the least constrained parameter, the modulus of elasticity of the masonry is adjusted for the model to agree with the experimental results.

Keywords: Vibration, structural health monitoring, cultural heritage, masonry towers.

1. Introduction

Historical masonry buildings are vulnerable to inertia forces induced by earthquakes. In many cases, the limited ductility of the masonry and the slenderness of the structures and its irregular geometry can induce severe damages even under seismic events of moderate intensity [1–4]. The vulnerability of cultural heritage structures is a relevant problem in countries like Italy with a medium-high seismic hazard in a large part of its territory [5, 6].

Tall and slender masonry buildings may exhibit high sensitivity to dynamic actions (traffic induced vibrations, swinging of bells, wind) and high seismic vulnerability [7]. The research on effective strategies for the vulnerability reduction of the architectural heritage focuses more and more on the methods for structural safety assessment and measures of passive mitigation of seismic effects. The potential of earthquakes to cause largescale destruction and the vulnerability of heritage structures makes their Structural Health Monitoring (SHM) of key importance [8, 9]. In this framework, the Ambient Vibration Surveys (AVS) is a powerful tool based on a non-destructive methodology which allows indicators of the global structural behaviour (such as frequencies and modal shapes) to be identified. In the past, AVS and modal identifica-

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tion have gained a lot of interest [10, 11], due to the availability of non-expensive instruments and due to the development of powerful system identification techniques [12, 13].

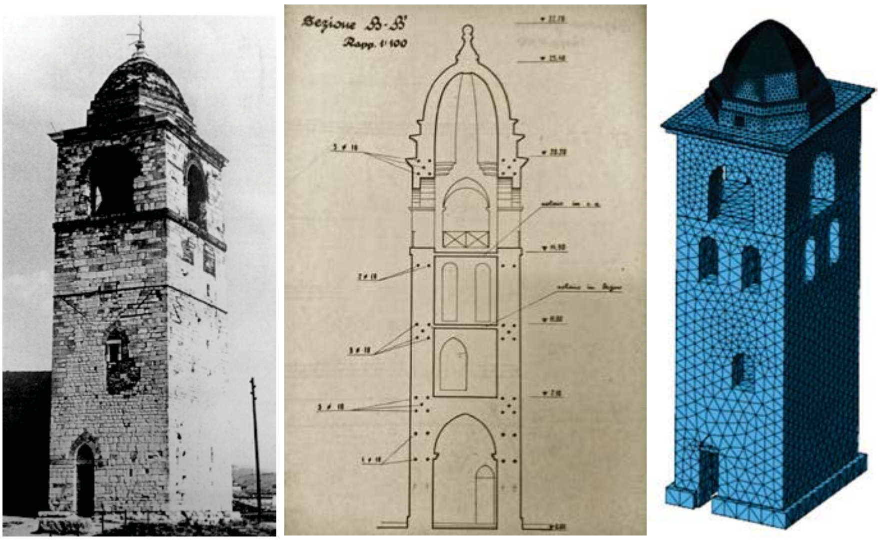
In this work, the opportunities provided by dynamic identification techniques for the non-destructive evaluation of heritage structures are discussed with a focus on different bell towers, located in the Marche region (Central Italy). All of these towers were stricken by the long seismic sequence of Central Italy between August 2016 and January 2017, and are investigated in detail in order to have an insight into their dynamic behaviour. In order to reduce the length of the paper the illustrated methodological approach pertains to a case study selected among the twelve considered (Fig. 1).

Figure 1. Locations of the monitored masonry towers in the Marche Region (Central Italy).

In particular, the experimental investigations and the operational modal analysis results are presented for the San Ciriaco Belfry in Ancona. The main goal of this research is to develop a preliminary 3D Finite Element Model (FEM) able to match the results of Operational Modal Analysis (OMA), and for this purpose some uncertain parameters of the model (basically the Young's modulus and density of masonry in different regions of the structure and some added masses are introduced to take into account the weight of non-structural elements like bells) are selected as *updating parameters* and iteratively modified to minimize the differences in the natural frequencies between FEM and OMA, at least for the first mode frequencies.

2. The Case Study

The church of Saint Ciriaco is a Roman Catholic cathedral in Ancona and in the center of Italy (Fig. 1). It is the seat of the Archbishop of Ancona. The building is an example of mixed Romanesque-Byzantine and Gothic elements, and stands on the site of the former acropolis of the Greek city, the Guasco hill which overlooks Ancona and its gulf. Italic temple, perhaps dedicated to Aphrodite, existed on the site as early as the 3rd century BC. On top of it and in the 6th century AD a Palaeo-Christian church was built that had a nave and three aisles with the entrance facing southeast. Some remains of it still surviving include a mosaic pavement and perimeter walls. In 995–1015 AD a new church was built, which kept the original walls. Over the centuries the church changed shape and look several times, and presently the surface is decorated with the white stone from Mount Conero.



(a) (b) (c)

Figure 2. Belfry of San Ciriaco Cathedral: (a) Façade when the *mofore* was closed, (b) retrofitting interventions, (c) FEM of the actual tower.

The bell tower is in an isolated position with respect to the church. It is mentioned from 1314 and it was built above a pre-existing late 13th century military tower (Fig. 1). In 1599 almost a complete reconstruction of the dome, which was covered with bronze slabs obtained from the fusion of the cathedral doors, was accomplished following the fall of a thunderbolt in 1584 and a subsequent fire. In the reconstruction of 1607 of the belfry dome and the closure of *monofore*, the static improvement were also done (Fig. 2a). In 1643 a lightning stroke the dome of the tower and further new restorations were made. During World War I, the basilica and belfry were damaged by a bombardment of the Austro-Hungarian fleet. The damage was restored in 1920, but in World War II the Anglo-American aerial bombings destroyed the south transept and the Crypt of Tears under it in the basilica, along with the art treasures housed there, and some damages was done in the belfry. Once the transept was rebuilt, the church was officially reopened in 1951. Between 1963 and 1966 static stability interventions of the tower were done again and in particular: (i) replacement of the existing floor of the belfry in a new reinforced concrete partially embedded in the wall, (ii) new independent castle for the bells resting on a concrete slab, (iii) reopening of the four *monofore*, (iv) improvement of the perimeter walls with reinforced perforations (Fig. 2b), (v) reconstruction of the dome mantle and construction of a four-ramp iron staircase. Further damage was caused by an earthquake in 1972 and this followed with a new restoration and another official opening of the complex in 1977.

A preliminary FEM has been implemented by using the 3D solid elements in Midas FEA© (Fig. 2c) [14] with the geometry of the structures and focusing on the variations in wall thickness, on geometrical and structural irregularities, and on wall connections. Finally, the major internal openings in the buildings, like that in the vaults, have been reproduced.

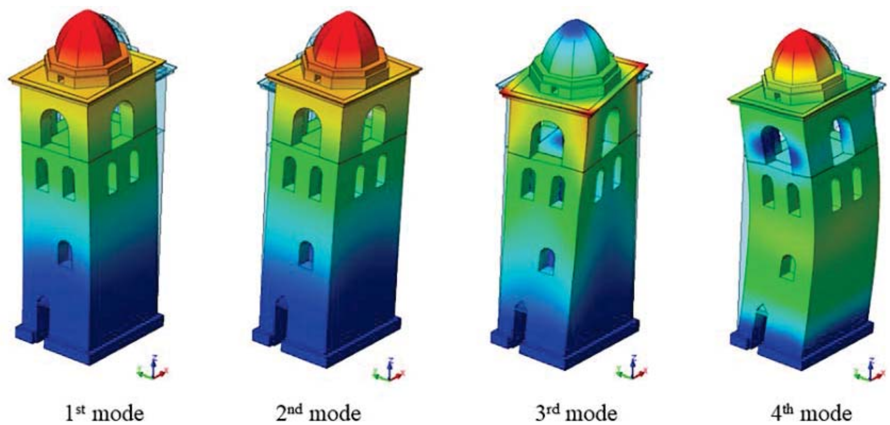


Figure 3. Preliminary analysis of the belfry employing four vibration modes.

Table 1. Modal properties for the starting numerical model.

Mode	Frequency	Period	TRAN-X		TRAN-Y	
n.	(Hz)	(sec)	Mass(%)	Sum(%)	Mass(%)	Sum(%)
1	2.338	0.428	0.15	0.15	57.17	57.17
2	2.853	0.351	57.19	57.34	0.14	57.31
3	6.031	0.166	0	57.34	0.07	57.38
4	8.472	0.118	0	57.34	26.03	83.41

The 3D FEM has been used at first to assess the (linear) dynamic behaviour of the starting configuration of the Tower. To calculate the modal shapes and considering the large number of degrees of freedom, the Block Lanczos method has been used with consistent masses. The main results are reported in Fig. 3 and Table 1.

3. Dynamic Identification

The dynamic monitoring has been carried out with the use of 5 seismic accelerometers with high sensibility. In particular, they are triaxial MEMS-Piezo (the first feature for self-levelling) 1V/g sensors with a frequency range 0.8-100 Hz, and a dynamic range of 120 dB. The sensors have been disposed on various positions on the belfry (Fig. 4). The four records of the AVS have been produced with a sampling frequency of 1000 Hz.

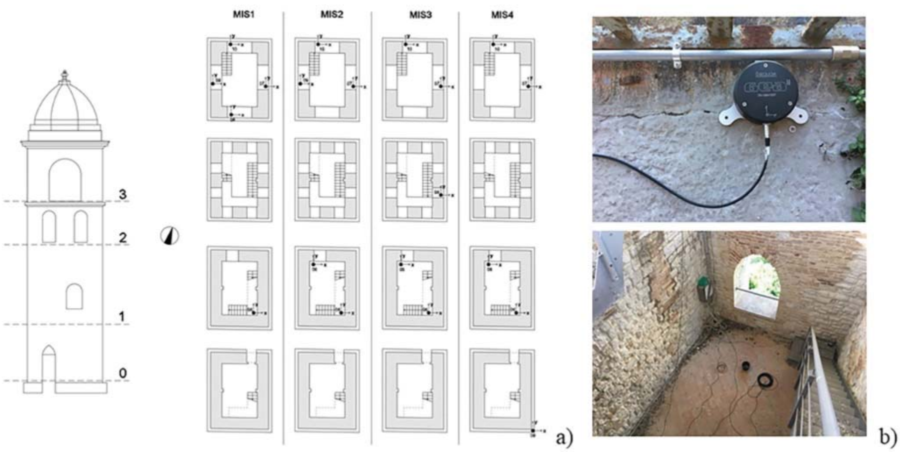


Figure 4. Layout of the accelerometers in the tower.

Table 2. Frequencies identified with Cov-SSI method.

Mode Number	Frequency (Hz)	Damping (%)	Complexity (%)
1	3.354	1.737	0.418
2	4.143	1.344	0.171
3	7.675	0.717	5.663
4	10.187	1.802	0.329

The acquired data have been then treated with the application of the pass band filters and with a decimation of the data to obtain the final sampling frequency of 17.1 Hz. The output-only modal parameter estimation has been carried out according to the COVariance Stochastic Subspace Identification method (Cov-SSI) [15] that works on output correlation for the estimation of system matrices and, therefore, of eigenproperties. This method operates directly in time domain and is based on a state space description of the dynamic problem. The stabilization diagram obtained from the analysis of the collected data through Cov-SSI is reported in Fig. 5 and allows the determination of the *n* eigenvectors which are representative of structural modes (Table 2).

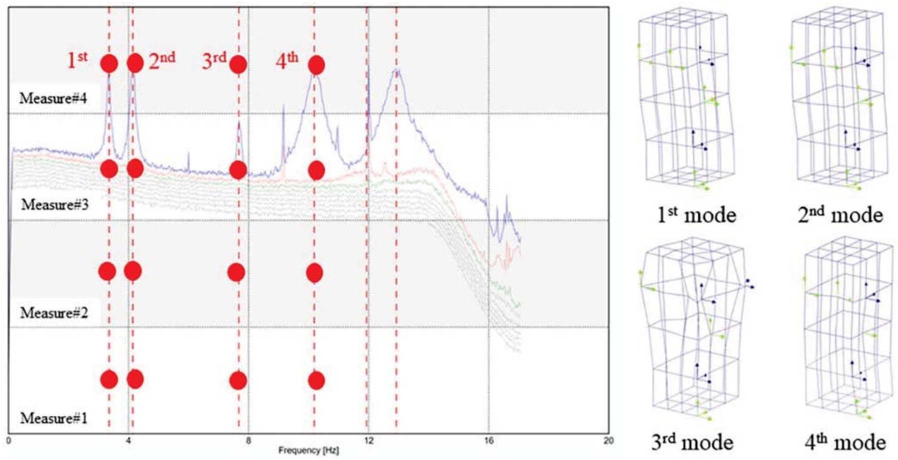


Figure 5. Stabilization diagram and modal shapes identified with Cov-SSI method.

4. Numerical Calibration: First Results

An ongoing calibration of the numerical model is carried out by increasing the Young's modulus of the masonry of the belfry (Table 3) in order to obtain a good fitting between the first two measured frequencies, leaving the modal shapes unchanged with respect to those reported in Fig. 3.

Table 3. Final modal properties after the end of calibration of the numerical model.

Mode n.	Exp. Frequency (Hz)	Num. Frequency (Hz)	Δf (%)	TRAN-X Mass(%)	TRAN-X Sum(%)	TRAN-Y Mass(%)	TRAN-Y Sum(%)
1	3.354	3.354	0.00%	0.15	0.15	52.74	52.74
2	4.143	4.036	2.58%	52.76	52.91	0.13	52.87
3	7.675	8.002	-4.26%	0.1	52.91	0.07	52.94
4	10.187	10.301	-1.12%	0.01	52.92	24.5	77.44

In order to obtain a better fitting with the third and fourth modes, as can be seen from Table 3, we also considered a different masonry materials for all the walls of the belfry, i.e., stone masonry and solid bricks, respectively, in the exterior and interior parts. Further changes of the Young's modulus do not lead to a better fitting, which implies the need to further update the model with secondary elements such as the internal steel staircase to obtain a lower discrepancy between the higher modes. These improvements will be reported in future works.

5. Conclusions

An ambient vibration survey has been used to assess the dynamical behaviour of the San Ciriaco Belfry in Ancona (Italy) and different consecutive surveys were conducted for the accurate estimation of the dynamic characteristics of the building. Moreover, a preliminary finite element method with solid elements has been employed and updated by utilizing the experimental measurements and obtaining encouraging results. Future works, based on this preliminary sensitivity analysis, should improve the identifications of the most sensitive parameters for choosing the updating parameters. Furthermore, the model updating technique based on a sensitivity-based method should be used to minimize the errors between experimental vibration data and numerical response values.

6. Acknowledgements

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New Simplified Method for Seismic Behaviour Evaluation of Structural Units in Masonry Aggregates

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Abstract. The aim of the research presented in this paper was to evaluate the seismic behaviour of masonry building compounds that is a common typology characterizing several Italian historic towns. This study was carried out by performing the analysis of an aggregated construction in the town of Sora (Frosinone, Italy) that was damaged after the 2009 L'Aquila earthquake. A comparison between the results obtained by using the commercial software 3Muri and those derived from the application of the Italian Guidelines on Cultural Heritage show that the Guidelines provide results on the safe side in predicting the seismic behaviour of the accounted building compound. On the basis of these results, it is necessary to perform further analyses aimed at opportunely improving the simplified method proposed by the Italian Guidelines for the evaluation of the behaviour of building compounds under earthquake actions.

Keywords: Masonry aggregates, cultural heritage, seismic behavior

1. Introduction

The historic and recent Italian earthquakes have highlighted the problem of the seismic vulnerability of existing masonry constructions. The Italian territory offers a wide varieties of existing masonry buildings which are characterized by different construction typologies. Most of these buildings fall, however, within a time period where the knowledge about the seismic behaviour of structures, performance of materials, and earthquake actions was very limited. For this reason, a relevant number of existing buildings built without considering adequate regulations do not possess minimum safety requirements against earthquake actions, and as a consequence are

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characterized by a remarkable seismic vulnerability. Moreover, the growing housing need, the configuration of the territory, and the traditional construction techniques, resulted in the assemblage of multiple structural units, called "aggregates". The interaction among the units comprising an aggregate plays a relevant role for seismic evaluation. In particular, the behaviour of each building particularly depends on its position in the aggregate and the seismic analysis requires a unitary approach for the whole aggregate. In the present paper the attention is focused on the seismic vulnerability analysis of building aggregates, and in particular, an analysis of a masonry building compound located in the municipality of Sora, a town located in central Italy in the province of Frosinone, was carried out with the aim of comparing the results obtained from the evaluation of the seismic vulnerability of a structural unit assumed both as a component of the aggregate and as an isolated building. Moreover, the study was carried out by using the commercial computer code 3Muri [1] and also by the simplified method contained in the Cultural Heritage Guidelines [2] for the evaluation of seismic risk.

2. The Case Study

The building aggregate employed for this study is located in Borgo San Rocco, in the historical centre of the city of Sora, in the province of Frosinone. The city of Sora is located near the central Apennines, between the two regions Lazio and Abruzzo at about 300 meters above the sea level. In the past it was struck by seismic events of various magnitudes, after which it was almost completely rebuilt. The village of San Rocco, where the investigated aggregate is located, dates back to the nineteenth century. Here the streets are flanked by dense residential areas that develop in elevation on several levels.

The building compound considered here is composed of 15 structural units made of masonry stones arranged in a chaotic way. Very little information on the masonry properties is, however, at disposal, so that a limited knowledge level (denoted as LC1 in the Italian standard NTC2018 [2]) was available for this study. Different types of floors (reinforced concrete, steel, timber, and vaults) are present as horizontal structures of structural units. Roofs are made of timber beams with overlying timber planks. The bird-eye view and some of the original drawings of the building compound are depicted in Fig. 1.

3. Modelling and Analysis With the Software 3Muri

The software 3Muri was used for modelling and analysing the aggregate characterizing the case study, where the walls are divided into macro-elements represented by masonry piers and spandrels, as well as the rigid nodes connecting them. According to this schematization, the wall model is similar to that of a plane frame, and the modelling phase started by importing the graphical model of the aggregate at different levels by taking into account the centreline axis of masonry walls and by inserting, where appropriate, doors and windows. Subsequently, geometrical and mechanical properties of masonry walls, floors and roofs were assigned to different macro-elements composing the walls. Subsequently, dead, permanent and variable loads were applied on floors and roofs. This information together with site characteristics allowed the software program to evaluates the seismic forces applied to the aggregate by considering the two load patterns (i.e. proportional to the masses and proportional to the first vibration mode) as suggested by the NTC2018 .

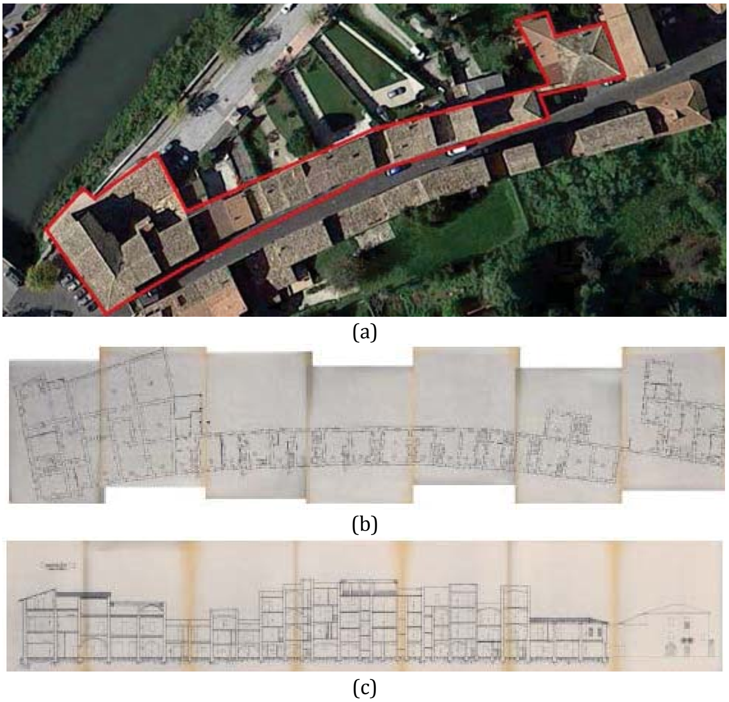


Figure 1. Borgo San Rocco (Italy): bird-eye view (a), first floor plan layout (b) and structural section (c).

The macro-element model of the studied building compound is shown in Fig. 2. The software 3muri allows the determination of capacity curves along the two principal directions X and Y of the entire building aggregate, whereas the capacity curves of singles structural units are derived from a manual procedure consisting of step-by-step determination of the base shear of each masonry wall of units in the aggregate and the average value of roof displacement.

This procedure for obtaining the capacity curves of structural units in the context of the aggregate, i.e. considering the interactions among the units, is strongly desirable since, according to previous studies [3,4], the seismic behaviour of units considered isolated from the aggregate could be quite different from that of the same units inserted in the building compound. In particular, in the case of isolated structural units it is possible to observe an underestimate of the stiffness and, at the same time, an overestimate of the ultimate displacement respect to the case of the same buildings included in the compound. These results are, respectively, due to the lack of loads applied from a djacent structural units and the absence of torsion effects derived from the strongly irregular in-plane shape of the whole aggregate.

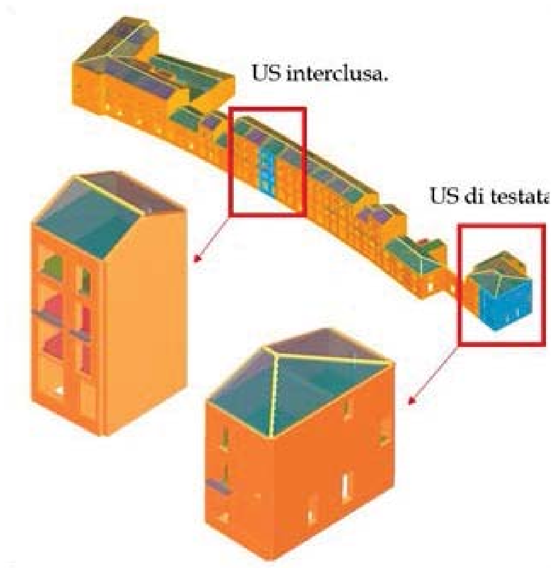
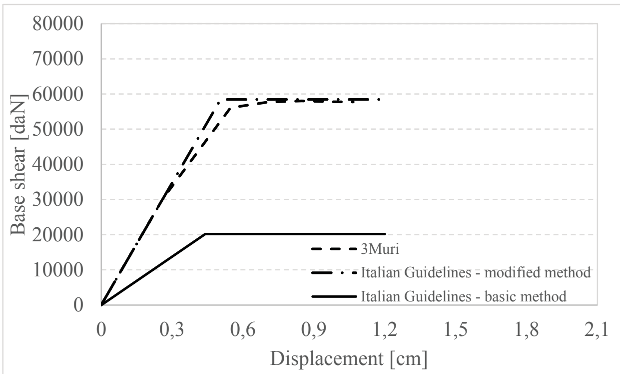
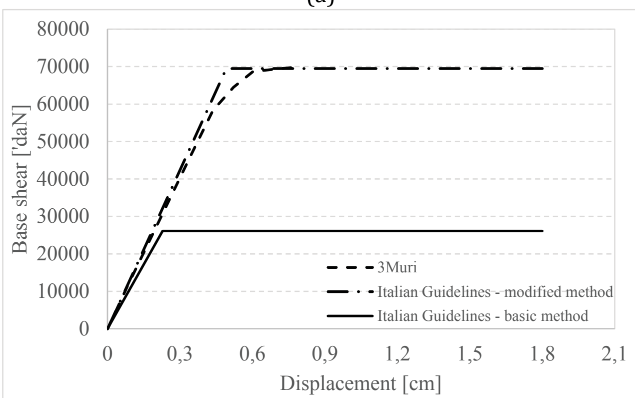


Figure 2. The 3Muri model of the inspected masonry aggregate.

For our case study, this modelling drawback is not considered since the simplified method of the Guidelines for Cultural Heritage is used to derive the pushover curves of the head and intermediate structural units. These curves are compared with the ones obtained from 3Muri according to the procedure previously presented (Figs. 3 and 4). The comparison among the capacity curves derived by considering different approaches underlines that the simplified approach provides a significant low value of the maximum base shear and lower stiffness and ultimate displacements. Therefore, they are too on the safe side in predicting the seismic behaviour of single structural units and stresses the need to improve the formulations proposed by the Guidelines for the evaluation of seismic response of aggregated masonry buildings. For this purpose–and in a previous research [5] a coefficient η depending on geometrical properties of masonry structural units (Fig. 5a) was introduced as a function of pier slenderness (b) to modify the base shear of buildings, so that their response evaluated in this simplified way results similar to the one obtained through a finite element analysis. Regarding the case study, the evaluation of the parameter η for the investigated structural units leads to values outside the domain carried out in the previous research activity (Fig. 5b). For this reason, further analyses on different masonry aggregates will be performed to evaluate in a more careful way the most reliable boundaries of this domain. In addition, considering the difference of stiffness between curves, the amplification of stiffness of curves with the same η factors used for base shear do not lead towards a good prediction of numerical non-linear responses of examined buildings. Therefore, a new corrective coefficient η’ equal to the ratio between the stiffness of capacity curves obtained from 3Muri and the stiffness of the Italian Guidelines curves is estimated and used to attain the same numerical stiffness, as shown in Fig. 5b. The calculation of η’ values as a function of parameter b in the examined case study leads towards the precautionary broken line illustrated in Fig. 5c, which can be used in future applications to predict the safe side of the simplified curve stiffness. As for the η factor, additional analyses must be carried out to evaluate the reliability of the considered broken line.



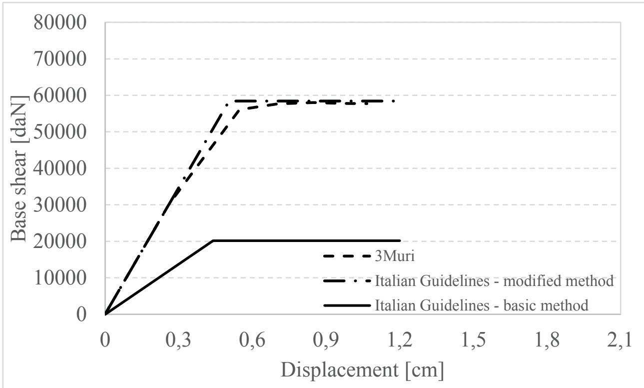
(a)



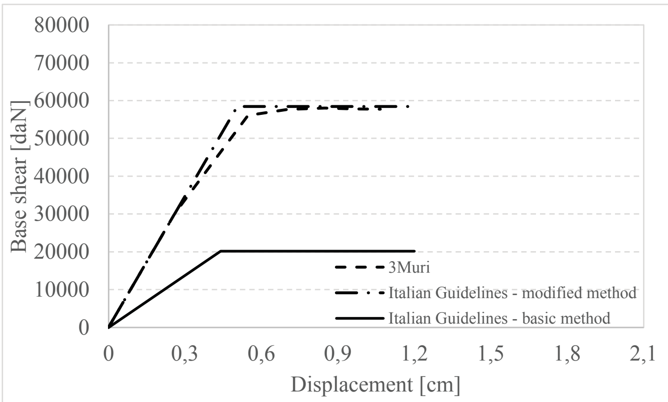
(b)

Figure 3. Comparison between the capacity curves derived from ~~the~~ different approaches of the intermediate structural unit in directions X (a) and Y (b).

In conclusion, the application of both η and η’ values to the studied structural units allows to significantly improve the simplified method proposed by the Italian Guidelines, because the simplified pushover curves fit very well the 3Muri curves. In this way, a quick and easy method is setup to foresee the seismic behaviour of masonry structural units grouped in aggregates.



(a)



(b)

Figure 4. Comparison between the capacity curves derived from ~~the~~ different approaches of the head structural unit in directions X (a) and Y (b).

4. Conclusions

In the present work a building aggregate located in the municipality of Sora (district of Frosinone, Italy) was investigated. Two structural units having head and intermediate positions in the compound were examined by means of both the 3Muri software and the methodology provided by the Italian Guidelines for Cultural Heritage. The capacity curves derived from the two analysis methods were compared to each other. From this comparison it was established that the Guidelines provide too precautionary results that are excessively far from the numerical responses of inspected structural units. For this reason, coefficients of both the base shear strength and stiffness were introduced to achieve Italian Guidelines capacity curves closer to the 3Muri ones.

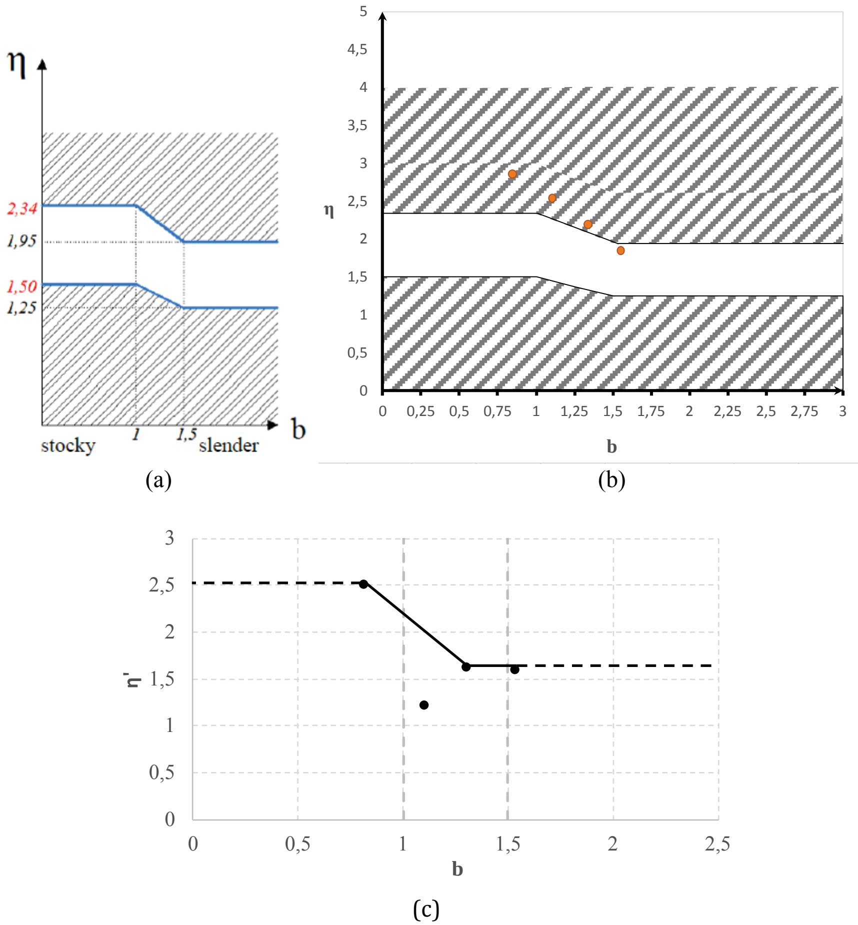


Figure 5. Original η-b domain (a), representation of values herein achieved in the original η-b domain (b), and the new coefficient η' to fit the numerical stiffness (c).

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Innovative Techniques for Masonry Ancient Buildings Conservation

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Abstract. This paper presents a review of recent innovative techniques for conservation of ancient masonry buildings where the architectural heritage consists of constructions in stone materials. These constructions are conditioned by the architectural styles of the past that are representative of all ancient cities. There is a huge variety of stone materials that have substantially different characteristics depending on the type of source rocks from which they are extracted. These materials are affected by synergistic chemical, physical, and biological degradation phenomena caused by the complex interaction between the materials and the exposure environment. The degradation of materials can compromise the structural behavior of the construction and increases its seismic vulnerability. The preservation of the architectural heritage built with stone requires restoration works able to neutralize or at least reduce the degradation of these extremely vulnerable materials and this paper illustrates a multidisciplinary research activity aimed at using an innovative product based on lime and nanoparticles of graphene in restoration and conservation of ancient masonry.

Keywords: Conservation, masonry, degradation.

1. Introduction

Stone is the main material used in the architectural and sculpture heritage and is characterized by a great variability depending on the type of rock from which is quarried. Due to the characteristics of durability, strength, workability and fire resistance, limestone was widely used in ancient times for churches and temples in the Mediterranean area and in other parts of the world. The limestone rocks of biochemical origin are often known with the local denominations, such as calcarenites or tuffs of Matera (Fig. 1).

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Figure 1. Saint Giovanni Battista Church built in tuff and located in Matera (Italy).

The calcarenites are affected by severe chemical, physical and biological degradation phenomena, due to their high open porosity that allows the entry into the pores of aggressive agents present in the exposure environment. The two most frequent and aggressive chemical processes are caused by the environmental pollution arising from the use of fossil fuels. Another frequent physical degradation phenomenon that affects the calcarenitic materials is the crystallization of soluble salts, which together with the wind erosion determine the alveolarization phenomenon. As regards the biological degradation phenomena. All the degradation processes imply microstructural changes and in some cases the physical loss of material, which leads to the loss of historic and cultural value of the architectural or decorative heritage. Limestone masonry walls are even more vulnerable to the seismic action, because these stones react as rigid and fragile materials, affecting the compression strength and having a limited capacity to tensile, flexural and shear strength [1]. Moreover, the mechanical capacity of the walls may decrease due to the loss of material of the limestone masonry by chemical or physical degradation processes.

Nanoscience deals with a large diversity of research fields and applications, due to the modification or improvement of the nanomaterials properties by the effect of the reduction in the size of the particles. The graphene is a flat sheet of monatomic carbon atoms linked by covalent bonds [2]; it is the thinnest possible 2D membrane in nature, and among other features, it has the highest stiffness and strength ever recorded [3]. These nanoparticles have an ultimate tensile strength of 130 GPa, compared to the 400 MPa of A36 structural steel, and have good elastic properties and are very light, weighting only 0.77 mg/m^2.The nanotechnology has provided new products for the conservation of architectural heritage, which has enhanced the properties for protection and consolidation of the traditional materials. Considering that one of the main purposes in the conservation of architectural heritage is to minimize the interventions for repairing or consolidating, this paper illustrates a multidisciplinary research activity on the use of an innovative product based on lime and nanoparticles of graphene in restoration and seismic retrofit of masonry constructions in calcarenites.

2. Recent Innovative Techniques for Masonry Conservation

There are important vulnerabilities of historical masonry buildings exposed to seismic behavior, such as the low mechanical properties of the unreinforced masonry walls and the lack of connections between the walls and with the horizontal structures, which because of cultural value prevents invasive interventions. It is therefore necessary to find solutions capable of improving the structural security and taking into account the conservation criteria of Cultural Heritage as well. Often, the aim of retrofitting of historic masonry is to increase the shear strength of the walls for achieving a better global behavior under seismic actions, and in recent years the procedure of strengthening masonry walls with the jacketing technique based on steel, Glass Fiber Reinforced Polymer (GFRP) or basalt with different mortars, has been investigated (Fig. 2).

Fig. 2. GFRP application to the masonry wall.

Although the research results have revealed that shear and flexural strength in masonry walls can be increased through the use of steel, basalt, and Fiber Reinforced Polymer (FRP) composites, some problems have been highlighted: Difficulty in the removal of the reinforcement; poor behavior of epoxy resins at high temperatures; high cost of epoxies, basalt and FRP composites; long term behavior of organic protectives and their difficulty to allow the water vapor permeability of the wall; and the low resistance of the steel to environmental conditions [4]. On the other hand, a system for improving the out-of-plane flexural strengthening of historic masonry walls was recently proposed [5] and named "reticolatus". The method consists in a reinforced repointing for improving regular and irregular masonry behavior, which is reversible and suitable for fair-face walls of historical buildings. This method employs an irregular net of thin stainless steel cords able to work in tension when fixed into the mortar joints following the joint texture. This technique is currently under development and its applications on test walls highlight the improvements in stiffness, resilient forces of cracking and generation of more distributed cracks in all the tests, and greater energy dissipation during earthquakes. Recently, the graphene as a nano-technological component mixed with lime has been used in Spain as a painting and restoration material, giving extraordinary physical properties to the mortar, such as hardness, strength and flexibility, which is linked with higher durability. However, the possibility of using graphene-lime mortar as a tensile strengthening technique has not yet been investigated. We intend to start this interdisciplinary work by studying the mechanical and physical capacities of the material and aim at applying it in restoration interventions as repointing of joints, which may be more compatible and more durable when affected by weathering, and have the capacity to withstand tensile stresses due to seismic action. Owing to the difficulties associated with the handling of monolayer graphene of monoatomic thicknesses and the extremely low forces required for axial loading, only a few experimental works have been reported in the open literature. Even these works are burdened to some extent by the necessity of approximation, because the actual thickness of the atomically thin layer is not known and a comparison to bulk materials is very difficult [6]. As shown in Fig. 3 [6], the first report on the Young's modulus of graphene ruled that its intrinsic strength reaches 300 GPa for monolayer graphene and was obtained by performing nanoindentation measurements using an atomic force microscope [3].

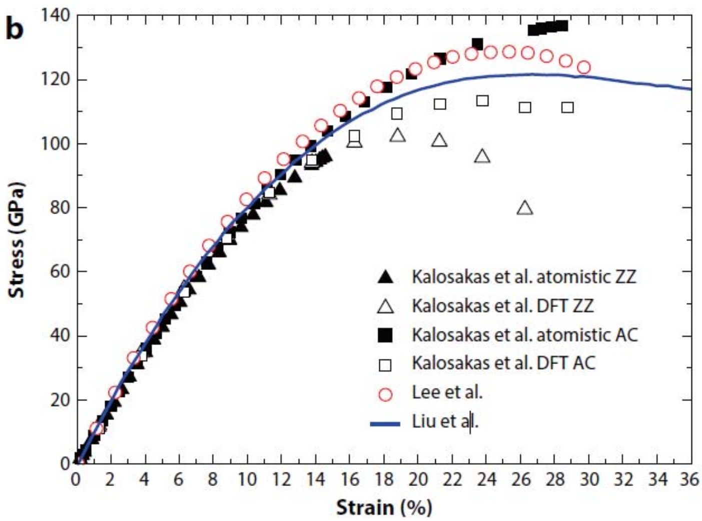

Figure 3. Stress-strain curves for pristine graphene [6].

Cementitious materials have been widely used in constructing architectural structures. Traditionally, mortar or concrete structures have been composed of cement, fine/coarse aggregate, water, some inorganic additives, and chemical agents. Concrete structures, however, are brittle and have low tensile strength, and multiple crack formations develop under mechanical and environmental loads, limiting their durability and contributing to increasing maintenance costs. The addition of graphene nanoplatelet (GNP) improves the strength of cement mortar by reducing water permeability and diffusion of chlorides. The addition of GNP increases the strength that is higher than that reported in the literature for compounds containing cement nanosize spherical particles of nano-SiO2 or nano-TiO2[7].

Another use of graphene with cement involves graphene oxide (GO) [7]. This is an intermediate product in graphene preparation that has many advantages as a reinforcing material such as ambiphilicity and has excellent mechanical, electrical and thermal properties. Such a paste of cement and GO (0.05wt %) increases the viscosity, decreases the fluidity, and shortens the setting time of the mortar. It also reduces the heat of hydration of the cement. The compressive and flexural strengths of hardened cement pastes increase by the addition of GO. The flexural strength was greater in 86.1, 68.5 and 90.5% after 3, 7 and 18 days, respectively, and the corresponding compressive strength increased by 52.4, 46.4 and 40.4%.

3. Conclusions

There are several techniques of structural seismic retrofit for limestone masonry architectural heritage, such as the polymeric, glass or basalt fibers. The use of these techniques is, however, limited when used in the faces of the wall and with the limestone. Therefore, new materials are required that allow better interactions with original materials of the architectural heritage. The research proved the compatibility of lime mortar for the conservation and restoration of limestone masonry heritage, in spite of its low resistance to compression, tensile and flexural strength when subjected to the seismic action. The future research should apply composites to the repointing of joints in tested walls and compare the outcomes of resistance with the most recent techniques of reinforcement of masonry walls and restoration.

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Seismic Retrofitting of an Existing RC School Building: BIM Modelling and Life Cycle Assessment

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Abstract. In this paper seismic retrofitting of an existing reinforced concrete school building located in Torre Del Greco near Naples is discussed. The school was designed to sustain only the gravity load and is composed of seven constructions seismically jointed to each other. One of these constructions was retrofitted with four different intervention techniques (reinforced concrete jacketing, steel jacketing, fibre-reinforced polymers wrapping, and concentric bracings) whose seismic effectiveness was evaluated with non-linear models. The environmental impact of these interventions was also assessed, and the choice of the best retrofitting system was determined from the economic and environmental (Life Cycle Assessment) points of view.

Keywords: Seismic retrofitting, BIM modelling, LCA, RC school building

1. Introduction

We consider in this paper seismic retrofitting of an existing Reinforced Concrete (RC) structure addressed on the COST Action C26 research project Urban Habitat Constructions under Catastrophic Events [1], which considered the behaviour of constructions under ordinary and exceptional actions. On this project, a particular attention was made to the seismic risk scenario deriving from a possible eruption of Vesuvius, which was taken as a case study in the Working Group 4 "Risk assessment of catastrophic scenarios in urban areas". Researchers from six Italian and foreign universities and research institutes performed an extensive in-situ survey of residential and school buildings of the historical centre of Torre del Greco, one of the most populated Vesuvius town about 20 km from Naples. In this paper the seismic vulnerability of an RC school building is discussed for the purpose of implementing different retrofitting systems which best characterize the structural, economic, and environmental points of view.

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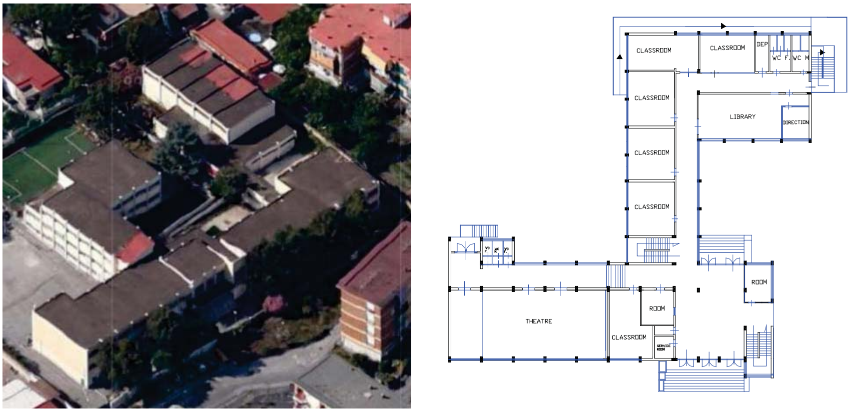
2. The B. V. Romano Secondary School Building: Survey and Structural Analysis

The secondary school B.V. Romano is an RC building located in Torre del Greco in a district of Naples. The school building is composed of 3 constructions connected to each other by seismic joints (Fig. 1a), but herein the attention is focused only on one of these buildings which hosts classrooms, a theatre, and libraries where the major activities of the school are concentrated. The inspected construction dates back to 1980s and 1990s, and develops on three floors with a total height of 10.60 m. The ground floor layout of the surveyed building is shown in Fig. 1b.

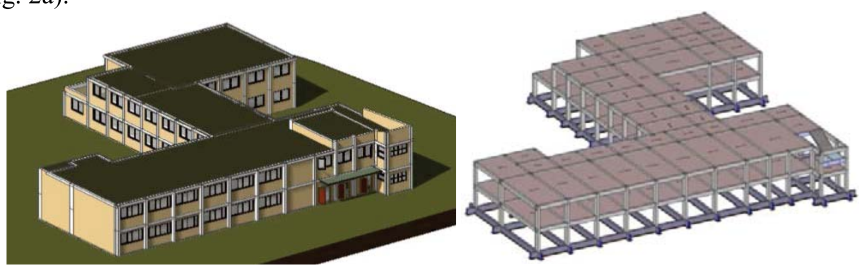


(a) (b)

Figure 1. A bird's-eye-view of the school complex (a) and the ground floor layout of the examined building (b).

The irregular L-shaped building is mainly composed of bidirectional seismic-resistant frames, which represents a construction practice typical of buildings of that period designed to resist seismic actions.

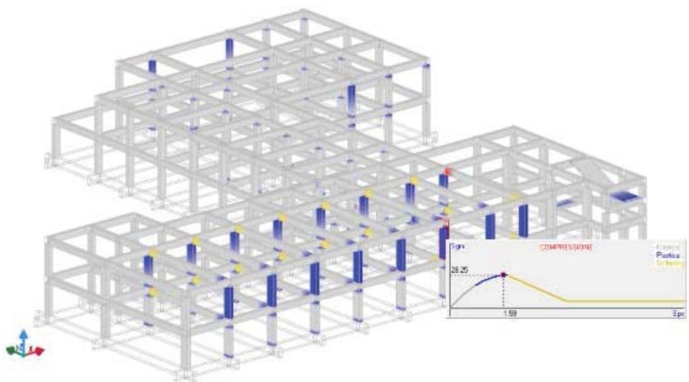
Starting from the architectural plan layout, the structure was modelled with the Building Information Modelling (BIM) approach as implemented by the Edificius software [2], in order to evaluate the geometrical aspects, the materials, the building systems, and all the elements necessary for the optimal understanding of the structure (Fig. 2a).



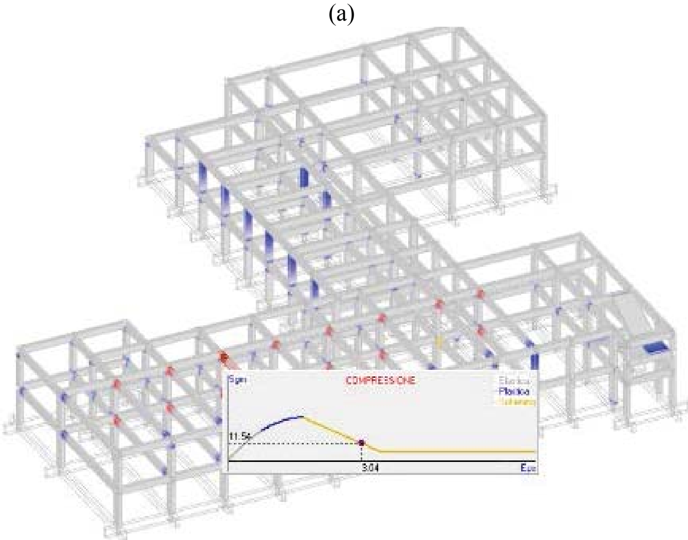
(a) (b)

Figure 2. BIM model (a) and structural FEM model (b) of the case study RC school building.

The BIM model leads towards the definition of the structural characteristics of the building (Fig. 2b) through the implementation of the Edilus software [3] for assessing the stresses acting on the frame members. Through the analysis of some similar buildings on the same inspected area and based on the BIM design process, the mechanical properties of materials and the geometrical dimensions of structural elements (columns, beams and floors) have been accomplished. Beams and columns have been modelled with one-dimensional elements, whereas the shell elements have been used to simulate the presence of both the floors and the slope slab staircase. From the seismic nonlinear static analysis performed in direction *x*, it is found that first level columns attain the life safety limit state condition, whereas the beams are almost at the collapse limit state when pushover is applied in direction *y*. The structural damages deriving from pushover analyses are plotted in Fig. 3.



(a)



(b)

Figure 3. Seismic analysis results in directions *x* (a) and *y* (b).

3. Seismic Retrofitting Intervention Techniques

Various structural reinforcement systems, namely Concentric Bracings (CB) as global intervention and RC jacketing, steel jacketing, and Fibre-Reinforced Polymers (FRP) wrapping as local interventions, have been proposed. The design criterion aimed at attaining at least the minimum safety condition for all structural elements, so that an adequate building seismic retrofitting can be achieved and different strengthening techniques can be applied in order to avoid the limit of functionality and to regularise the dynamic behaviour of the building.

As far as the retrofitting intervention with RC jacketing is concerned, the strengthening of columns is achieved to attain the boundary of the M-N strength domain with 8 cm thick jackets made of C32/40 concrete all around the existing sections and new 4ϕ16 longitudinal bars made of B450C steel in compression and tensile zones. For shear reinforcement, ϕ8 stirrups with two legs and pitch of 10 cm are considered as new transverse bars of jackets. On the other hand, the beams are reinforced with 6 cm thick C32/40 jackets armed with top and bottom B450C steel 4ϕ16 bars and ϕ8 stirrups with two legs and pitch of 15 cm.

As for the jacketing with S275 steel members, the RC sections with poor behaviour have been reinforced towards bending moment with two 150x150x16 mm steel angles both in tensile and compression zones able to satisfy translation and rotation equilibrium momentum equations. To account for shear actions of each RC member side, six batten plates with each having thickness of 5 mm, width of 100 mm, and pitch of about 470 mm have been foreseen.

The FRP reinforcement analysis starts from the hypothesis of achieving a bending moment reinforcement with two layers of unidirectional Carbon FRP U-sheets with equivalent thickness of 10 mm, width of 300 mm, modulus of elasticity of 240,000 N/mm^2, and nominal strength of 4900 N/mm^2.

Finally, the global intervention with CB had the purpose of having the plastic behaviour of braces before the failure of joints and the instability and/or collapse of RC beams and columns. The cross-section of bracing was imposed to attain the limit slenderness value of 200 provided by the Italian standard NTC2008 [4]. This condition required the use of S275 steel HEA160 profiles, which have been placed opportunely in the building in order to limit the disturbance to the occupants (Fig. 4a).

The application of the aforementioned four retrofitting techniques to the RC school building under study provided seismic check results through the use of Edilus software as illustrated in Fig. 4b. From this figure is clear that the local intervention techniques provide similar seismic safety factors, intended as ratios between the capacity and demand displacements required by the earthquake, whereas the CBF, as a global retrofitting technique, allows to increase much more the seismic behaviour of the investigated building.

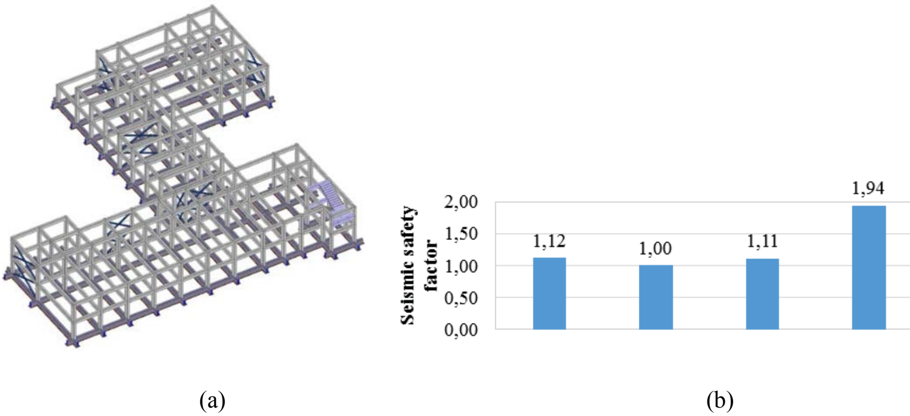


Figure 4. The school building retrofitted with CBF (a) and the seismic check results related to different intervention techniques applied (b).

4. Cost and LCA Comparisons

The comparison among inspected retrofitting systems is performed in terms of costs and Life Cycle Assessment (LCA). The economic analysis is shown in Fig. 5, from where is apparent that the least expensive solution is that given by RC jacketing, whereas FRP is the most expensive intervention. Regarding steel interventions, CB are cheaper than steel jacketing, since the latter are extended to a high number elements, with bracings required only in a limited number of bays.

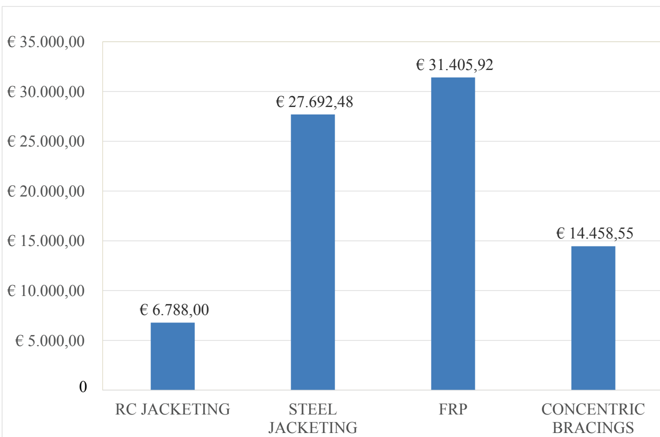


Figure 5. Comparison among reinforcing techniques in terms of cost.

LCA is a tool used to analyse the environmental impact of a product, an activity or a process for all the phases of its life cycle through the quantification of used resources, such as energy, raw materials and water, and emissions into the environment, water, and soil. An LCA analysis is herein performed by means of the

SimaPro software [5] in order to compare different retrofitting interventions (Fig. 6). Here, the environmental impact of FRP is not considered since no data related to this technique is present in the program database. From analysis results it is noticed that CB is the technique with the lowest environmental influence.

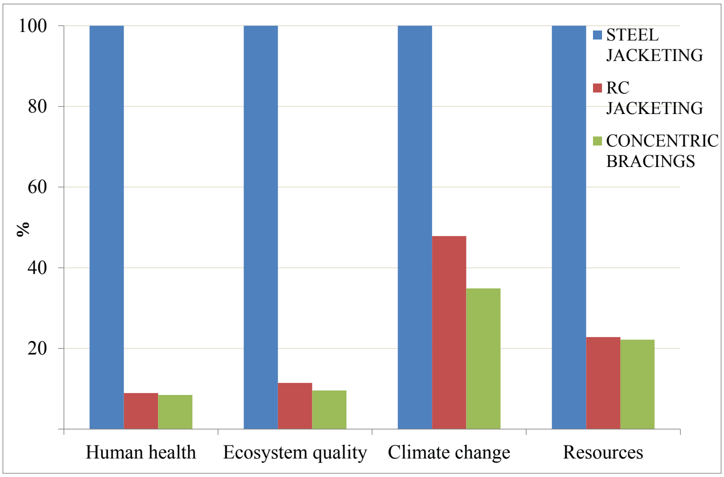


Figure 6. Comparison of different reinforcing techniques based on the LCA analysis.

By considering an analysis of seismic, economic and LCA factors, it is established that the best local intervention is given by RC jacketing that is inexpensive and simple to implement, whereas the optimal reinforcement technique is provided by CB, which gives the highest structural and environmental performances.

5. Conclusions

In this paper some results of seismic retrofitting of an RC school building located in Torre del Greco have been presented. Different local (RC jacketing, steel jacketing, FRP wrapping) and global (concentric bracings) strengthening techniques have been considered and their impact on the existing buildings has been evaluated from seismic (through a non-linear investigation), economic, and environmental (through a LCA analysis) points of view.

From the seismic point of view, the examined local strengthening techniques provide more or less the same equivalent benefits to the bare RC structure, whereas CB, as a global intervention system, offers the highest performance, also considering the limited amount of steel compared to the steel jacketing one. CB are also the preferred solution in terms of LCA, since they reduce much more than the other techniques the impact on the environment. In addition, their cost is lower than those of steel jacketing and FRP, and for these reasons it is possible to conclude that CB is the optimal reinforcement solution for the examined RC school building.

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Comparative Seismic Vulnerability and Risk Assessment Methods for Building Aggregates in Old Towns

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Abstract. This paper presents and analysis of seismic vulnerability and risk of building aggregates within the historical centre of Arsita, damaged in April 2009 by the L'Aquila earthquake. The vulnerability analysis has been carried out by comparing two different procedures, the Vulnus Vb 4.0 software developed at the University of Padua, and the macro-element analysis with the 3Muri software. The expected damage has been estimated in term of fragility curves for the whole aggregate and the single structural units located in the corner and intermediate positions. For the whole aggregate and high levels of peak ground acceleration both software predict consistent results, but for single structural units the Vulnus method underestimates the seismic damage of 3Muri method.

Keywords: Masonry aggregates, vulnerability assessment, historical centres, damage scenarios, fragility curves

1. Introduction

Seismic risk assessment should be employed in any natural disaster prevention policy, for allowing to identify the specific areas at risk so as to subsequently implement the necessary actions for appropriate mitigation plans. Seismic risk of buildings, usually defined as the probability of exceeding a specified level of loss (economical and social) and referred to a time period, can be quantified in terms of fragility curves. The study reported herein shows a comparison in terms of fragility curves between two methodologies for seismic vulnerability estimation applied to buildings grouped in compounds.

2. The Arsita Historical Centre

Arsita is a town in the province of Teramo in Abruzzo, near the Gran Sasso massif. Its origins date back to the pre-Roman period, as evidenced by the archaeological re-

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mains found in 1985, such as tombs and various kits and jewellery, but its current urban context can be traced back to the late Middle Ages Renaissance. The historic centre of Arsita mostly consists of masonry buildings arranged in aggregates of constructions generally developed on two levels. Generally, the floors are made of either steel or timber. The masonry quality is fairly poor with low mechanical resistance, also due to the progressive degradation induced by atmospheric agents and lack of maintenance.

A series of catastrophic seismic events struck the investigated area. On April 6, 2009 an earthquake of magnitude M_w= 6.3 at 9.5 km depth epicentre struck the Abruzzo region [1], producing a large number of collapsed buildings, deaths and injuries. This earthquake can be considered as an exceptional seismic event for two fundamental reasons: The peak ground acceleration (PGA) was higher than that prescribed by the Italian code and the seismic vertical component of acceleration, which is usually neglected in the seismic design, reached significant levels [2].

3. Seismic Vulnerability Assessment

The case study is a building aggregate in the historical centre of Arsita. It is composed of four structural units (SU), denominated 8A, 8B, 8C and 8D (Fig.1).

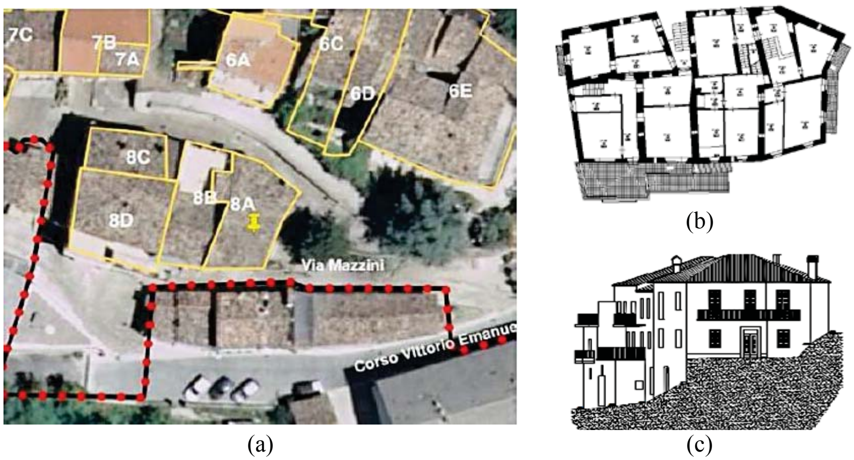


Figure 1. (a) In-plane configuration, (b) typical floor layout, and (c) South-West view of the studied building compound.

The Vulnus Vb 4.0 software [3] provides three vulnerability indices (I_1, I_2, I_3), combined using a *fuzzy function*, that take into account the in-plane mechanisms, out-of-plane mechanisms and the global vulnerability according to the GNDT form, respectively. This methodology, based on a probabilistic approach, allows for the development of fragility curves as relationships between the mean damage grade μ_D and the PGA [4] in order to estimate the expected damage values for both the whole aggregate and the single SU (Fig. 2). The damage cumulative probability distributions are represented by the upper and lower bounds of the fragility domain and by a *mean distribution curve*, which represents the most probable expected damage values for different intensity seismic grades. On the other hand, for comparison purpose, a mechanical procedure for assessing seismic vulnerability is carried out by the 3Muri software [5].

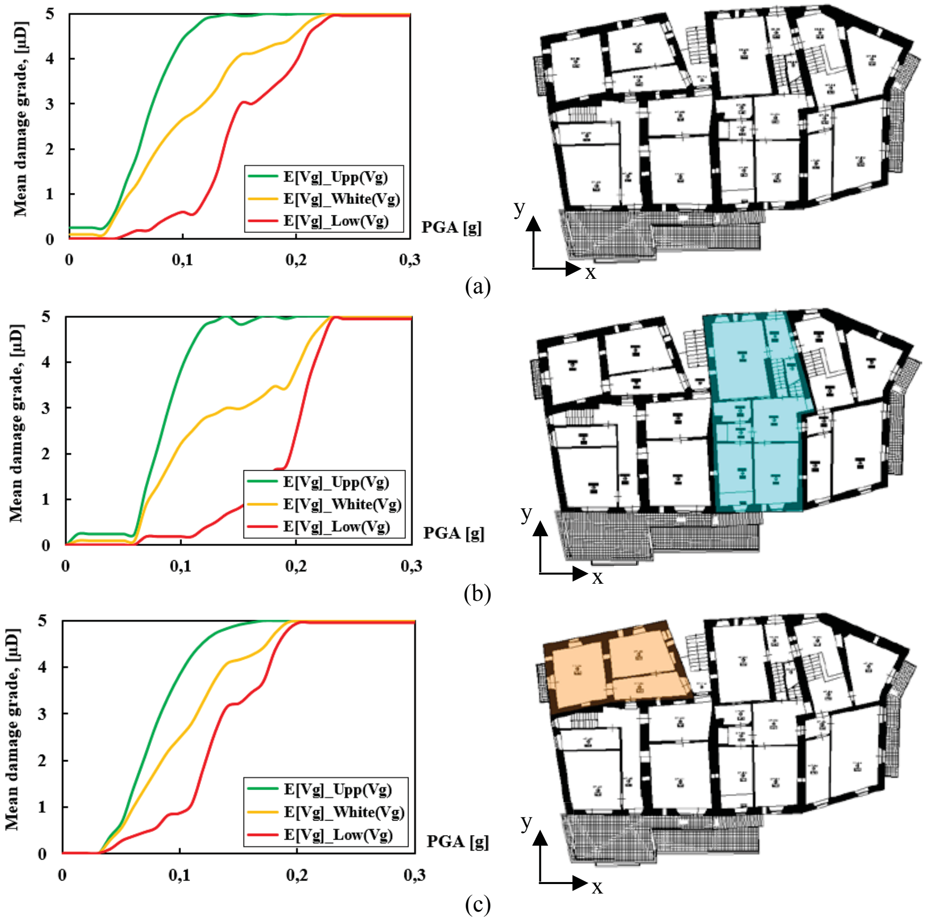


Figure 2. (a) Fragility curves in X direction for the whole aggregate, (b) for intermediate, and (c) corner SU according to the Vulnus software.

Firstly, non-linear static analyses are performed on the whole aggregate. Subsequently, in order to consider the effect of the mutual interaction among single SU, the pushover curves of intermediate and corner buildings are derived through an appropriate reconstruction procedure [6]. Later on, the fragility curves are defined on the basis of damage thresholds (DSi, with i = 1, 2, 3 and 4) defined in Table 1 [7]. In the mechanical approach framework, the mean damage grade, within the range [0-5], is estimated as the ratio between the seismic demand displacement and the seismic capacity one. As an example, the fragility curves of the whole aggregate and intermediate (8 B) and corner (8 C) SU in the X direction are shown in Figure 3.

Table 1. Damage levels for deriving mechanical fragility curves.

Damage Level		
DS1	$0.7 \cdot \Delta_y$	No damage
DS2	$1.1 \cdot \Delta_y$	Moderate
DS3	$0.5 \cdot (\Delta_y + \Delta_u)$	Intensive
DS4	Δ_u	Collapse

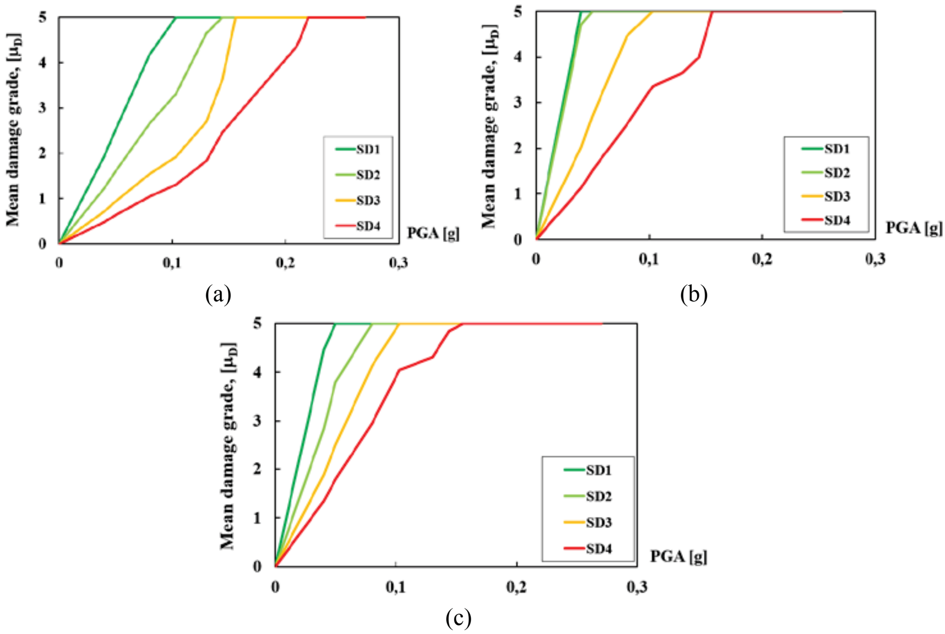
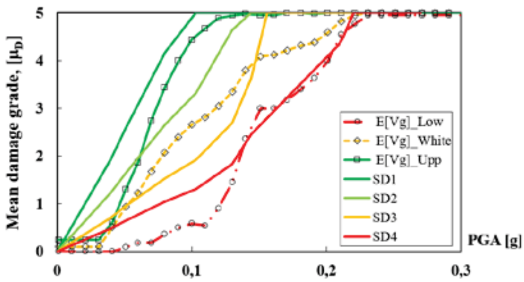


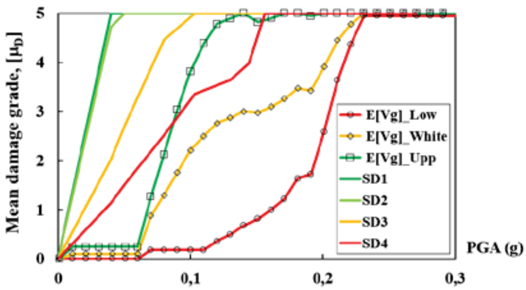
Figure 3. (a) Fragility curves in X direction for the whole aggregate, (b) for intermediate, and (c) corner SU according to the employed mechanical approach.

4. Damage Correlation

The most probable estimation of the expected damage is carried out through a direct comparison between the proposed methodologies. As an example, Fig. 4 shows such comparisons for the entire building aggregate and for the single intermediate SU 8 B in X direction.



(a)



(b)

Figure 4. (a) Comparison among fragility curves in X direction for the whole building aggregate, and (b) SU 8 B.

Considering the entire aggregate, it is apparent that, even if the mechanical approach generally gives rise curves on the safe side, the two methodologies have comparable damage values in the range 0.12g-0.25g for all the limit states considered. The Vulnus software appears to be therefore reliable in predicting the seismic behaviour of the whole building compound. On the contrary, with regard to the analysis of the individual SU 8 B, the Vulnus software tends to underestimate too much the damage grades foreseen by the mechanical approach curves. Therefore, for seismic vulnerability assessment of single SU it is preferable to use the fragility curves deriving from the 3Muri analyses.

5. Conclusions

The seismic vulnerability and risk of a building compound and some of its SU within the historic centre of Arsita has been evaluated through two methodologies based on probabilistic (Vulnus software) and mechanical (3Muri software) approaches. From the results obtained and considering the whole aggregate, the Vulnus software fragility curves fit with a good approximation the mechanical approach for high levels of PGA. On the contrary and in the case of single structural units, the Vulnus software does not provide precautionary results, since it tends to largely underestimate the expected seismic damages predicted by the other approach.

Acknowledgements

The Authors would like to acknowledge Eng. Marco Munari for the collaboration in using the Vulnus Vb 4.0 software.

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Life Cycle Assessment for Vertical Addition Interventions of Existing Masonry Buildings

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Abstract. Several methods were employed to assess sustainable development of building structures with the goal to determine their least environmental impacts. The Life Cycle Assessment (LCA) method was used to evaluate the environmental impact of different construction systems, namely reinforced concrete, masonry, glued laminated timber, and hot-rolled steel, for vertical addition of an existing masonry building. The method takes into account both the production phase and the functional unit installation, but it neglects both the recovery phase and the life end recycling of studied structures. The SimaPro software and the IMPACT 2002+ methodology were employed for the analysis of the environmental impact of the super-elevated structure according to 14 categories of the LCA inventory phase and following four damage categories: Human health, Ecosystem quality, Climate change, and Resources. The results have shown that the production phase is much more impacting than the application phase. Finally, from the comparative LCA analysis it has been demonstrated that the less impacting structure is the one made of hot-rolled steel.

Keywords: Existing masonry building, LCA, sustainable development

1. Introduction

Sustainability implies a development process that sustains over time the reproduction of economic, human/social and natural capitals [1], and in 1987, the World Commission on Environment and Development outlined that "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs" [2]. In response to this need, several provisions were given. A first order of indications comes from the environmental criteria contained in the multi-criteria assessment tools for the environmental certification of buildings (e.g. Leadership in Energy and Environmental Design, known as LEED), which was born on voluntary basis. A second set of indications comes from the environmental assessment of LCA, which, having as horizon the life cycle of products, allows for an

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understanding if technical and manufacturing processes or materials choice can reduce environmental impacts. LCA is born with the political and environmental strategies and regulations. It is a process, allowing for quantifying and assessing the environmental damage related to the whole life cycle (from cradle to grave) of building products, which finds international recognition in the ISO 14040 standard [3]. It should be emphasized that maintenance, repair and replacement (in relation to the durability of materials) processes are not negligible in the environmental balance, since they greatly increase the environmental impacts in the life cycle, especially for "technology-intensive" buildings, such as Zero Energy buildings [4]. The very low or almost zero energy demand should be covered to a very significant extent by energy from renewable sources produced onsite. The UNI EN 15804 standard [5] on the Environmental Product Declaration (EPD) [6], which is an independently verified and registered document that communicates transparent and comparable information about the lifecycle environmental impact of products, involves the obligation to declare the useful life (reference service life) of buildings goods [7] by empowering producers and designers to give high importance to the LCA method application. In fact, extension of the life of buildings and their parts is essential in the environmental sustainability interest. In this sense the maintenance operations, such as repair, replacement and regeneration, are considered positive from the environmental point of view, since they allow the "conservation" of the used materials and, therefore, the prolongation of the useful life of buildings still having a given quality. The demolition of the building would result in the loss of embodied energy in the building and the need to make a new energy investment for new constructions. Finally, another key issue in the LCA evaluation of buildings is represented, in addition to the disposal, by the impact energy of the demolition and separation of materials.

2. Analysis Methodology

The methodological approach used herein aims at assessing which of different construction technologies appear to be the best for a vertical addition system from the environmental point of view. In the first stage, these technologies must be examined according to the objectives and purposes of the assessment. A crucial first step is the definition of the functional unit, especially in comparative evaluations by starting from the function and reference performance of the inspected system and identifying alternative structures. The definition of functional unit is used to quantify a reference flow object of study or the amount of materials needed to meet the expected performance. The different reference flows of various structures are assumed to be useful quantities to calculate inputs and outputs of the evaluation problem. Also in this phase, it is necessary to define the system boundaries, which constitute the interfaces with the environment and with other products systems. They define which procedures are to be included and what to be excluded from the survey. In order to clarify the system boundaries, a flow chart representing the analysed processes and the flows between processes is generally created. The second phase of the LCA method consists of collecting data (inventory) related to processes. For each process inputs and outputs should be quantified and all flows related to each process in each stage of the product life cycle should be evaluated. At first, the overall processes are modelled, so as to have a support for assembling all the data. The material and energy flows are then determined on the basis of both incomes and partial process outputs in relation to the system boundaries. Subsequently, by connecting together the various analysed passages it is possible to simulate the network of connections existing between the structures and the environment. In this way the balances of mass and energy, which become the true inventory of the overall system, can be tracked. In conclusion, all of the material and energy flows passing the boundaries previously set, always referred to the chosen functional unit, are quantitatively evaluated. The third phase of the LCA method is the estimation of environmental impacts, i.e. the evaluation of the contribution of each substance listed in the inventory of different categories of environmental impact. First, the "classification" is done aiming at examining the flow of material and energy, surveyed in inventory, which are assigned to the environmental categories. In the fourth stage, from reading of the entire analysis, the selection of the most impacting life cycle processes and materials used in order to achieve an environmental improvement is highlighted.

The building under study, built around 1900, is located in the district of Naples and as shown in Fig.1 is made of tuff masonry stones [9]. For the population overcrowding problem, the possibility of adding a new story is evaluated. We examined different construction systems made of reinforced concrete, masonry, glued laminated timber, and hot-rolled steel from the environmental point of view for determining, through a LCA analysis, the best option for the vertical addition of the examined masonry building.

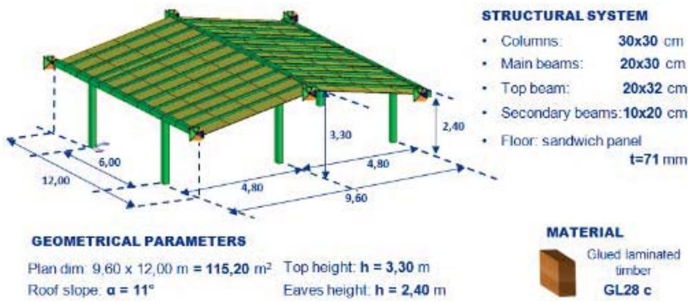
Figure 1. The **c**ase study of a masonry building subjected to a vertical addition intervention.

3. Definition of Functional Units and LCA Analysis Results

Since all the flows to and from the environment must be related to a clear functional unit established for that stage, the details of the amount of materials characterising the investigated vertical addition structures have to be defined. Therefore, through an estimative metric computation carried out on the different structural types (Fig. 2), designed in a previous research work [8], the suitable amount of concrete and steel bars, masonry, glued laminated timber, and hot-rolled steel has been evaluated.

The environmental impact analysis was conducted by means of the Impact 2002+ method and the results are presented in terms of "End point category" or damage categories (Human health, Ecosystem quality, Climate change and Resources).

(a)



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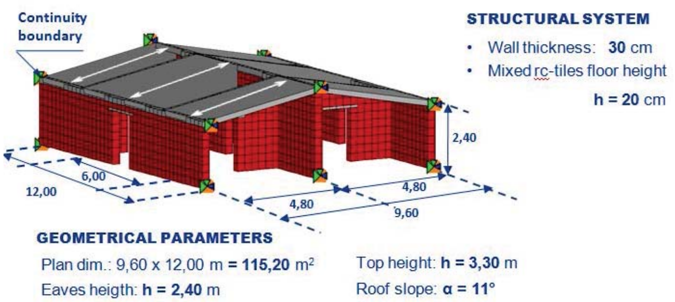

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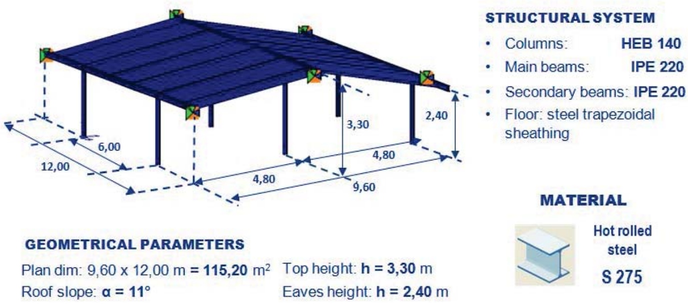

(d)

Figure 2. The selection of the vertical addition structure functional unit made of reinforced concrete (a), glued laminated timber (b), masonry (c), and hot-rolled steel (d).

Different structural systems were analysed with the SimaPro software [9] and compared to each other in order to find the less impacting vertical addition structure (Fig. 3).

As seen from Fig. 2, the worst system is that made of masonry, which attains a 100% impact on Human health, Climate change, and Resources categories, and achieving only an impact of 23% in the Ecosystem quality category.

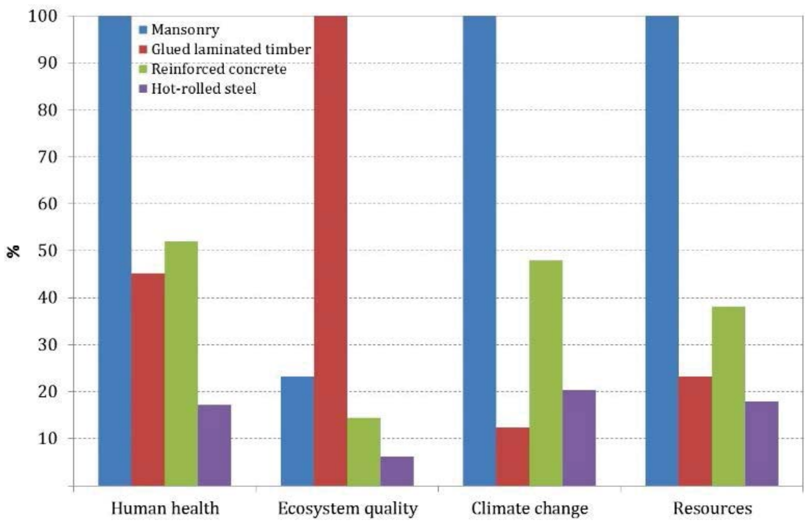

Figure 3. LCA comparative analysis results among different vertical addition structures.

The reinforced concrete represents the most impacting material in three of the four environmental categories. The third place is occupied by the glued laminated timber structure, which attains a 100% impact in the Ecosystem quality class. Finally, the best performance is achieved with the steel structure, which attains the last place showing maximum and minimum impacts of 20% in the Climate change category and ~~of~~ 6% in the Ecosystem quality class, respectively.

4. Conclusions

In recent years, the development, implementation and adoption by the construction industry operators of instruments to assess the environmental sustainability of buildings and materials has been significantly increased. The Life Cycle Assessment methodology is a valuable tool for the environmental sustainability evaluation. In fact, such a method goes beyond just assessing the energy performance of buildings, but analyses all the aspects and impacts associated with the built cycle life, from the production of materials, passing through the construction and use if buildings or facilities, and up to their demolitions. In literature studies there are widespread applications of the LCA methodology for the environmental performance evaluation of new constructions. In this work the attention was focused on the application of the LCA method for identifying, through a comparative analysis, the best material, among reinforced concrete, masonry, glued laminated timber, and hot-rolled steel, for the vertical addition structural system of a Neapolitan tuff masonry building.

The study conducted with the SimaPro software shows how, in the construction of a vertical addition structure of a typical existing building representative of the South Italy and by analysing the four multiple categories of damage, the structure made of hot-rolled steel is the less impacting one from the environmental point of view. In fact, steel, compared to other materials investigated, exhibits the minimum impacts, equal to 20% in the Climate change category, 17% in Resources and Human health categories, and 6% in the Ecosystem quality category. However, the above analysis has some gaps related to the intrinsic limitations of the LCA method. Indeed, this methodology allows for the assessment of impacts defined only locally, but the study conducted at either regional or global levels may not be representative of local conditions. In addition, the environmental impacts are described through a stationary type approach without being defined in space and time. Also, the choices and assumptions made, such as setting the system boundaries, establish under subjective way the data origin and the impact categories. In addition, models applied in the assessment of environmental impacts may not be available for all applications, because they are directly dependent on the assumptions made. Finally, it must be remembered that in the examined case study the demolition and reuse of building materials has not been inspected. It is worth noticing that~~,~~ the steel should be even more the least impacting material since, unlike other materials herein considered, it is highly recoverable (98%) and recyclable (88%). In conclusion, also taking into account both the various uncertainties associated with the use of the LCA method and the absence of information on recycling and recovery of materials different from steel, this work can be used as a guideline for designers and practitioners involved in the selection of best intervention strategies for restructuring the urban vertical addition structures.

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Preventive Conservation of Monuments Based on DELPHI Method and Fuzzy Logic

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Abstract. Preventive conservation requires identification, evaluation, and prioritization of the maintenance and restoration of cultural heritage under different hazards. The degradation of monuments is due to the effects caused by different agents (earthquakes, floods, weathering, pollution agents, anthropogenic factors) that produce total or partial losses of architectonic elements or their alterations. The conservation degree of each monument depends on the vulnerability, and its index is an indirect function of the level of deterioration, whereas the hazards depend on the localization and its environment conditions, social development and anthropogenic agents. RIVUPH and Art-Risk are Spanish projects based on the analysis of environmental risk in historical cities and models to assess vulnerability and lives of buildings in order to improve the preventive conservation of monuments with similar characteristics. For this purpose, two different approaches have been evaluated: DELPHI method and Fuzzy Logic,

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where both tools are based on the opinion of experts in the field. The vulnerability analysis of three churches of Seville (Spain) have been studied to assess the monuments' conservation degree. Both models (DELPHI and Fuzzy Logic) are able to forecast the necessities of restoration overlapping different scenarios.

Keywords: Hazard, vulnerability, preventive conservation, artificial intelligence, GIS, heritage building.

1. Introduction

European Council established the recommendations on architectural heritage protection against natural disasters such as earthquakes, floods, fires, etc. [1]. Since 1993 the concepts have evolved, including preventive conservation, emergency managements, and resilience. Preventive conservation reduces high cost of cultural heritage interventions and allows to preserve buildings and to increase the resilience of monuments in historical cities.

An optimal maintenance or preventive conservation strategy acts both against disasters and against damages caused by the passage of time, and for this purpose new methodologies based on multi-scenario risks as a combination of hazards and vulnerabilities have been developed [2].

2. Methodology

The conservation degree of each monument defines its vulnerability, response to emergency situations, and preparedness for resilience, whereas the hazards depend on their design, location and its environment conditions, social development, and anthropogenic agents. RIVUPH and Art-Risk are Spanish projects based on the analysis of environmental risk in historical cities and models to assess vulnerability and lives of buildings in order to improve the preventive conservation of monuments with similar characteristics.

In this paper, two different approaches based on DELPHI method [3] and Fuzzy Logic [4] have been applied to three monuments (Santa Marina, Omnium Sanctorum, and San Marcos) by 10 experts as a blind interlaboratory experiment.

3. Results

Santa Marina, Omnium Sanctorum, and San Marcos are Gothic-Mudejar churches dating from the thirteenth and fourteenth centuries and are located in the historical city of Seville (Spain), established as parish churches after their recapture in 1248. Table 1 shows the expanded vulnerability index (Vie%) and fuzzy buildings service life (FBSL) of the three buildings studied by the 10 experts.

Table 1. Expanded vulnerability index (Vie%) and fuzzy buildings service life (FBSL) of Santa Marina, Omnium Sanctorum, and San Marcos churches in Seville.

Churches	Vie(%)	FBSL (years)
Santa Marina	30±9	21±8
Omnium Sanctorum	42±18	27±6
San Marcos	23±5	27±11

Expanded vulnerability index (Vie%) suggests that the Omnium Sanctorum building needs an intervention before the church Santa Marina, whereas the fuzzy building life FBSL index suggests that Santa Marina is the monument that needs first intervention. The deviations vary between 5-18 years and depend on the experts' opinions about the degree of conservation. This implies that further studies and a second round analysis on expert decisions are necessary to categorize the damage.

4. Conclusions

Both DELPHI method and Fuzzy Logic procedures provide protocols to develop policies for making decisions about which monuments should be preserved on a list of monuments. These methodologies allow comparisons of risks of buildings of similar characteristics to analyses strategies for cultural heritage preservation, though they are limited in accuracy. This enables Public Administration to make decisions for preventive conservation, resilient policies, and prioritize the restoration resources of a city or even a region. Further studies should focus on the uncertainty associated in the analysis.

5. Acknowledgments

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Vulnerability, Digital Image Analysis and 3D-Documentation Applied to the Study of Building Resilience

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Abstract. Vulnerability assessment is a way to evaluate the resilience of a monument. RIVUPH and Art-Risk are Spanish projects based on the development of new tools for preventive conservation strategies. For this purpose, the vulnerability of buildings has been studied with different techniques based on DELPHI methodologies and compared with in-situ diagnosis. The vulnerability analysis depends on the degree of conservation of monuments and the vulnerability index (VI %) was calculated based on a vulnerability matrix (VM) which is also based on intrinsic variables and lives of monuments that depend on weathering forms, their evaluation, and their extension. The weathering forms evaluation can be studied according to risk assessment. This methodology has been compared with weathering maps, carried out by digital image analysis, CAD, 3D-documentation, LIF-2D maps or UAVS application with IR and cameras. These techniques have been applied to different monuments studied in Spain and Colombia in order to understand the advantages and disadvantages for the surveillance and monitoring of vulnerability. The combination of these methods of monitoring allows quantifying the vulnerability of cultural heritage monuments, and is a very useful tool to evaluate and prioritize the resilient policies.

Keywords: Vulnerability, weathering maps, resilience, heritage building.

1. Introduction

Risk assessments are based on the management of the triangle defined by use, conservation (that is vulnerability), and development of its cultural value [1]. Knowledge of risks and hazards are based on the experience and the archive of previous disasters. This information allows to decide the best strategies for preventive conservation [2]. Nevertheless, the behavior of a building under these episodes or after the events de-

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pends on the degree of conservation or vulnerability. Ortiz and co-workers [3] have developed a methodology for risk and vulnerability that evaluates the conservation degree based on diagnosis and frequency or extension of damage. This methodology could be used before the disaster, after the disaster, or during the period of recovering. In this paper different methodologies to evaluate weathering maps are analyzed.

2. Methodology

The vulnerability index (VI%) for each monument is determined by an on-site study, where the frequency and weathering degree of the deterioration patterns were considered during an on-site inspection [3, 4]. The weathering forms could be set according to risk assessment with tables of frequency and level of damage: Frequency between 1 and 3, where 1 means that it is difficult to detect this weathering form, 2 implies that the weathering form is identified easily, and 3 is applied if the pathology occurs at a high rate. On the other hand, the weathering degree is classified in five relative classes, according to the scale used by Fitzner [5]. Weathering forms frequency and damage value are combined in order to obtain a numerical value of the weathering forms' intensity for each monument [3, 4].

Weathering maps is a way to evaluate the frequency and level of damage that allow a quick assessment for vulnerability approach; different methodologies such as digital image analysis, CAD, 3D-documentation, LIF-2D maps or UAVS application with IR and cameras were compared in order to study the monitoring advantage.

3. Results and Discussion

The vulnerability has been studied on about one hundred monuments that has allowed to develop a cognitive diagram of relationships between different variables and the vulnerability index to improve the method of risk analysis.

Foundation, structure, and construction methods have the clearest influence on the vulnerability index, since these variables could produce the collapses of monuments and total or partial losses of buildings. Physico-chemical characteristics, texture and fire-resistance define the conservation degree of the materials and have a medium influence, which is mainly dominated by the quality of materials. Aesthetic appearance has the lowest influence of the variables, in spite of being the first pathology to be detected.

Digital image analysis [6, 7, 8], CAD [9, 10], 3D-documentation [11], LIF-2D [12] maps or UAVS application with IR and cameras [13] allow to detect weathering forms, though not all the types could be detected. Table 1 summarizes the methods, cases of study and the advantages and disadvantages for vulnerability assessment. All the techniques are non-destructives and the main differences are based on the accuracy of detection and the possibility to quantify.

Table 1. Methods and their advantages and disadvantages for surveillance and monitoring of vulnerability.

Methods	Case Study	Advantage and Disadvantage
Vulnerability	Churches of Seville	Low-cost methodology that allow a fast diagnosis

Index Frequency and level of damage	Churches of Colombia Modern Building of Cuba,Walls of Seville	The quantification is subjective
2D Maps Digital Image Analysis (AUTOCAD AND ADI)	Cathedral of Cadiz (18th cent.) Different churches of Seville (13th-18th cent.) Tobacco Royal Factory (18th cent.) Roman Wall of Marchena	AUTOCAD & ADI allow to assess main weathering forms DIA Based on black and white analysis allow to quantify DIA Problems with shadow and reliefs DIA allows to identify thickness of some weathering forms CAD Time consuming and need of scaffolding CAD Quantification based on weathering forms inspection
3D Maps (AUTOCAD AND ADI)	Magdalena Church (Sevilla) (17th-18th cent.) Cathedral of Cadiz (18th cent.)	3D Maps allows to quantify structural damages and the relationship between weathering forms and architectonic structures
2D and 3D Maps UAVS	Tobacco Royal Factory (18th cent.) Church in Castellon	No need of scaffolding Presence of defocused and blurred frames (IR and visual) Shadows and wind: Choose cloudy days and/or the right hour for testing Higher sensitivity is desirable for IR and visible camera Time-consuming for digital mosaic images Quality of images taken from the UAVs does not allow a clear quantification of damages Temperature differences have been detected on cornices and basements with the UAVs Special care should be devoted to select sensors that fit their usually limited payload capability
LIF-2D maps	Chapel del Buen Aire (San Telmo Palace, Seville, 17th-18th cent.) St. Augustine Church (Marchena, Sevilla, 18th cent.) San Jerome Church (Granada, 18th cent.) Saint Christ of Health Church (16th-17th cent.)	Analytical information on 2D images distribution of different consolidant treatment, detachment, fractures and bio-attack Fast, Non invasive, Remote (up to 25 m) Sensitive and selective The technique gives additional information on: Different materials and methods applied Conservation degree Bio-attacks and biocrust and stones Laboratory data bases are needed prior to field campaigns The use of digital image analysis combined with statistical analysis improve the possibility to extract information. Further studies are necessary because of LIF+PCA+DIA are a very promising technique for Cultural Heritage

DIA and UAVS are useful after disasters, while LIF and CAD are useful for the evaluation of monuments, but they are time-consuming. Most of these techniques could cover only part of the weathering forms, so it would be advisable to use a combination of them. Further studies will be necessary to match vulnerability index and weathering maps.

4. Conclusions

The application of weathering maps based on DIA and UAVS to diagnosis and resilience generally reduces the time of analysis, because these techniques can cover the target area in a very short time and a safer way. Each technique is suitable for different weathering forms, which necessitates the availability of different equipment and software with different sensors. Assessment for CH must be carried out to demonstrate the quality of the results. The combination of these methods of monitoring allows quantifying the vulnerability of cultural heritage monuments, and it is a very useful tool to evaluate and prioritize the resilient policies.

5. Acknowledgments

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Diagnosi e monitoraggio per la valutazione e riduzione del rischio sismico del patrimonio storico in muratura dei Sassi di Matera

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Riassunto. La conservazione, il recupero e il risanamento conservativo del patrimonio storico architettonico risultano temi di ricerca attuali e di particolare interesse, considerando la eccezionale ricchezza del patrimonio storico-architettonico in muratura presente in Basilicata e nell'area della città di Matera. Nonostante i numerosi studi condotti risultano molteplici i problemi rimasti irrisolti che riguardano il patrimonio architettonico materano e nella fattispecie gli edifici in muratura. Questi ultimi versano in condizioni di degrado e gli interventi risultano spesso non tempestivi e non efficaci con conseguente perdita di valori irriproducibili e irripetibili per la società di cui sono emanazione. Ad oggi gli interventi standard eseguiti sui patrimoni architettonici risultano spesso inadeguati, a causa di una non adeguata programmazione della diagnostica e del monitoraggio del bene su cui intervenire. Risulta necessario, pertanto, effettuare campagne di indagini tecnologicamente sviluppate sulle murature tipiche della Basilicata, al fine di definire modelli operativi per il calcolo della vita residua delle opere, utili a privati ed enti gestori. In tale ottica, la diagnostica innovativa, il monitoraggio e la definizione di modelli di calcolo semplificati di comprovata validità effettuati sugli edifici in muratura del Materano, svilupperebbe codici di pratica validi e utilizzabili per tutti gli edifici in muratura presenti sul territorio italiano.

Parole chiave: Diagnostica, monitoraggio, Sassi di Matera.

1. Introduzione

L'attività di ricerca si pone l'obiettivo di effettuare opportune metodologie di rilievo, indagine storica e tecnologica, diagnosi e monitoraggio. Come esplicitato precedentemente l'utilizzo della calcarenite di Matera impone di focalizzare l'attenzione verso indagini materiche, quindi esecuzione di prove su malta e sugli

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elementi lapidei che costituiscono le murature. L'esecuzione di campagne di indagini innovative permette la creazione di modelli di calcolo semplificati ottenuti dalla correlazione tra indagini diagnostiche, monitoraggio e calcoli analitici al fine di definire una metodologia operativa da utilizzare per gli edifici in muratura.

Il patrimonio architettonico della Basilicata e, nello specifico, della città di Matera (Fig. 1) rappresenta un bene e una risorsa di inestimabile valore per la collettività [1]. Costruito tradizionalmente in muratura, utilizzando blocchi di calcarenite, risulta essere il frutto congiunto di una straordinaria stratificazione di ricchezze, di civiltà e di diversità che hanno caratterizzato i luoghi nel corso della storia e che rappresentano un'evidente testimonianza dell'identità storica-culturale dei popoli e di come questa sia mutata nei secoli.

Figura 1. Chiesa di San Francesco D'Assisi (sinistra) e Chiesa di San Pietro Caveoso (destra) nella città di Matera patrimonio UNESCO.

Gran parte del patrimonio architettonico e culturale di Matera, estremamente vulnerabile ai fenomeni naturali quali terremoti e/o alluvioni, necessita di studi e analisi approfondite. Con il fine di evidenziare le criticità intrinseche che caratterizzano le strutture in muratura, il primo passo verso la tutela e la conservazione di tale patrimonio deve essere diretto verso una profonda comprensione dello stato dell'arte. In tale ottica, imprescindibile è la fase preliminare di diagnostica e monitoraggio del patrimonio. Attualmente, nonostante lo sviluppo tecnologico abbia portato allo studio e al perfezionamento di nuove procedure, le tecniche utilizzate risultano essere spesso obsolete. Nasce dunque la necessità di una svolta che consiste nell'effettivo utilizzo di tali metodologie d'indagine avanzate.

Necessario è lo sviluppo di strumenti innovativi per il monitoraggio e la diagnostica che passa attraverso l'esecuzione di una campagna di indagini in sito e in laboratorio [2], da effettuarsi sul patrimonio storico costruito nell'area materana. La grande varietà di tipologie di Chiese sia scavate che costruite presenti nella città di Matera la rendono il caso studio ideale per definire codici di pratica utilizzabili anche per altre Chiese in muratura presenti sul territorio nazionale.

2. Obiettivi

L'attività di ricerca si pone l'obiettivo di proporre opportune metodologie di rilievo, indagine storica e tecnologica, diagnosi e monitoraggio al fine di proporre un protocollo operativo per la conoscenza del patrimonio del costruito in muratura. La caratterizzazione del singolo manufatto impone l'attenzione verso indagini materiche, quindi esecuzione di prove su malta e sugli elementi lapidei che costituiscono le murature.

L'esecuzione di campagne di indagini innovative permette, inoltre, la creazione di modelli di calcolo semplificati ottenuti dalla correlazione dei risultati ottenuti dalle indagini diagnostiche, il monitoraggio e da calcoli analitici. Nella Fig. 2 si schematizzano gli obiettivi.

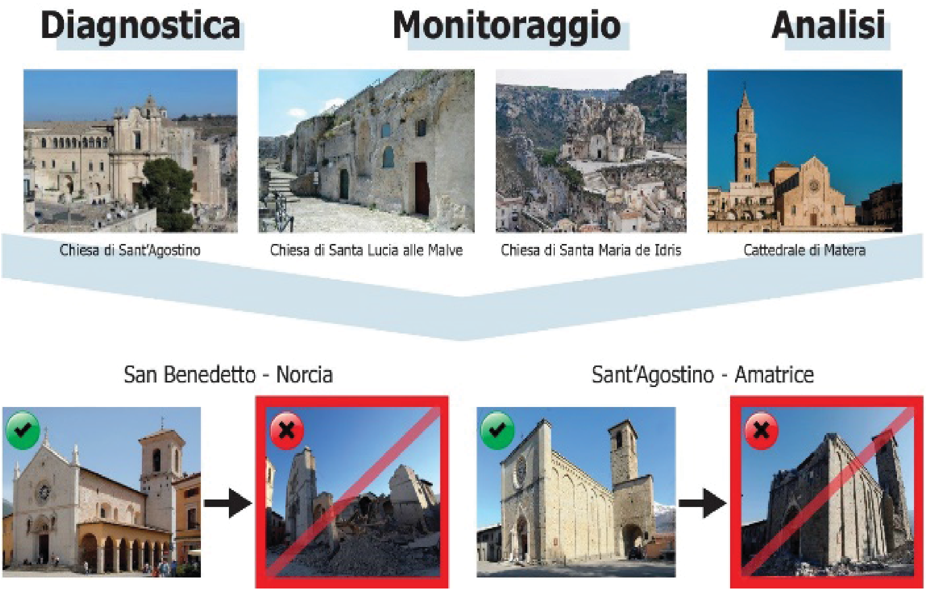

Figura 2. Schematizzazione degli obiettivi.

3. Metodologia proposta

La proposta di un protocollo operativo, attraverso la sua applicazione, può consentire di pervenire alla conoscenza del manufatto, ovvero della geometria (dimensioni degli elementi strutturali principali e secondari), dei dettagli costruttivi, del danneggiamento e dello stato di degrado. Tale protocollo si suddivide in due fasi.

La prima fase, eseguita esclusivamente in sito, consiste nel rilievo da eseguirsi con la tecnologia avanzata della rappresentazione e del rilevamento assistito [3] (sistema di rilevamento architettonico ed urbano con tecnologia Laser Scanner 3D). Il risultato dell'acquisizione è un insieme di punti sparsi nello spazio in modo più o meno regolare che comunemente viene chiamata “nuvola di punti”. Tale tecnica innovativa consente di definire in maniera dettagliata la geometria di elementi strutturali anche complessi (quali ad esempio volte, archi e cupole). Altre tecniche innovative che consentono di effettuare rilievi geometrici utilizzano la fotogrammetria. La fotogrammetria è una tecnica che permette di acquisire dei dati metrici di un oggetto tramite l’acquisizione e l’analisi di fotografie. Lo sviluppo di mezzi aerei a pilotaggio remoto, quali droni, hanno permesso di utilizzare la fotogrammetria anche per rilievi architettonici. Tramite alcuni software si eliminano gli errori intrinsechi della fotografia quali per esempio la deformazione prospettica e la deformazione ottica. Successivamente gli stessi software consentono di estrapolare quelle che sono le sezioni e i prospetti piuttosto che il modello 3D degli edifici precedentemente fotografati. La Fig. 3 mostra un rilievo effettuato con la tecnica del Laser Scanner 3D e uno con la tecnica fotogrammetrica. Nella seconda fase si prevede di effettuare indagini tradizionali ed innovative sia in sito che in laboratorio. Tra le prove tradizionali, vi è per esempio, quella del martinetto a piatto singolo.

Figura 3. Rilievo effettuato con la tecnica del laser scanner 3d (sinistra) e rilievo effettuato con la tecnica della fotogrammetria (destra).

Le indagini effettuate tramite il martinetto [4] singolo hanno lo scopo di determinare lo stato tensionale locale all’interno di una struttura e la definizione di parametri di deformabilità e resistenza della muratura. Il martinetto piatto singolo si basa sul concetto di eseguire un taglio in un corpo e di sostituire al materiale asportato delle forze che siano in grado di ripristinare le condizioni iniziali dell’elemento. Nella seconda fase, una delle indagini innovative proposte, consiste nel monitoraggio dinamico delle strutture che insieme al tradizionale monitoraggio statico, sta guadagnando negli ultimi anni un sempre crescente interesse sia nel panorama della ricerca scientifica che in ambito professionale. Attraverso l’analisi dei dati acquisiti è possibile risalire ai principali parametri modali della struttura (frequenze proprie, smorzamenti e forme modali) e conoscerne il comportamento dal punto di vista dinamico [5]. Tali parametri dinamici costituiscono “l’impronta digitale” dell’edificio e la ripetizione delle prove a distanza di tempo consente l’identificazione di mutamenti non sempre individuabili con monitoraggi statici. La conoscenza dei parametri modali permette, inoltre, la calibrazione di modelli strutturali agli elementi finiti (modelli FEM) che possono essere utilizzati sia per la valutazione della vulnerabilità sismica della struttura e quindi per il progetto di eventuali interventi, sia per l'individuazione delle cause che possono aver determinato cambiamenti nel comportamento dinamico. Si prevedono, inoltre, nella seconda fase indagini materiche: prove penetrometriche (in sito), calcimetriche (in laboratorio) ed osservazioni al microscopio elettronico a scansione (innovative). Le diverse tipologie di indagini saranno scelte opportunamente in relazione agli output che quest'ultime permettono di ottenere in riferimento al caso studio in esame.

4. Analisi dei risultati

La proposta di modelli di calcolo semplificati parte dall'esecuzione di due differenti tipologie di analisi presenti in letteratura e attualmente utilizzate in ambito professionale. La prima tipologia di analisi contempla una modellazione semplificata per macro-elementi, con relativa analisi e valutazione dei possibili meccanismi di collasso che possono coinvolgere gli stessi. Tale metodologia, sebbene meno raffinata, risulta poco onerosa in termini computazionali. La seconda tipologia prevede una modellazione agli elementi finiti di macro-elementi, con relativa analisi non lineare "pushover" e meno semplificata, al fine di valutare in questo caso la curva di capacità del macro-elemento che si andrà a modellare. Tale metodologia a differenza della precedente consente di ottenere risultati più attendibili a discapito degli oneri computazionali che risultano essere superiori. I modelli di calcolo più complessi si andranno ad adeguare al caso studio scelto e alle prove in sito e in laboratorio effettuate. I modelli di calcolo adattivi sono in grado di ricavare risultati estremamente attendibili a valle di calcolazioni matematiche complesse. Pertanto da quest'ultimi si andranno a ricalibrare i modelli di calcolo semplificati al fine di migliorarli dal punto di vista dell'accuratezza dei risultati.

5. Conclusione

In conclusione, il protocollo operativo proposto permetterebbe di standardizzare le procedure di indagini che portano alla conoscenza del manufatto storico. Attraverso lo studio di numerosi casi studio, scelti ad esempio in funzione della tipologia strutturale, sarà possibile calibrare i risultati delle analisi semplificate di macro elementi in funzione delle analisi pushover ottenendo così risultati più speditivi e con un livello di accuratezza maggiore utilizzabili da tutti i tecnici professionisti che operano nel campo della conservazione e recupero del patrimonio storico.

Riferimenti

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NDSHA
Scenario Based Seismic Hazard Assessment

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Abstract. For relevant engineering purposes, or for historical buildings and monuments, a viable alternative to standard estimates of seismic hazard is represented by the use of the scenario earthquakes, characterized in terms of magnitude, distance and faulting style, and taking into account the complexity of the kinematic source rupturing process. This multi-scenario-based Neo-Deterministic Seismic Hazard Assessment (NDSHA) method naturally supplies realistic time series of ground motions that are readily applicable to engineering analyses. Such a methodology has been successfully applied to many urban areas worldwide for the purpose of seismic microzoning, to strategic buildings, lifelines and cultural heritage sites, and in this paper its application is presented for the city of Trieste.

Keywords: Earthquake scenario, seismic hazard, seismic input

1. Introduction

NDSHA is a widely applied neo-deterministic procedure for physics-based seismic hazard assessment, that supplies realistic time histories from which it is possible to retrieve, in correspondence of earthquake scenarios: (a) Peak values for ground displacement, velocity and design acceleration at bedrock level for the regional scale, and (b) spectral accelerations, time histories, and other relevant damage indicators, for the local scale [1-4].

Where the numerical modelling is successfully compared with records, the synthetic seismograms permit the microzoning, based upon a set of possible earthquake scenarios, and where no recordings are available the synthetic signals can be used to estimate the ground motion without having to wait for a strong earthquake to occur (pre-disaster microzonation). This approach allows to incorporate all available information collected in geological, seismotectonic and geotechnical databases of the sites of interest as well as advanced physical modelling techniques to provide a reliable and

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robust basis for the development of a neo-deterministic design basis for cultural heritage and civil infrastructures in general.

The NDSHA methodology has been successfully applied to many areas worldwide [1-3], to strategic buildings, lifelines and cultural heritage sites, and, for the purpose of seismic microzoning, to several urban areas (e.g. in the framework of the UNESCO/IUGS/IGCP project “Realistic Modelling of Seismic Input for Megacities and Large Urban Areas” [2]. In this work we show some examples of multi-scenario hazard study for North-East Italy, and in particular for the city of Trieste, by also using the web application created by Vaccari [5].

2. Site-Specific NDSHA

2.1. Some Computational Basics

The computation of seismograms by means of NDSHA is accomplished in two steps of simulations, by the rupture process on the faults and by the propagation of seismic waves through the definition of a transfer function (Green’s function) (Fig. 1). A double-couple or a tensor that represents a dislocation consistent with the tectonic character of the considered source (seismogenic zone, seismogenic node or fault description) represents the focal mechanism at the hypocenter, whereas the sources are modeled as point sources scaled in size and duration (STSPS) (Fig. 2).

The STSPS model is based on an extended source model provided by the PULSYN06 algorithm [6] which considers a reference scaling law for source spectra (SLSS). The SLSS used in the “Model 6” of Panza and co-workers [3] reasonably represents the seismic source data at a global scale, whereas Magrin and co-workers [7] updated the SLSS focusing on the Italian region. A further upgrade of the procedure is the generation of different stochastic realizations of the source model (slip distribution and rupturing velocity), for each source-to-site path. This is done to account statistically for the variability of the ground motion at a site due to unpredictable variations in the rupture process, which can have a strong impact on ground motion critical features.

In the standard NDSHA the Green’s function at a site is computed using the Modal Summation (MS) technique ([1] and references therein). The MS technique is computationally very fast and provides an adequate simulation of ground motion in the far field, while the Discrete Wave Number technique (DWN) is used in the near field conditions (short paths).

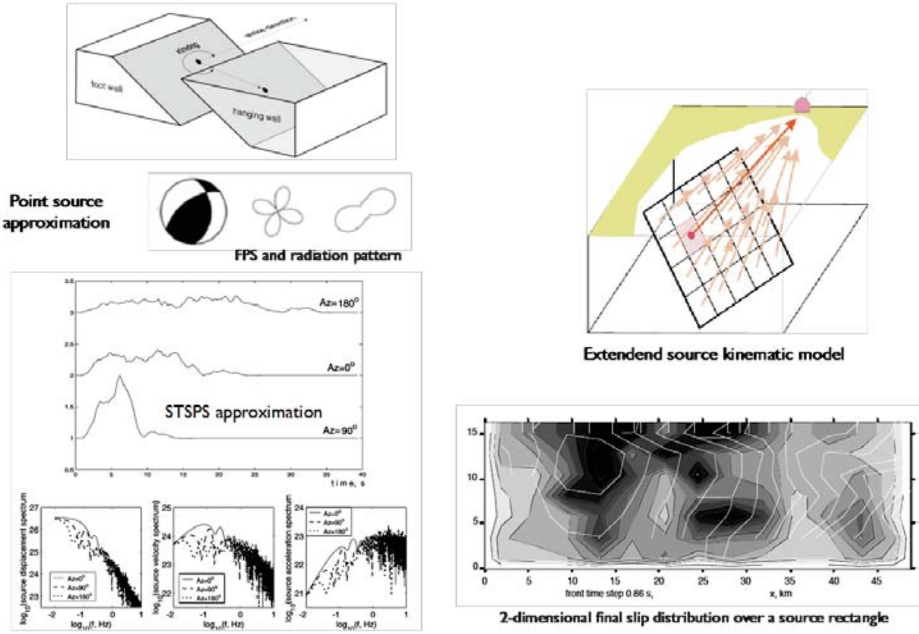


Figure 1. Representation of source models in NDSHA.

2.2. Parametric Studies

One of the most difficult tasks in earthquake scenario modelling is the treatment of uncertainties, since each of the key parameters has an uncertainty and natural variability, which often are not quantified explicitly. A possible way to handle this problem is to vary the modelling parameters systematically. Actually, a severe underestimation of the hazard can be produced by fixing a priori some source characteristics and thus the parametric study should take into account the effects of various focal mechanism parameters (strike, dip, rake, depth, etc.).

The analysis of the parametric studies allows for the generation of advanced groundshaking scenarios for the proper evaluation of the site-specific seismic hazard, with a complementary check based on both probabilistic and empirical procedures.

As an example of the application of NDSHA for Venice, 16 seismogenic sources were identified, and the parameters of the focal mechanisms of these sources were then the object of parametric studies to determine the predominant seismic input for this city (Fig. 3).

In all cases and in order to obtain the Maximum Credible Earthquake (MCE) and the associated shaking scenario, the maxima of transversal accelerations T (SH waves, Love modes) and Radial R and vertical Z (P-SV waves) accelerations were studied separately (Fig. 4).

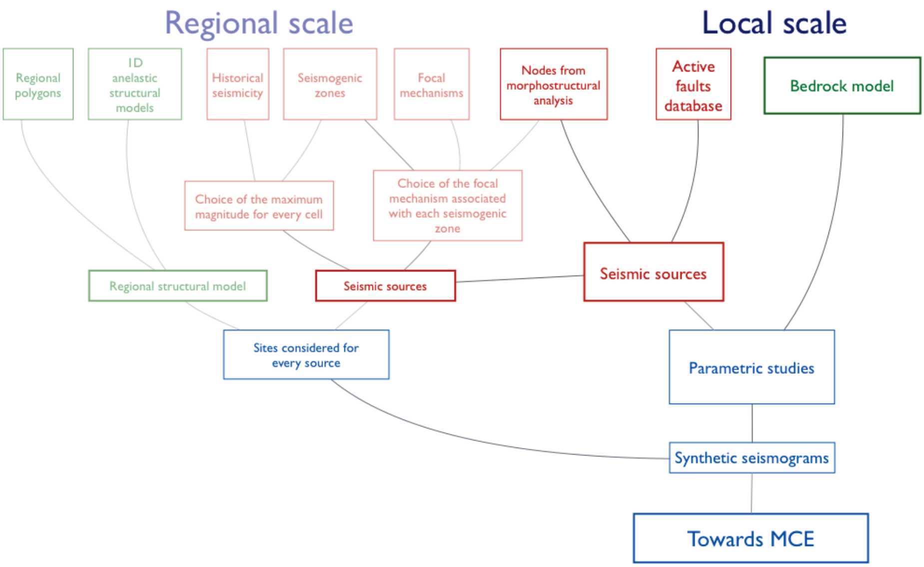


Figure 2. Flowchart of local NDSHA, usually adopted for regional scale, for MCE scenarios.

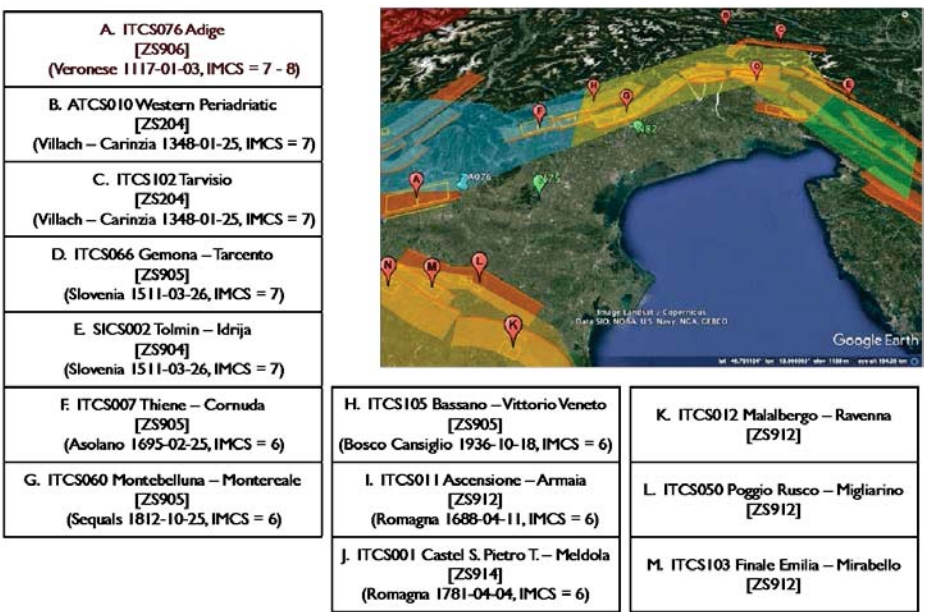
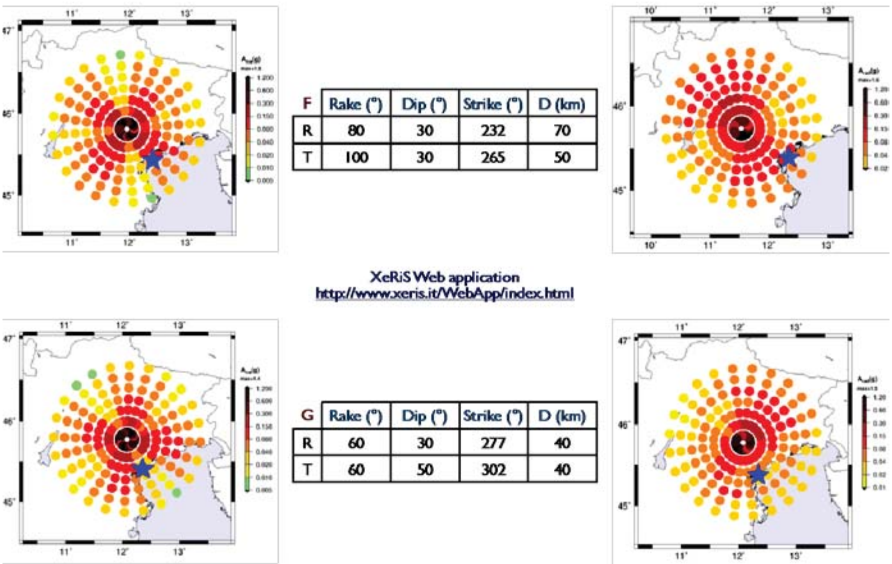


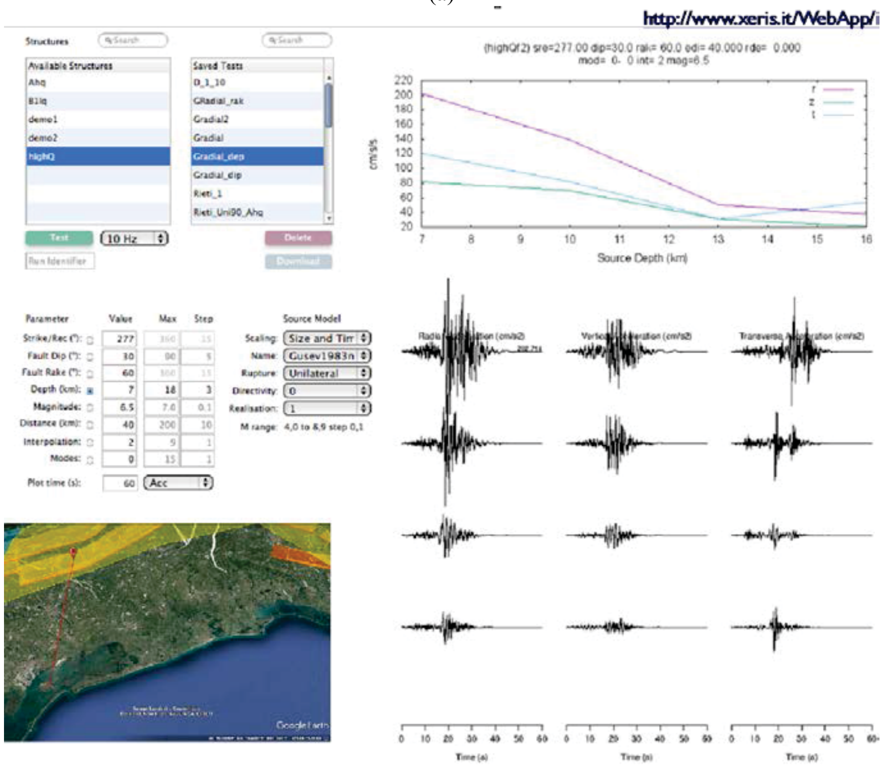
Figure 3. Earthquake scenarios considered for the city of Venice.



F	Rake (°)	Dip (°)	Strike (°)	D (km)
R	80	30	232	70
T	100	30	265	50

G	Rake (°)	Dip (°)	Strike (°)	D (km)
R	60	30	277	40
T	60	50	302	40

(a)



(b)

Figure 4. Examples of parametric studies performed for local scale scenarios: Strike and distance for F and G (a); depth for G (b).

2.3. Site Effects Estimation

Once the gross features of the seismic hazard are defined and the parametric analyses have been performed, a more detailed modelling of the ground motion can be carried out for sites of specific interest. Such a detailed analysis should take into account the source characteristics, the paths and the local geological and geotechnical conditions.

A hybrid method based on computer simulations that exploits the knowledge about the source process, the path source-to-site and the local site conditions has also been developed, and it combines MS with the finite-difference technique [1]. Here the wave field generated by MS is introduced in the mesh that defines the local hetrogeneous area and is propagated according to the finite-differences scheme (Fig. 6). The site effects are then evaluated as spectral amplifications, described by the ratios (2D/1D) of the acceleration response spectra, with 5% damping, computed along the bedrock model (1D) profile and along the one containing the local model (2D) (Fig. 6).

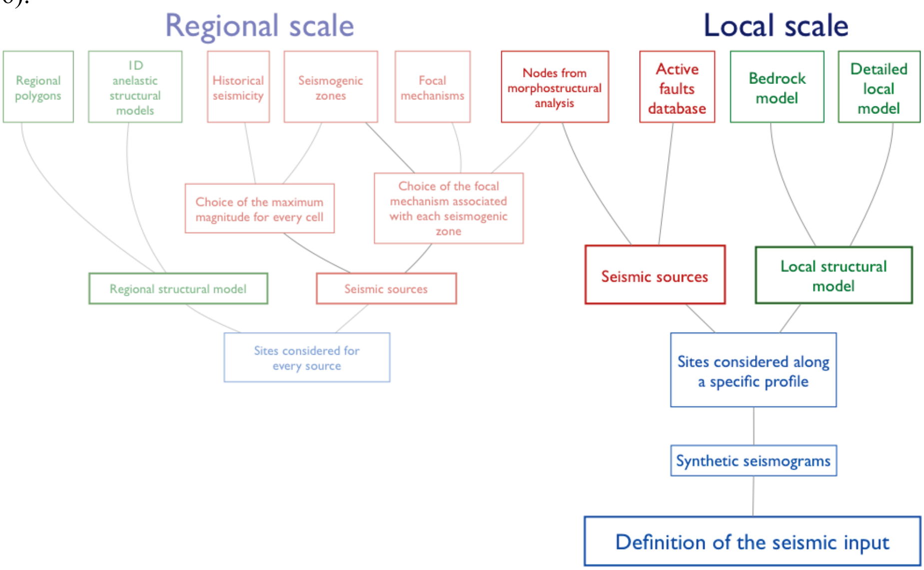


Figure 5. Flowchart of local NDSHA, usually adopted for regional scale, for the definition of seismic input at selected sites.

2.4. Application to Trieste

An example of the application of NDSHA technique to the city of Trieste is given in Fig. 7. The procedure we developed and applied to several relevant buildings of the Trieste Province (and later to the Marciana Library in Venice) that led to the seismic verification of a building by: (a) use of a scenario based NDSHA approach for the calculation of the seismic input, and (b) control of the numerical modeling of an existing building, using free vibration measurements of the real structure. The key point of this approach was to restrict collaboration of the seismologist and civil engineer, from the seismic input definition to the monitoring of the response of the building in the calculation phase.

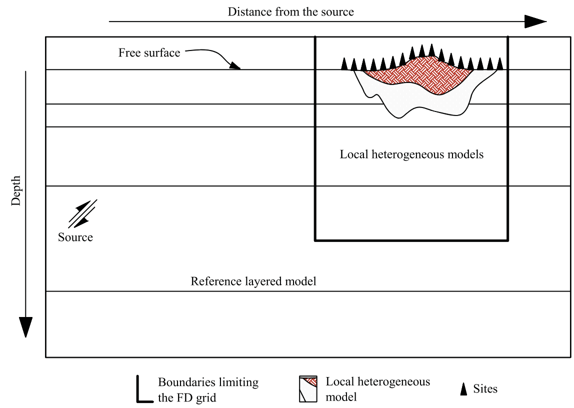


Figure 6. Scheme of the hybrid approach adopted for the computation of the seismic input at a local scale.

Figure 8 provides a summary of the process: The engineer can “enter” in the spectrum by adopting the correct range of periods, I_E, and then "get out" with realistic values of acceleration, I_A, to be applied to the calibrated model. This is obtained by taking into account the appropriate amplification given by the scenario input.

NDSHA-MCSI (henceforth called MCSI) can be defined as a Response Spectrum or as a set of accelerograms (Fig. 9), and in engineering analysis all the accelerograms generated by NDSHA can be used to perform nonlinear analysis of a structure. However, since thousands of ground motions are simulated, the available information needs to be prioritized, in order to reduce the analysis time. Following the NDSHA method, MCSI can be defined at a given site at two levels of detail: The first provides the “Maximum Credible Seismic Input at bedrock” ($MCSI_{BD}$), without considering the site effects; and the second considers the local structural heterogeneities that are then carried out for each source-to-site path as described before, allowing us to determine the “Maximum Credible Seismic Site Specific Input” ($MCSI_{SS}$). The procedure described and validated in Fasan and co-workers [4] has also been applied to selected sites in Trieste.

3. Discussion and Conclusions

The seismological and morphostructural analyses allow for the definition of the “scenario earthquakes", i.e. of the strong earthquakes that may take place in the region of interest. For those earthquakes, a database of accelerograms is obtained by the realistic modelling of the ground motion, carried out using the physical-mathematical principles that are at the basis of the generation, propagation and local amplification of the seismic waves [1-3], as suggested by the NTC 2008 and 2018 Italian regulations.

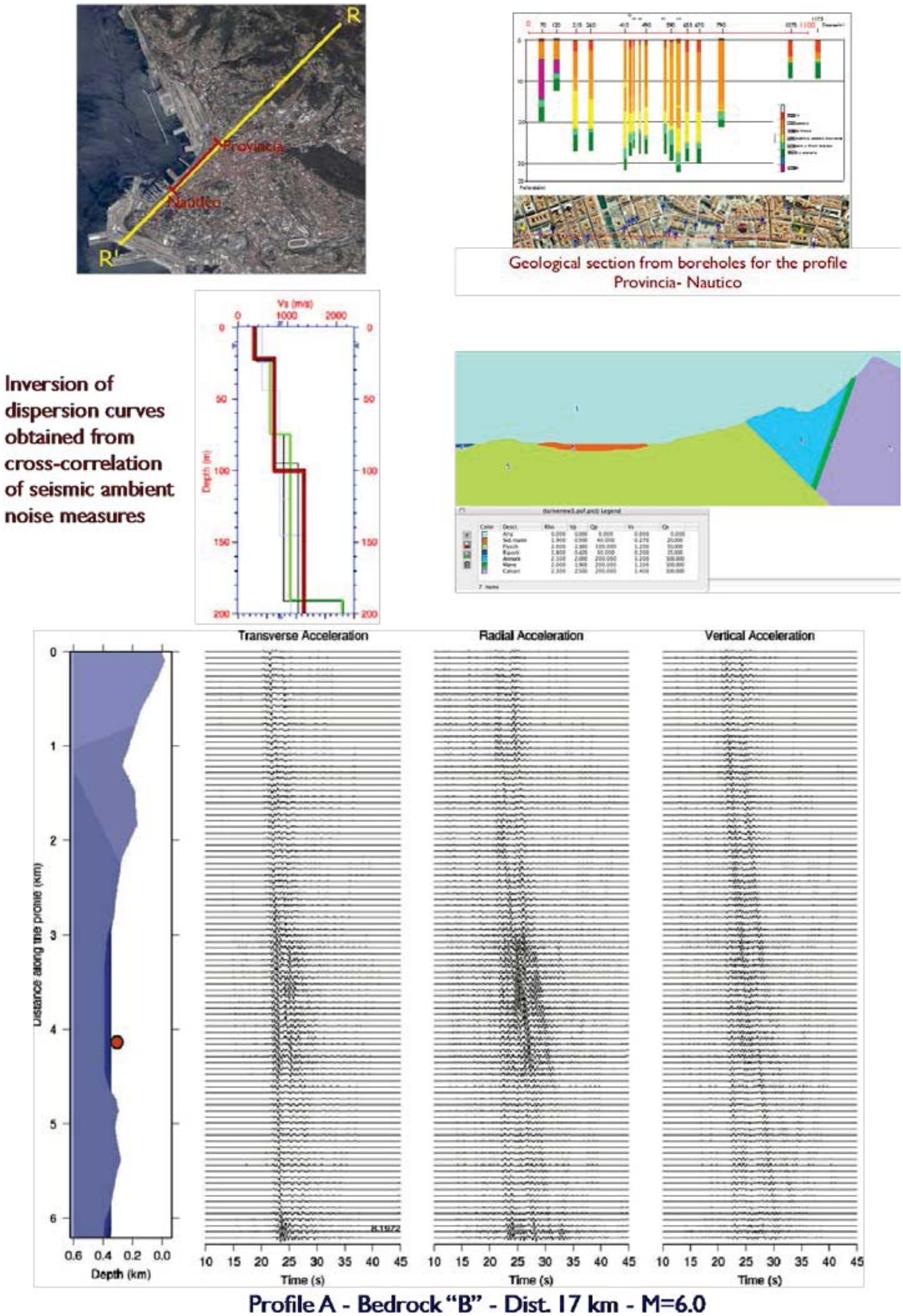


Figure 7. Application of NDSHA for the city of Trieste. Selected profile (top) and synthetic seismograms (bottom).

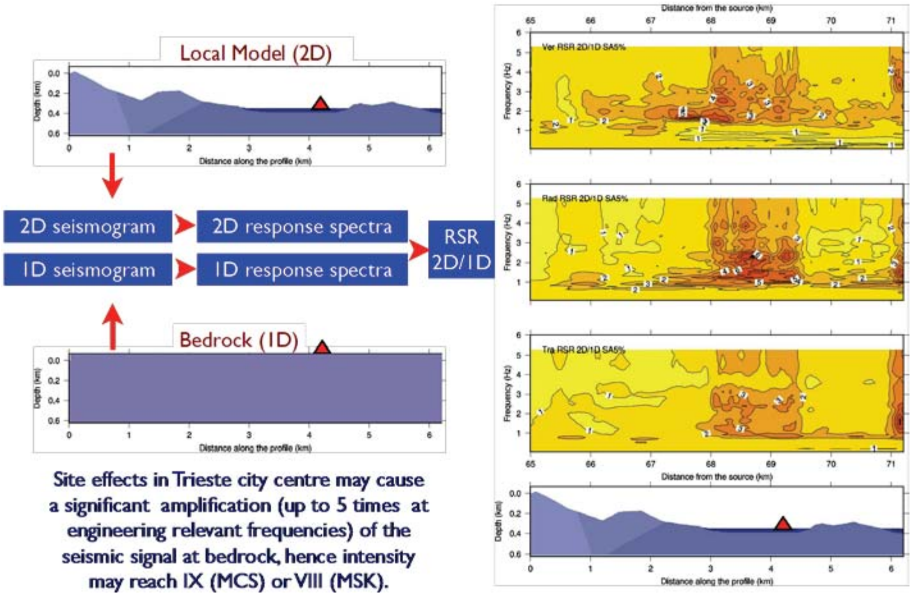


Figure 7. (continued) Application of NDSHA for the city of Trieste. Response spectra ratio..

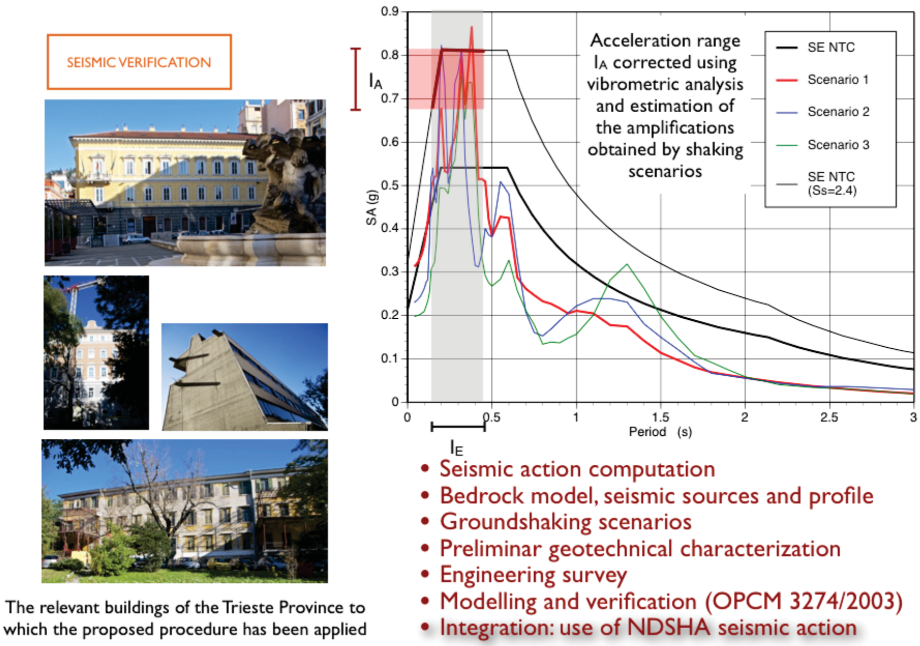


Figure 8. Summary of the seismo-engineering analysis performed for some schools in Trieste.

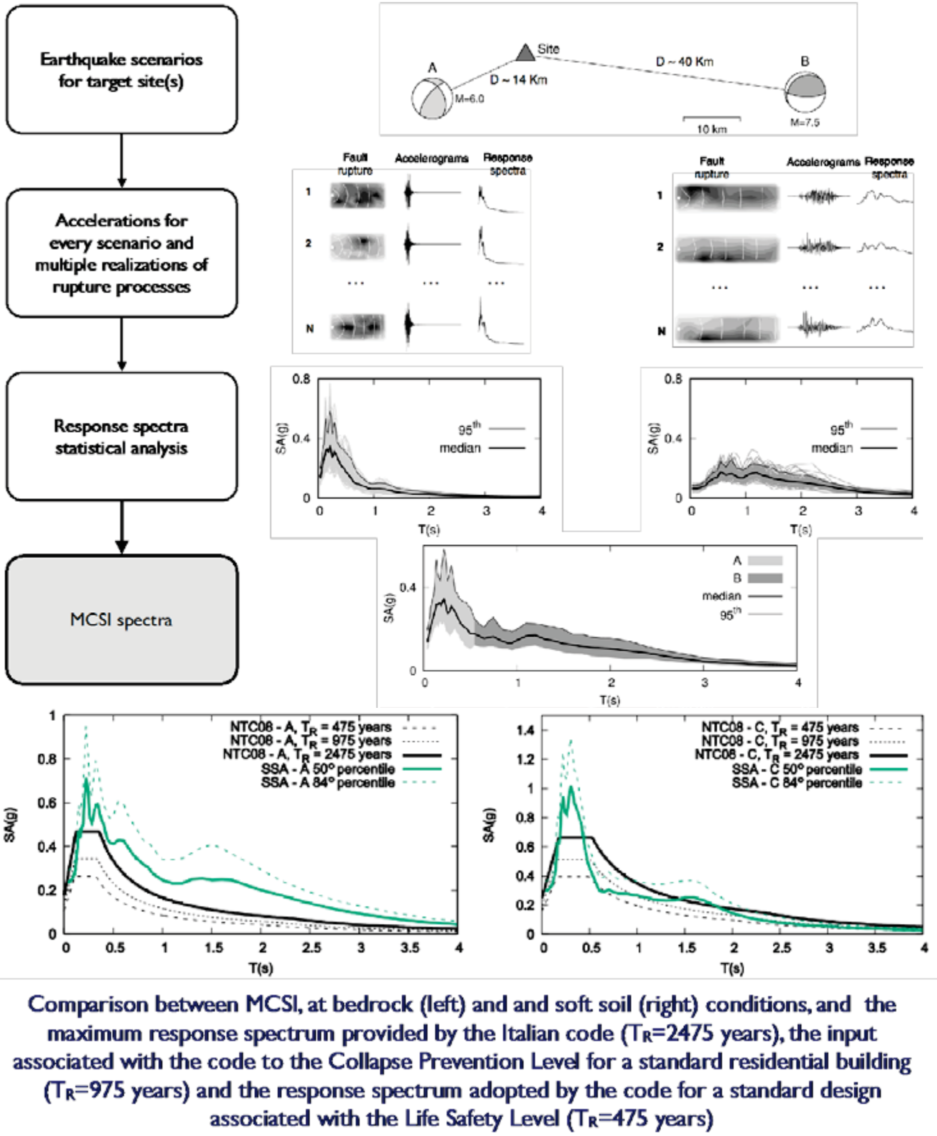


Figure 9. MCSI approach (a) applied to the city of Trieste (b).

The results obtained from parametric studies for the kinematic parameters of the seismic sources and for different soil conditions can be used to estimate the possible related uncertainty associated with the spectral shapes defined for the microzoning. The results shown represent also a paradigmatic example of the inadequacy of simplified approaches based on scalar correcting coefficients (e.g. for site conditions): The MCSIs evidence that local effects can lead to spectral values that are, at different periods, well above or below those of the elastic design spectra given by the Italian code on account of local conditions. Therefore, the seismic source process, the propagation of earthquake waves and their combined interactions with local effects should be duly taken into account to safeguard the tensorial nature of earthquake ground motion. NDSHA naturally supplies realistic and reliable time series of ground motions that are readily applicable to seismic isolation techniques and useful for the preservation of historical monuments and relevant man-made structures.

4. Acknowledgements

This contribution is intended to be just a window on some potential applications of NDSHA; most of the content and figures shown in this contribution have been produced thanks to the ideas and efforts of unique friends. One special thought goes to Alex: “Che la Terra ti sia lieve”.

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NDSHA
Computational Aspects of the Neo-Deterministic Seismic Hazard Assessment

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Abstract. Reliable assessments of ground shaking scenarios with the aid of computers before the occurrence of an earthquake can be of extreme value in planning the design of new structures, or in retrofitting of existing ones in the areas of interest. Obtaining realistic estimates of the ground motion expected in case of an earthquake is a task that seismologists tackle using dedicated and powerful computational software. The time series generated, and the corresponding response spectra, can be used by civil engineers in designing seismo-resistant structures capable of surviving future earthquakes with limited damage. The complexity of the earthquake phenomenon usually translates into powerful but unfriendly software that can intimidate those who might be interested but not familiar with the matter. A web application has been developed that isolates the user from the intricacies of the underlying computational engine, and a friendly graphical user interface allows for the modelling of ground shaking scenarios based on the knowledge of the physical properties of the earthquake source and of the medium through which travel the seismic waves. Some predetermined source and soil models can be selected, or new, ad-hoc models can be generated or uploaded by the user. The underlying computational engine allows the generation of the time series (displacement, velocity, acceleration) in a matter of seconds for the simplest configurations. With an acceptable computational time, more detailed modelling of the source rupturing process and of the layering underneath the sites of interest can be taken into account, depending on the characteristics of the model.

Keywords: ground shaking scenarios, synthetic seismograms, response spectra, neo-deterministic seismic hazard assessment

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1. Introduction

In the framework of the cooperation project "Definition of seismic hazard scenarios and microzoning by means of Indo-European e-infrastructures", supported by Regione autonoma Friuli Venezia Giulia (Italy), a web application prototype has been developed to enable scientists to compute a wide variety of synthetic seismograms, dealing efficiently with the variety and complexity of the potential earthquake sources and of the medium travelled by the seismic waves. In its simplest configuration and once the source mechanism and the physical properties of the Earth's upper crust have been defined, a ground shaking scenario can be generated at a site of interest in a matter of seconds, thanks to the optimized analytical approach to the problem. The computational time increases to minutes when complicated source models are adopted for the rupturing style on the fault plane. A hybrid analytical/numerical approach with reasonable computational time allows for the consideration of a complicated layering underneath a series of sites aligned along a profile, including lateral heterogeneities.

2. The Computational Engine

The computational engine used by the web application, already described by Vaccari [1], is based on the Neo-Deterministic Seismic Hazard Assessment (NDSHA) methodology of Panza and co-workers [2,3] for the generation of synthetic seismograms. It allows for a rapid definition of seismic and tsunami hazard scenarios for a given event, at local or regional scales. "Neo-deterministic" means scenario-based methods for seismic hazard analysis, where realistic and duly validated synthetic time series, accounting for source, propagation, and site effects, are used to construct the earthquake scenarios. The user interface of the web application has been designed to hide the intricacy of the underlying computational engine, yet allowing the users to act even on the deeper aspects of the model parameterization.

3. The Web Application

The web application prototype developed with a support from Regione autonoma Friuli Venezia Giulia was designed specifically to enable seismologists and civil engineers to compute a wide set of synthetic seismograms, dealing efficiently with the variety and complexity of the potential earthquake sources and of the medium travelled by the seismic waves. Rather than describing the web application capabilities by words, we will present screenshots of the implemented software that illustrate the functionalities aimed at the computations of the ground shaking scenarios.

3.1. Definition of Layered Structural Models

For quick execution of parametric tests that allows exploring the influence of the source mechanism on the ground shaking characteristics at a site of interest, the modal summation technique [4,5] is used for the generation of synthetic seismograms. This is a fully analytical approach and requires the definition of the properties of the layers (thickness, density, Vp and Vs velocities and their attenuations Qp and Qs, respectively). Some predefined models are available in the web application for soil categories defined by seismic codes, and once the layer properties have been defined the Love and Rayleigh modes (Fig. 1) can be generated in less than a minute and are stored permanently allowing for the quick computation of synthetic seismograms for any variation of the earthquake source property.

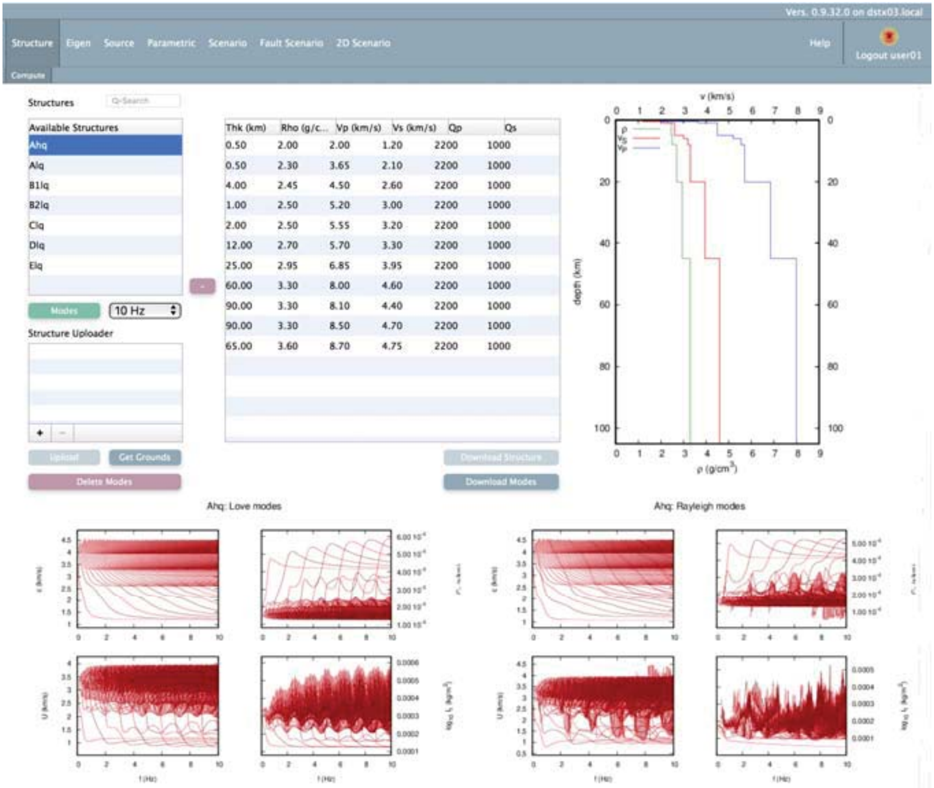

Figure 1. Panel used for the definition of the layer properties, and the computation of the Love and Rayleigh modes later used for the quick generation of ground shaking scenarios.

The original computer codes have been highly optimized in view of the advances of the computer industry since the time of their original development. Apart from the obvious speed improvement due to the enormous advances in CPU technology, the availability of much larger memory capacities suggested and allowed the refactoring of large chunks of code to avoid bottlenecks that could considerably slow down the program execution. As a result, a set of modes that once required half a day to be computed on a large mainframe computer can now be obtained on a laptop in less than a minute.

3.2. Computation of Eigenfunctions

This panel of the web application shown in Fig. 2 is mostly educational and playing with it is not strictly necessary for the computation of the ground shaking scenarios, but it helps to understand the physics of mode excitation by the seismic source.

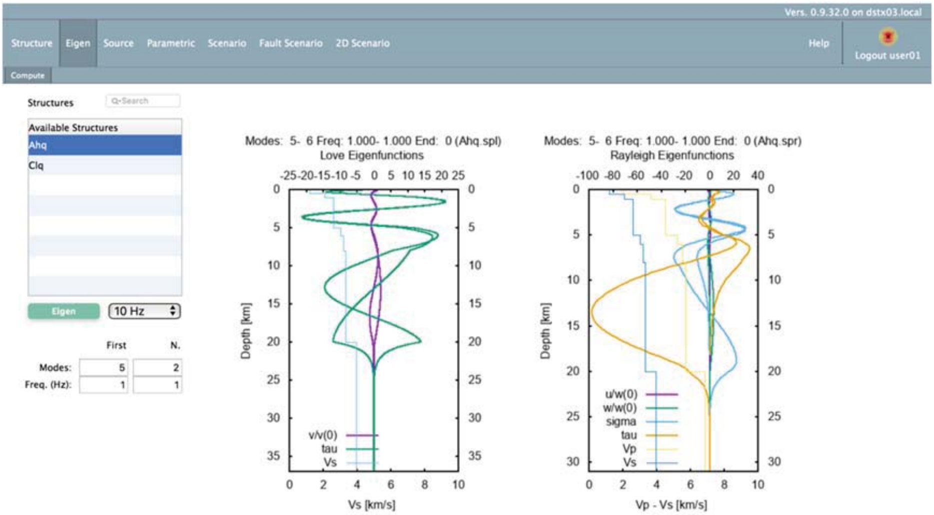

Figure 2. Panel used to visualize the eigenfunctions for selected modes (Love and Rayleigh) and frequencies.

3.3. Modelling the Source Rupturing Process

While we a have a good understanding where the next earthquakes may occur, we don't know the characteristics of the rupturing processes that will generate future earthquakes. In the panel of Fig. 3 the user can generate several realizations of the rupturing process, each one different in terms of slip distribution and of rupture velocity on the fault plane. The directivity effects can also be taken into account, and the generated source time functions can be used to generate the synthetic seismograms that are at the base of the ground shaking scenarios.

3.4. Parametric Tests

Once the modes and the source time functions have been generated, the parametric tests can be easily performed in a matter of seconds to explore the dependency of the ground shaking scenarios on the specific parameter of the model that has been varied. Usually, the highest frequency content of the time series is 10 Hz, and for some tasks and mostly when dealing with displacements rather than accelerations, the cutoff frequency can be lowered to 1 Hz. This allows taking into consideration the periods longer than 10 s, which may be of interest for strong and distant events that may pose at risk the classes of elongated structures like tall buildings, bridges, pipelines, etc.

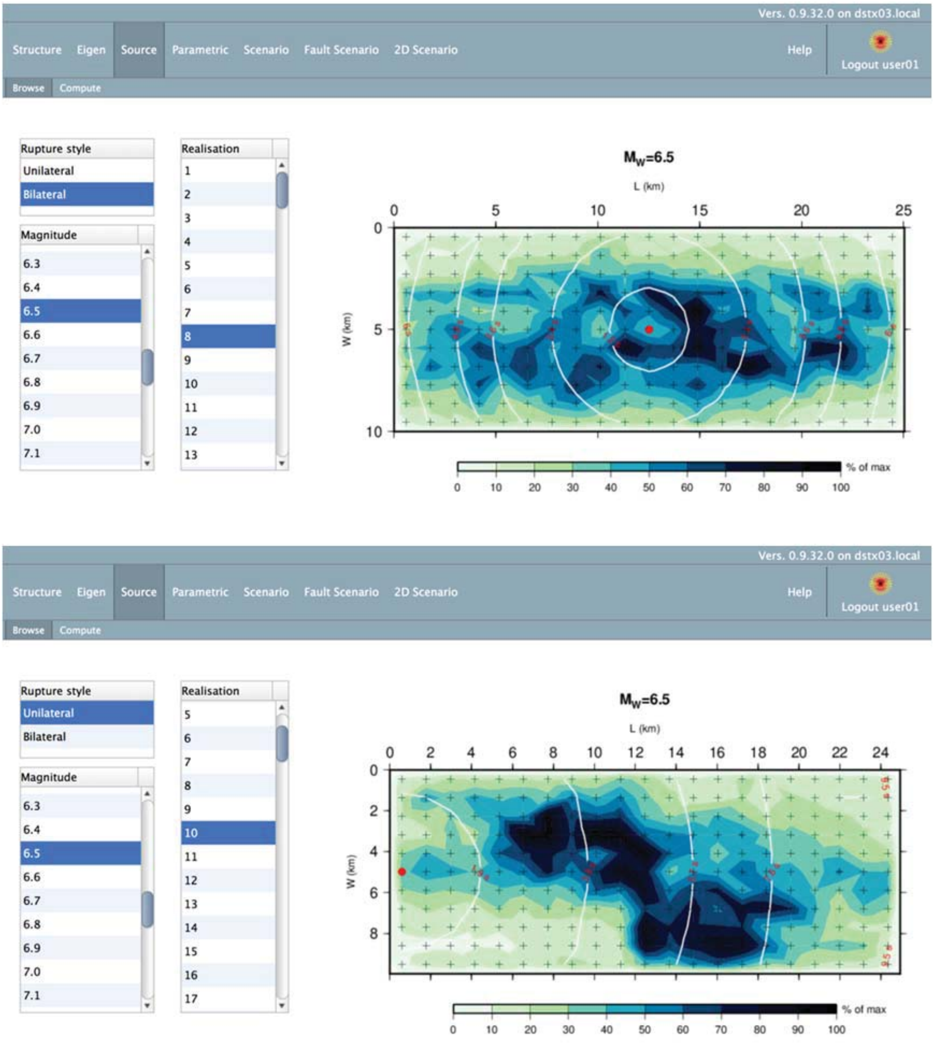

Figure 3. Panel used to generate the source time functions corresponding to complicated rupturing processes on the fault. Here two different realizations are shown for a M=6.5 earthquake. The dark areas correspond to a large slip on the fault, and the red dot shows the nucleation point of the rupture (top: bilateral rupture; bottom: unilateral rupture). The white isochrones describe the rupturing process.

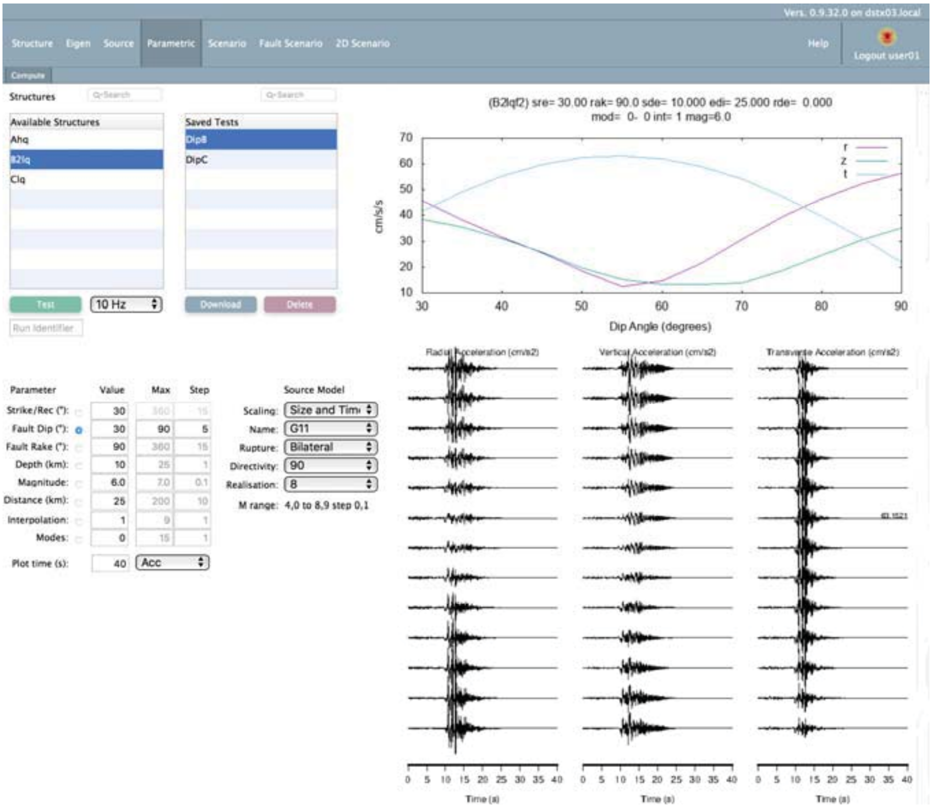

Figure 4. Panel used to quickly generate synthetic seismograms for a layered Earth model (whose modes have been computed as shown in Section 3.1) and one realization of the source rupturing process (obtained as shown in Section 3.3). In this example, the inclination (dip) of an inverse fault has been increased from 30° to 90° with a step of 5°. The panel shows the variation of the acceleration peak as a function of the dip (top-right plot) and the accelerograms obtained for the three components of motion (radial, vertical and transverse, from left to right in the bottom-right plot).

3.5. Simple Earthquake Scenarios

Another functionality offered by the web application is the quick generation of a ground shaking scenario around the epicenter of an earthquake, as shown in Fig. 5. The user can select the layering characterizing the region, the source rupturing model, the orientation of the fault mechanism, the minimum and maximum epicentral distances, and the step used to distribute the sites where the synthetic seismograms will be generated. The scenarios can be obtained in terms of displacement, velocity, or acceleration for NS, EW, vertical, radial, and transverse components of motion. The map produced in this panel summarizes the peak values obtained around the epicenter. Nevertheless, the full time series remain available for further analyses.

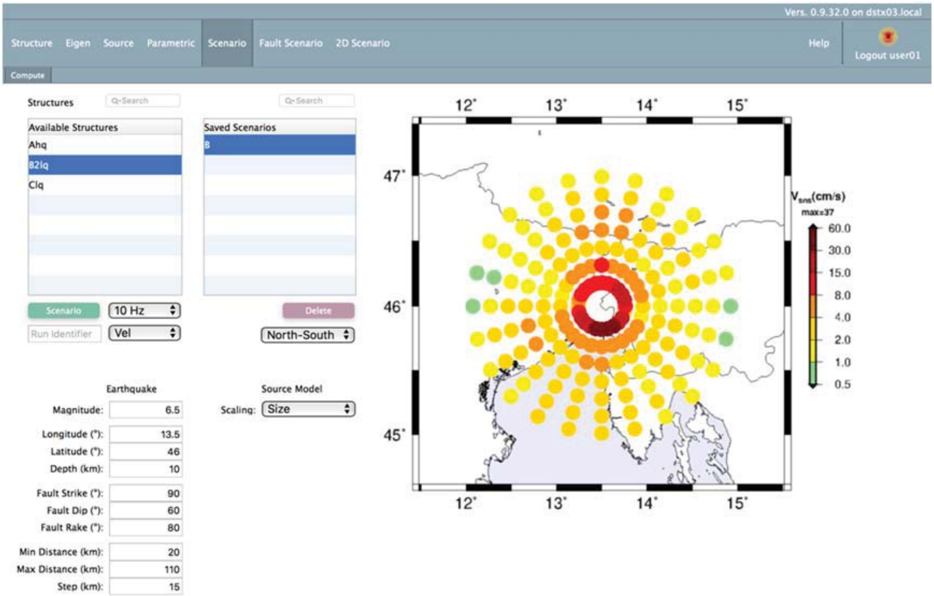

Figure 5. Panel dedicated to the computation of a ground shaking scenario around an earthquake's epicenter. In this example, the map produced shows the distribution of the peak values of the NS component of velocity.

3.6. Ground Shaking for Extended Source Models

The prediction of the ground motion expected at a single specific site is in general necessary and recommended to increase the level of detail included in the modelling. And when modelling the source, a truly extended source model should be considered, and even more so for small epicentral distances. The approach implemented in the underlying computations layer is based on the extended source model (ES) described by Gusev and Pavlov [6] and Gusev [7]. Figure 6 shows the web application panel that allows this kind of modelling. This is the latest functionality added, and is still under the development at the time of this writing.

3.7. Site Effects Along a Laterally Heterogeneous Profile

When the site of interest lies on a complicated subsurface geology, the effects of lateral heterogeneities cannot be neglected. They can generate, combined with the characteristics of the incoming wave field originated at the source, significant amplifications, and often at very specific frequencies. Figure 7 shows the amplifications estimated along a laterally heterogeneous profile by taking into account also the topography of the area. For this type of modelling, the web application makes use of the computer codes that implement the hybrid approach developed originally by Fäh and

Panza [9] and also described in Panza and co-workers [2]. The methodology combines the modal summation and finite difference techniques.

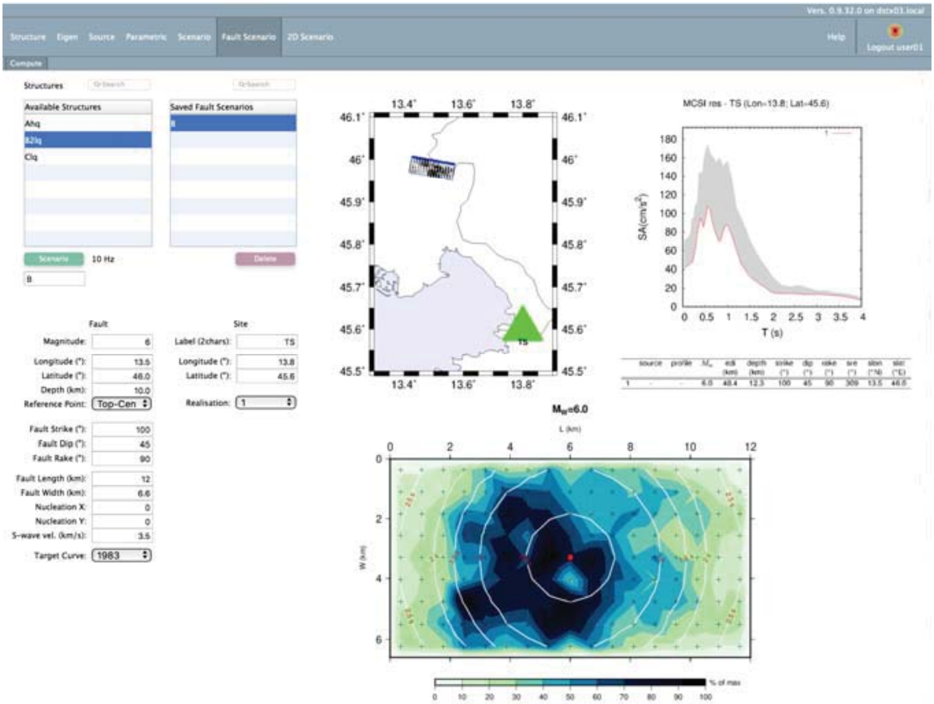

Figure 6. Panel dedicated to the computation of multiple ground shaking scenarios at a single site for many realizations of the rupturing process of an extended fault. The fault and site positions are shown in the map. Synthetic accelerograms and their response spectra are computed at the site for many realizations of the source rupturing process (up to several hundreds). The top-right plot is the so called Maximum Credible Seismic Input (originally defined MDSI [8]) obtained by using a statistical analysis, period by period, of the generated response spectra. The grey area in the MCSI plot spans from the median to 95th percentile. The user can select which realization is shown in the bottom part of the panel.

A laterally homogeneous inelastic layered model is defined to represent the average lithospheric properties along the path from the source to the vicinity of the site. In this part of the model wave propagation is modelled by the modal summation technique. But since the modal summation is fully analytic, there is no computational time penalty associated with the length of the path in this part of the model. The generated wavefield is then introduced in the mesh that describes the local heterogeneous area characterizing the site of interest, where it is propagated according to the finite-difference scheme. With this hybrid approach, the source, path, and site effects are all taken into account, and the detailed ground shaking scenarios can be efficiently evaluated along a 2D profile even at large distances from the epicenter.

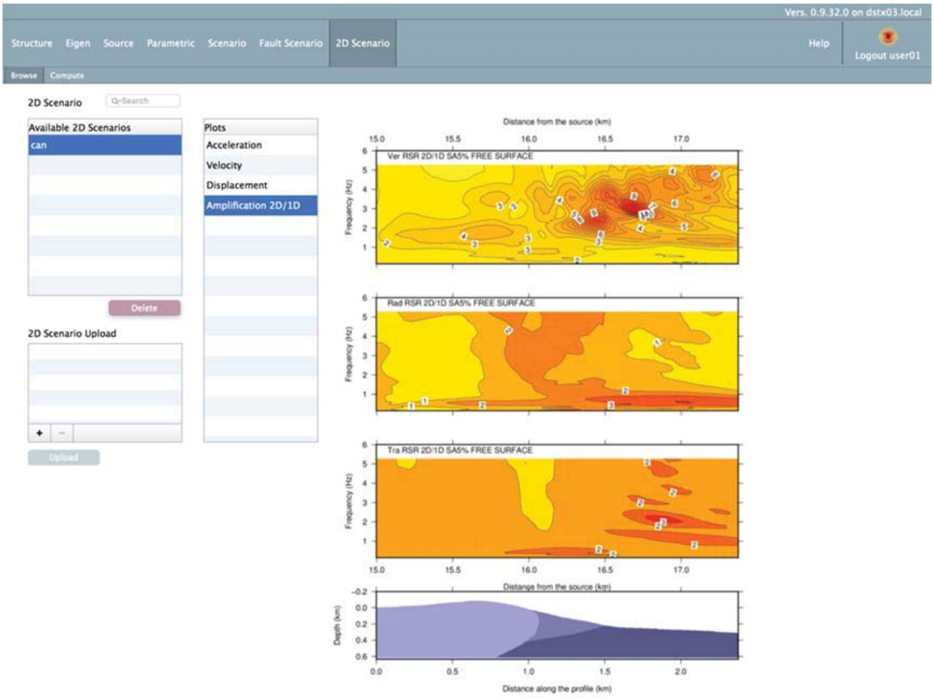

Figure 7. Panel dedicated to the computation of ground shaking scenarios along a laterally heterogeneous profile. Here the amplifications (dark red areas) are shown with respect to a laterally homogeneous bedrock model. From top to bottom, the amplifications are shown along the profile for the vertical, radial, and transverse components. The abscissa shows the position along the profile, represented at the bottom, while the ordinates in upper images refer to the frequencies at which the amplifications eventually occur.

4. Conclusions

As already pointed out by Vaccari [1], it is a matter of fact that the seismic regulations currently adopted worldwide are mostly based on probabilistic estimates of the seismic hazard. This is very likely due to the lack of adequate tools that might have provided viable alternatives at the time the regulations were formulated.

The web application described herein aims at demonstrating that something different can finally be used to improve the preparedness against future earthquake events. With the underlying NDSHA computational engine, the end-user can be kept well isolated from the complexity of the modelling tools, and there is no steep learning curve to be followed before the user can generate a ground shaking scenario. This is particularly true for the design and execution of quick parametric tests in laterally homogeneous layered models, where the source or layer properties are varied, and the effects (or lack thereof) of their variation on the ground shaking can be immediately verified in the obtained scenarios. Under these conditions, it is a matter of minutes for civil engineers or city planners to obtain a first-order estimate of the seismic input expected for the next earthquake.

The benefits of the methodology upon which the web application is based have been recently proved in the city of Trieste (Italy). Commissioned by the Provincia di Trieste Authorities, ground shaking scenarios have been generated in the city along several 2D profiles [10]. The amplifications obtained due to the combined interaction of source, path and site effects have produced spectral accelerations higher than those predicted by the official hazard maps that are based on probabilistic studies and currently adopted by the law. The seismic input specifically computed at selected sites of interest for the Provincia di Trieste Authorities has been used to verify the behavior of some relevant buildings under the seismic load, and to plan retrofitting that will hopefully avoid heavy damage, or even the collapse of structures during an earthquake.

The web application has been developed with the Xojo object-oriented cross-platform development tool (www.xojo.com), and has been installed and tested successfully, together with the computational software (mostly FORTRAN codes) on Mac OS and Linux servers. The application doesn't require huge computational resources, it can be installed even on laptops, and scales very well with the number of CPUs available to the server. Specifically, the computation of multiple realizations of the rupturing process, described in Section 3.6, can be distributed on several threads of multi-core CPUs, and the administrator of the web application can limit the number of parallel threads that can be invoked by the users.

Free access to the web application is granted for educational purposes to students and researchers collaborating with the Department of Mathematics and Geosciences of the Trieste University in the framework of established common projects or Memorandum of Understanding. A commercial implementation is available at www.xeris.it, with a free demo and with limited functionality.

5. Acknowledgements

The web application was initially developed within the project "Definition of seismic hazard scenarios and microzoning by means of Indo-European e-infrastructures" funded by Regione autonoma Friuli Venezia Giulia in the framework of the interventions aimed at promoting, at regional and local levels, the cooperation activities for development and international partnership "Progetti Quadro ai sensi della Legge regionale n. 19 del 30 ottobre 2000".

The underlying computational engine, based on the pioneering work by Prof. Panza, is the result of years of development and testing by several researchers and dedicated Ph.D. students who graduated here at the Department of Mathematics and Geoscience at the University of Trieste.

Finally, with extreme sadness for his premature and unexpected passing away, we want to remember here the exceptional figure of Dr. Alexander Gusev, who came to Trieste to help us implement in our NDSHA programs his codes for the modelling of the source rupturing process. His kindness and competence will never be forgotten.

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THEME

Education/*Educazione*

From left to right and top to bottom. Grazia Paolella, Annamaria Imperatrice, Ida Mascolo, Flavio Dobran, Gianfranco Gambardella, Luigi Altavilla, Alessandro Attolico, and Fabiana Mennella.

Il Vesuvio tra storia, arte, scienza e gestione della cosa pubblica

Grazia Paolella*

Università Suor Orsola Benincasa
Napoli, Italia

Riassunto. Il Vesuvio, quel capolavoro paesaggistico, amato dai campani e invidiato dai forestieri, quella superba cartolina da cui Napoli non può prescindere, quel profilo così familiare per la città partenopea, fonte inesauribile di interesse scientifico e motivo pregnante di ispirazione artistica, può, improvvisamente, destarsi e rivelarsi per quello che è, - ed è stato storicamente - un grosso pericolo incombente, mostrando tutta la sua forza minacciosa e devastatrice, tutta la sua furia distruttiva, se i preposti non si mettono, immediatamente, all'opera, con competenza, per avviare un programma serio, operativo, oculato, al fine di creare condizioni adeguate di sostenibilità e resilienza vera e propria, da attuare, prima che sia troppo tardi! L'auspicio sotto il quale il Convegno nasce è sicuramente produrre risultati, acquisizioni, confronti importanti sul piano scientifico, ma anche input, indicazioni, linee direttive per gli amministratori della cosa pubblica, per i tecnici, per gli esperti, per tutti gli addetti a vario titolo, i quali, di concerto con scienziati, intellettuali e studiosi, potranno compiere, finalmente, passi coraggiosi, importanti, decisivi per il futuro delle città campane e 'vesuviane' in particolarre.

Parole chiave: Vesuvio, fascino paesaggistico, fonte di ispirazione letteraria e di interesse scientifico, pericolo, prevenzione, pianificazione

1. Lo Sterminator Vesevo

Con l'International Conference on Resilience and Sustainability of Cities in Hazardous Environments, November 26-30, 2018, a Napoli, lo "sterminator Vesevo", di leopardiana memoria [1], si pone al centro dell'attenzione mondiale, come punto di partenza e di arrivo di un'indagine e di una progettualità, di ampio respiro, sullo sviluppo sostenibile, nei luoghi con peculiari caratteristiche geomorfologiche di rischio e pericolo ambientale.

Il Vesuvio, nella sua maestosa, affascinante e intrigante bellezza, non offre solo un incomparabile paesaggio, dal tratto unico e inconfondibile e dal microclima dolce e gradevole, è, da sempre, oltre che motivo di riflessione del mondo scientifico, anche fonte di ispirazione artistica a tutto tondo, dalla narrativa, alla poesia, alla pittura, alla scultura, alla canzone napoletana.

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In particolare, nel campo letterario, innumerevoli sono gli esempi di scrittura potentemente descrittivi e significativi, a partire dagli incisivi, emozionanti racconti del drammatico evento eruttivo del ’79 d.C., curati da Plinio il Giovane, nelle famose tre lettere a Tacito [2]: “… la … forma (del Vesuvio) era più simile ad un pino … come da un tronco enorme la nube svettava nel cielo alto e si dilatava e quasi metteva rami … si estendeva in un ampio ombrello, a tratti riluceva d’immacolato biancore, a tratti appariva sporca, screziata di macchie, a seconda del prevalere della cenere o della terra che aveva sollevato con sé … Sul versante orientale, un nembo nero e orrendo, squarciato da guizzi sinuosi e balenanti di vapori infuocati, si apriva in lunghe fiamme, simili a folgori, anzi più grandi …”.

L’elemento prorompente più fortemente caratterizzante non solo delle descrizioni di Plinio, ma anche di autori di epoca successiva come Hamilton [3,4], Goethe [5], Dickinson [6], (quest’ultima, la Emily, non per essersi mai recata sul posto ed aver vissuto in prima persona, ma solo per essersi basata sulle narrazioni altrui ed essere rimasta affascinata al punto da dedicare ben tre sonetti al Vesuvio) è il coinvolgimento emotivo di fronte alla carica di esplosiva vitalità del vulcano ed al suo impetuoso dinamismo e, al tempo stesso, il fascino del pericolo, lo spavento, il sentimento della paura verso la forza distruttiva della natura.

Wolfgang Goethe, nel suo Viaggio in Italia [5], a seguito delle sue ‘appassionate’ escursioni al cratere, durante le quali aveva accuratamente preso nota di tanti interessanti particolari, dedicava alla descrizione emozionante e suggestiva del Vesuvio, alcune tra le sue più felici e toccanti pagine:“… la lava scorreva ed essendo tramontato da un pezzo il sole, si vedeva la corrente di fuoco rosseggiare, mentre la fiamma incominciava a indorare la nuvola di fuoco, che lo accompagnava; la montagna faceva sentire profondi boati; sulla cima, sovrastava un pennacchio enorme immobile, le cui differenti masse venivano squarciate ad ogni sbuffo come da lampi e illuminate a rilievo … Da lassù, fino alla marina, una striscia rovente … la lava piena, era … cosa da farmi sbalordire”.

Lord William Hamilton, ambasciatore britannico, alla corte borbonica a Napoli, dal 1764 al 1800, famoso studioso, vulcanologo e collezionista, compì, numerose e coraggiose ascensioni al cono del Vesuvio, soprattutto nel corso di eruzioni, scrivendo importanti ed imprescindibili racconti, divenuti poi oggetto di studio e di riflessione per i contemporanei e per i posteri [3,4]. Precise e potenti le sue descrizioni: ” Quando sono stato alla sommità del Vesuvio con il bel tempo, ho trovato così poco fumo che mi era possibile vedere bene nel cratere, le cui pareti interne erano incrostate di sali e minerali di colori diversi, bianco, verde, giallo carico e giallo pallido … “. A seguito dell’ardita osservazione diretta, sul posto, dei fenomeni eruttivi, così raccontava: “Passai tutto il giorno e tutta la notte … sul Vesuvio e seguii il corso della lava fino alla sua sorgente. Essa usciva come un torrente dal fianco della montagna, a circa mezzo miglio di distanza dalla bocca del vulcano, accompagnata da violente esplosioni che lanciavano il materiale in fiamme ad altezza considerevole, mentre la terra vibrava …” E ancora: “Pochi giorni prima dell’eruzione, vidi il fenomeno descritto da Plinio il Giovane, cioè il Vesuvio mostrava le sembianze di un pino e il fumo, che … sembrava nero durante il giorno, all’avvicinarsi dell’eruzione, assumeva, di notte, l’aspetto di fiamma”.

Giacomo Leopardi [1], il grande poeta che visse gli ultimi suoi anni alle pendici del Vesuvio, nella villa dell’amico Ranieri, dal vulcano, che tutti i giorni aveva sotto i suoi occhi, trasse ispirazione per le sue due poesie Alla Luna e La Ginestra … In quest'ultima, esprimeva la forza vitale della ginestra, rappresentativa di quella che può appartenere all'essere umano, offrendo una memorabile descrizione del paesaggio vesuviano: "Qui sull'arida schiena del formidabil monte sterminator Vesevo, la qual null'altro allegra arbor né fiore, tuoi cespi solitari intorno spargi, odorata ginestra, contenta dei deserti … questi campi di cenere infeconda e ricoperti dell'impietrata lava, che sotto i passi del peregrin risona, sovente in queste rive, che, desolate a bruno veste il frutto indurato e par che ondeggi, seggo la notte …".

2. Convivenza col lo "Sterminator"

Ecco lo scenario, il contesto e, al tempo stesso, l'oggetto di interesse e di attrazione del Convegno Internazionale su Resilienza e Sostenibilità Delle Città in Ambienti Pericolosi, organizzato volutamente in quella perla della città partenopea, che non può prescindere dall'immagine stessa del suo vulcano, che ne è sicuramente l'emblema. Eppure quel profilo così familiare, quel gigante 'buono', quasi 'amico' per i napoletani, può, improvvisamente, destarsi e rivelarsi per quello che è minaccia incombente, fonte di grosso pericolo, come ha dimostrato la storia lontana e più recente, ricostruita, in questo lavoro, attraverso alcuni fondamentali echi letterari. Può cogliere tutti di sorpresa e tirar fuori tutta la sua forza devastatrice, tutta la sua furia distruttiva … se 'uomini di buona volontà' non si rimboccano subito le maniche.

L'auspicio sotto il quale il Convegno nasce è sicuramente produrre risultati, acquisizioni, confronti importanti sul piano scientifico, ma anche input, indicazioni, linee direttive per gli amministratori della cosa pubblica perché si mettano, immediatamente, all'opera, per avviare un programma operativo oculato, corposo, adeguato a creare condizioni efficaci di sostenibilità e resilienza vera e propria.

E' giunto il momento che i tecnici, gli esperti, gli addetti a vario titolo compiano, finalmente, passi seri, coraggiosi, importanti, decisivi per il futuro delle città campane e 'vesuviane' in particolare.

L'intento ambizioso e pregevole della Conferenza Internazionale è riunire accademici, ricercatori, urbanisti, ingegneri, geofisici, ambientalisti, educatori, intellettuali e rappresentanti delle Istituzioni, per confrontarsi sulla progettazione di adeguati percorsi di studio e sull'attuazione di condizioni di resilienza e sostenibilità, all'interno degli habitat urbani della fascia vesuviana e in particolare per quello che riguarda Napoli, la città sede del Convegno.

Lavorare in sinergia, in modo significativo, costruttivo per la promozione della resilienza richiede l'apporto di più risorse professionali, che abbiano il comune intento di inseguire, realmente, l'obiettivo dello sviluppo della sostenibilità, per la costruzione di una vita, che rinunzi al fatalismo, al pressapochismo, al pessimismo, alla miopia che solo riesce a intravedere scenari cupi e disastrosi di fuga e di deportazione di massa di intere popolazioni, come soluzione estrema di fronte al verificarsi di un'eventuale eruzione più o meno violenta e distruttiva del Vesuvio, quell'amico vulcano, che è parte integrante, sostanziale ed anzi l'emblema del territorio campano. Fa da sfondo alle più belle immagini del golfo di Napoli, esercita un indiscutibile richiamo turistico, è motivo di fertilità della terra, della bontà di particolari colture, è garante di una magnifica posizione geografica e di un piacevole clima, è motivo di interesse per la ricerca scientifica mondiale, è fonte inesauribile di ispirazione nell'arte, dalla poesia, alla pittura, dalla scultura alla canzone … ma … tutto questo non può indurci a crogiolarci passivamente in una sorta di incosciente idoleggiamento, di incanto, di distacco, di sogno … deve, invece, spingere ad avere un serio e propositivo atteggiamento di ricerca, coniugata con studi di fattibilità, che, tendendo alla realizzazione della resilienza, porti a vivere serenamente nelle città, avendo determinato tutte quelle condizioni operative, che rendono possibile uno sviluppo sostenibile di una civiltà, che così, non più condannata a morire, potrà sopravvivere nella sua unicità, restando saldamente e orgogliosamente legata alle sue radici storico-culturali.

La promozione dello sviluppo sostenibile dei centri urbani, che gravitano in ambienti che presentano elementi di pericolosità e rischio, da un punto di vista geologico, è considerata, purtroppo, generalmente, illusoria per la maggior parte degli urbanisti, delle autorità cittadine ed anche degli stessi abitanti, che trovano solo possibile affidarsi al caso, al destino o, nel migliore dei casi, a San Gennaro, a San Vincenzo Romano, alla Madonna e al buon Dio … L'idea della sostenibilità incontra, quindi, resistenze, aggravate dalla preoccupazione per le spese che una lungimirante, costruttiva, concreta, coraggiosa pianificazione a lungo termine potrebbe richiedere, come prodotto finale scaturente da una proficua collaborazione interdisciplinare a monte, intesa come aperto, sereno, composito, armonioso gioco di squadra.

Sarebbe il caso di smettere di pensare soltanto ai piani di evacuazione, agli esodi di massa, che, tra l'altro, non possono che essere drammatici per le popolazioni interessate e rappresentare fonte di disagio, distruzione e morte e, nel migliore dei casi, quando l'incolumità è salva, causa di perdita del senso di appartenenza. Le 'deportazioni' risulterebbero problematiche, per le autorità stesse, perché questi flussi 'migratori' sarebbero destabilizzanti per le strutture socio-politiche ed economiche, sia a livello locale che nazionale [7].

Napoli e le città limitrofe sono abitate da milioni di persone e presentano almeno quattro grossi fattori di rischio: (1) la coesistenza di due grandi complessi vulcanici attivi, il Vesuvio e i Campi Flegrei, (2) l'evenienza di possibili terremoti dovuti alla collisione dei continenti africano ed euroasiatico, (3) la presenza, nelle discariche abusive di grandi quantità di rifiuti tossici, radioattivi, (4) la vulnerabilità dei centri urbani, che non sono stati progettati tenendo conto dei loro insiti potenziali pericoli.

Di fatto, gli abitanti, a parte isolate, positive generose eccezioni a carattere locale, non sono stati educati e preparati ad affrontare il rischio e non sono stati messi nelle condizioni di evitare possibili disastri e potersi, orgogliosamente, considerare parte di una società civile, moderna e avanzata.

Si tende a procrastinare un'oculata, consistente programmazione, che andrebbe fatta proprio ora che non si è ancora in situazione di emergenza, prima che sia troppo tardi!

Non appare più rinviabile la soluzione del problema e ci convince ed entusiasma la posizione dello scienziato Flavio Dobran, esperto in materia di processi vulcanici, studioso e ricercatore indipendente di fama mondiale, il quale ha coraggiosamente abbracciato questa causa e diffonde, attraverso tutti i possibili canali, la realizzazione della resilienza e sostenibilità napoletana. Da anni, cura pubblicazioni e promuove informazione scientifica a tutti i livelli, persino nelle scuole, di ogni ordine e grado, napoletane e della provincia, nella convinzione che il discorso della prevenzione sia prioritario e passi attraverso l'educazione ambientale, all'interno delle scuole [8,9].

Nei miei anni di dirigenza scolastica, abbiamo proficuamente lavorato insieme, fianco a fianco, in modo capillare, riuscendo ad ottenere una sentita, vivace partecipazione, sia da parte di docenti che di discenti, i quali non si sono limitati solo allo studio e alla ricerca, già di per sé importanti, ma sono stati propositivi nel fare riflessioni ed indagini e hanno aderito a tutte le iniziative, da me organizzate di comune accordo con Dobran, con marcato interesse e con vero entusiasmo. Anche nel presente Convegno, Flavio ha fortemente voluto la partecipazione dei giovani, attraverso il mondo della scuola e ha voluto dedicare un giorno intero, il 30 novembre, alle scolaresche, incontrandole nella cornice più indicata, quella della Sala dei Baroni, del Maschio Angioino.

3. Conclusioni

É auspicabile che l'impegno serio, appassionato di quell'autentico scienziato, che è Flavio Dobran, mosso unicamente da puro amore per le scienze e per la verità, le proposte sue e quelle dei vari relatori, provenienti dal mondo scientifico e non, tutto il dibattito che ne scaturirà risulti un volano vero per studi di fattibilità, e loro implementazioni nel tempo, altamente professionali e per una non più rinviabile, corposa, realistica pianificazione di opere volte non solo ad educare le persone al rischio, ma soprattutto a prevenire e ad arginare i disastri, a mettere in campo tutte le possibili risorse, da quelle intellettuali a quelle materiali e finanziarie, per assicurare condizioni di sviluppo sostenibile alla città di Napoli e ai vari centri urbani dell'area vesuviana e quindi benessere, tranquillità per i loro abitanti, i quali, non più spaventati da cupi e drammatici scenari, potranno coltivare il loro amore per i luoghi di origine, alimentare il loro senso di appartenenza ed ergersi in difesa della sopravvivenza del patrimonio culturale campano, nonché dell'evoluzione positiva della stessa civiltà della Campania felix.

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Educazione rischio-Vesuvio tra chiarezza, buon senso e perseveranza

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Riassunto. La scuola ha una buona vocazione ad indirizzare a un comportamento pratico, razionale e morale il discente. La sua azione vuole naturalmente approdare a criteri assimilati di osservazione, analisi, paralleli a realtà e questioni in base alle quali si allineano scelte legate all'insieme di norme e di valori propri dell'etica che orientano verso doveri integri da rispettare per se stessi e per gli altri. La scuola, l'esercizio della mente e delle mani vanno a coronare, nella determinazione temporale complessiva delle loro performance , un ampio processo formativo orientato soprattutto a condurre alla acquisizione del SENSO CRITICO, incomparabile ed efficace mezzo che, nella connessione di una più ampia forza collettiva, può veramente indirizzare a lineamenti di possibili risoluzioni di quei grandi problemi che affliggono l'umanità. Nella nostra realtà legata al Vesuvio la scuola opera un'azione mirata alla riappropriazione dell'assopito istinto di conservazione della vita che il lungo sonno del vulcano ha determinato nei vesuviani e che li distrae dal maturare un pensiero di progetto di vita nel quale considerare un allontanamento di residenza dall'amato e fertile territorio, splendido, oltretutto, dal punto di vista paesaggistico. Opera sulla corretta informazione circa le previsioni di eruzione legate principalmente a misure temporali di accumulo di energia magmatica scandite dagli eventi del passato e che mostrano un imminente risveglio, oltre il rituale insegnamento relativo alla conoscenza dei vulcani ed ai fenomeni ad essi legati.

Parole chiave: Educazione, scuola, etica ambientale

1. Introduzione

Nei principi fondamentali dei nostri sistemi educativi si è definitivamente consolidato, negli anni, l'impegno della disciplina ambientale come strumento della società umana positivamente diretta a potersi sviluppare in un appropriato rapporto con la natura. Si è discusso sulla corretta educazione per un'azione fondamentale di cambiamento di mentalità dell'uomo nei confronti della natura stessa affinché potessero giungere a soluzione quei grandi problemi dell'habitat che dagli anni addietro ad oggi hanno drammaticamente evidenziato i loro aspetti più preoccupanti in rapporto a sviluppo, conservazione, sicurezza [1].

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Nel cominciare a trattare più da vicino la questione, focalizzo un significativo, importante punto relativo alla sfera delle proposte didattiche attraverso un dato di fatto acquisito: la scelta delle strategie atte a presentare una qualsiasi disciplina ai ragazzi è compito esclusivo dell'insegnante. E' inutile e talora dannoso pretendere di stabilire dei metodi di lavoro senza tenere conto di quelle che sono le caratteristiche dell'operatore e dell'utenza, senza cioè conoscere la metodologia didattica dell'insegnante e la composizione, sempre diversa ed eterogenea di ogni singola classe [2]. Sono alla discrezione dei docenti le strategie metodologiche specifiche nell'impostazione anche di un qualsiasi laboratorio di disciplina ambientale. Quando l'attività di laboratorio va a realizzarsi su di un territorio quale quello vesuviano – che raccoglie realtà di esistenze radicate e rapporti di grandi, viscerali legami tra uomo e luogo di appartenenza che sovente vanificano qualsiasi parametro naturale di senso/istinto del pericolo e della sopravvivenza – i docenti incominciano ad avvertire fortemente la necessità di una proposizione di adeguati percorsi conoscitivi dotati di forti stimoli nel quadro orientativo circa le strategie didattiche. Linee che non intendono rinunciare, oltretutto, a quegli aspetti di una educazione/formazione che consentono una visione completa, a largo raggio, della totalità delle problematiche in rapporto ad un libero arbitrio per serene scelte presenti e future dei cittadini e per la concezione di personali progetti di vita riferibili ad un'impostazione a monte del domani di ciascuno. Pensiamo sia possibile potere affermare, dopo confronti, momenti di scambi e verifiche sul campo svoltesi in occasione di convegni, mostre di prodotti di laboratori ambientali delle scuole del territorio vesuviano, che dunque è andata affermandosi una buona sensibilità degli educatori in tal senso. Una marcia in più di cui sembra essersi dotata la macchina di una palpabile consapevolezza del più grande pericolo, si spera consentirà di allentare l'intenso traffico, l'intasamento della brutta strada denominata *rischio vulcanico*.

Bisogna pure considerare altri aspetti della educazione al rischio Vesuvio che è necessario tener presente se si desidera assicurare elementi di persistenza e costanza ad una efficace azione mirata e di ampia veduta della scuola rispetto a questi problemi. In primo luogo l'opportunità di formulazione di programmazioni impostate sulla scorta delle rilevazioni statistiche sull'andamento della popolazione vesuviana rispetto ai livelli di completamento degli studi. Se i risultati dei sondaggi, come purtroppo si pensa, tenderanno a permanere più o meno sui valori del Censimento degli ultimi anni ed il dato essenziale risulterà vicino al 21% della popolazione, circa i laureati ed i diplomati, bisognerà prendere atto che la scuola, in relazione al percorso educativo sul rischio, non potrà avvalersi ancora appieno della sinergia dei tre momenti significativi dell'azione didattica offerta rispettivamente a ciascuna fascia d'età di ciascun ciclo. Verrebbe ancora a mancare, per la rimanente percentuale di cittadini, l'ultimo percorso –dai 15 anni in su- il più significativo, quello dell'"apprendimento filosofico", com'e stato definito e bene argomentato dal Prof. Flavio Dobran nel volume"Educazione al rischio Vesuvio" (1998), per l'acquisizione di un "…pensiero sistematico-teoretico" grazie al quale "…gli studenti si riconoscono come parti di processi complessi il cui apprendimento porta alla scoperta della verità su se stessi e sul loro ambiente".

La 'fetta' più grande di popolazione alle falde del Vesuvio continua oggi ad avvalersi, nella vita, soltanto dell'esperienza dei due primi cicli di studio ed è probabile che tale monca condizione sia destinata a rimanere sostanzialmente ancora per lungo tempo invariata, venendo a minare, in una certa misura, quei risultati finali tanto auspicati dagli educatori e che si configurano nella efficace conquista di capacità, abilità, interesse alla risoluzione dei problemi. Tale realtà nella quale l'attuale situazione vesuviana è ancora immersa, aveva imposto ai disincantati operatori della scuola Secondaria di 1°Grado, già da tempi meno recenti, la scelta di linee progettuali didattiche rapportabili al fenomeno; itinerari educativi creati col buon senso, quasi con l'istinto dei docenti ben consapevoli di dover 'confezionare' pacchetti di emergenza, offerte formative a misura di ultima opportunità sul tappeto di successo scolastico, del resto ampiamente contemplate a cominciare dall'autonomia scolastica in poi, che potessero in qualche modo medicare e un pò guarire quell'incidentato (mancato) completamento di studi. Probabilmente proprio il buon senso e la libertà di scelta di strategie metodologiche dei docenti hanno saputo, e continuano a saper colmare in parte, questo grave vuoto riscontrabile sul cammino scolastico del gran numero di cittadini, determinato soprattutto dalle difficoltà della vita, ed è bene ricordare che, tra l'altro, nel panorama eterogeneo delle platee vesuviane esiste pure un valore elevato di evasione nella scuola dell'obbligo, tra il 17 e il 18% circa, che paradossalmente ha avvantaggiato e affinato le tecniche di azione didattica verso capacità apprezzabili che consentono di 'cucire' abiti del sapere per varie misure di necessità. Commissioni costituite all'uopo nei Collegi dei docenti, anno per anno, tracciano, così, criteri comuni per il raggiungimento degli obiettivi minimi relativi ai ragazzi coinvolti in queste dure realtà di disagio, per cercare di recuperare ed assicurare ad essi almeno quel tanto indispensabile di patrimonio di conoscenze, un bagaglio dei *saperi essenziali*, così denominato dalla "Commissione dei 44 saggi" in seno a ricerche e studi svolti quasi vent'anni fa per l'Autonomia scolastica [3].

Ma l'aspetto più significativo che può definitivamente fornire coordinate per il raggiungimento di una chiara comprensione delle caratteristiche attuali dell'azione didattica della scuola Secondaria di 1°Grado circa il rischio vulcanico lo troviamo, magnificamente, nel cambiamento apportato, per l'appunto, dall'*Autonomia* in vigore dal 1° settembre 2000 nella scuola italiana. Autonomia didattica, organizzativa, finanziaria, territoriale, del curricolo. Dall'approvazione della Legge 59 del 1997 "Bassanini", art. 21, è andata realizzandosi una trasformazione che sostanzialmente ha eliminato rigidità ed abitudini burocratiche per favorire un *sistema formativo flessibile* e responsabile centrato sui diritti dei cittadini ad apprendere, per agevolare risposte diverse alle diverse esigenze affidando maggiori responsabilità a tutti i livelli, per una società più consapevole.

La scuola è soggetto di connessione con il territorio per mettere in rete e collegamento tutte le esperienze formative possibili, per allargare le opportunità, per realizzare un ventaglio di possibilità del curricolo locale e rispondere meglio allo specifico di ciascuna scuola rendendo possibile una *relazione cultural***e** con i bisogni, la realtà, la cultura di un dato luogo. Tutto ciò, come si può immaginare, ha naturalmente messo in essere e in movimento, nella specifica realtà del territorio a ridosso del Vesuvio e suddiviso dal Piano di Evacuazione nelle cosiddette zone 'rosse' dell'area vesuviana [4], una migliore e più efficace azione della scuola verso la presa di coscienza dei cittadini nei confronti della delicata questione del rischio vulcanico. Realizzandosi in modo vario e partendo dalle più svariate angolature, i percorsi didattici, relativi al rischio, determinano uno stesso denominatore. Esso scaturisce dall'analisi che ciascuna scuola effettua del territorio per la focalizzazione dei bisogni dell'utenza. Successivamente in ciascun Piano di Offerta Formativa (POF) tale studio va a configurarsi anche con la appropriazione della conoscenza e presa d'atto dei problemi presenti nell'area di propria appartenenza. Data la macroscopicità del rischio, essa si è collocata ben presente nei POF delle scuole vesuviane che, attraverso i suddetti mezzi pedagogici, hanno efficacemente innalzato la *mission* verso un nuovo senso civile e democratico, realizzando, altresì, il cosiddetto *sistema formativo ad arcipelago*, dove i ponti, i passaggi, gli scambi evitano la povertà dell'isolamento [5].

2. Metodo di lavoro

L'intensa urbanizzazione del territorio vesuviano ed il grado di complessità della vita costituiscono, per i nostri giovani, motivo di incertezza e di caduta dei livelli di civiltà soprattutto in materia di tutela dell'ambiente e di stili di vita. Il progetto che ci proponiamo di realizzare ha come principio fondamentale quello di *educare: alla salute, alla conservazione della natura ed alla legalità,* in quanto solo la conoscenza delle relazioni esistenti tra *uomo-società-natura* permette di affrontare in maniera consapevole e responsabile le attuali e future sfide che possono compromettere la qualità della vita umana e sociale.

Il progetto Il Vulcano Ingabbiato rappresenta il tentativo di orientare i discenti e le loro famiglie verso uno stile di vita sano, responsabile ed ispirato ad un modello di sviluppo sostenibile. In particolare esso si propone di sviluppare tutte quelle competenze conoscitive e metodologiche capaci di permettere ai nostri allievi di svolgere il duplice ruolo di cittadino e di consumatore:

1. *come cittadino* dovrà riconoscere i propri diritti, farli valere e prospettare se stesso nel futuro;
2. *come consumatore* dovrà operare scelte oculate che soddisfino i propri bisogni senza compromettere l'ambiente e le varie forme di vita che in esso si svolgono (biodiversità).

Riteniamo che tale formazione sia legata alla capacità di comprendere le connessioni esistenti tra processi ambientali e quelli sociali. Il proprio territorio deve essere recepito come lo *spazio* naturale dove sono presenti persone, piante, animali, aziende ed istituzioni che interagiscono armoniosamente. Pertanto una cooperazione tra scuola, enti ed istituzione sui temi ambientali fa meglio capire al discente che il comportarsi ed il pensare in termini ecologici è un normale aspetto della vita quotidiana e non una situazione pedagogica "speciale".

2.1 Finalità che s'intendono perseguire e le metodologie

Le finalità che s'intendono perseguire nel progetto sono sensibilizzazione al rispetto ed alla salvaguardia degli habitat territoriali, conoscere la realtà locale in relazione all'attuazione delle leggi e promuovere una cultura del fare nella quale i ragazzi siano direttamente impegnati e che consenta loro di acquisire attraverso l'operatività, quella abitudine al rispetto ed alla cura. Le metodologie riguardono la didattica concepita come ricerca (Fig. 1) e la problematizzazione dei fenomeni naturali ai fattori socio culturali ed economici (Fig. 2).

2.2 Metodo concreto

Il metodo concreto mirava unicamente a fare *educazione attiva* dove l'allievo non è spettatore ma *attore* della realtà ambientale. Pertanto il ragazzo è calato direttamente nell'ambiente, un contatto vivo che esula dalla artefatta realtà antropizzata in cui è abituato a vivere.

Il «toccare con mano», leggere direttamente sul territorio i rischi naturali, acquisire la consapevolezza dei danni causati da attività incoscienti ed ignoranti porteranno alla comprensione delle problematiche territoriali nella loro globalità, a capire la complessità dell'ambiente e le interazioni che vi operano. Il che genererà una *nuova coscienza ambientale.*

2.3 Indicatori

Gli indicatori si riferiscono agli obiettivi misurabili, destinatori, finalità, metodologie, legami con altri progetti e possibilità di programmare il progetto in più esercizi finanziari:

A. Obiettivi misurabili che si intendono perseguire (partecipazione, attenzione, collaborazione, autonomia, disciplinarietà);

B. Destinatari a cui si rivolge (90 allievi, sezioni A-B-E-F-G, classi 1A-2A-3A-1B-2E-3E-2F-3F-G, allievi D.A.: n°4, allievi con problemi educativi);

C. Finalità che s'intendono perseguire (sensibilizzare al rispetto ed alla salvaguardia degli habitat territoriali, conoscere la realtà locale in relazione all'attuazione delle leggi);

D. Metodologie (didattica concepita come ricerca attiva, dalla problematizzazione dei fenomeni naturali ai fattori socio-culturali ed economici, didattica ludica);

E. Legami con altri progetti (tutti);

GVES, Napoli – New York, ISBN 978-88-903183-1-3

F. Possibilità di programmare il progetto in più esercizi finanziari (il progetto prevede n°1 esercizio finanziario: gennaio-maggio).

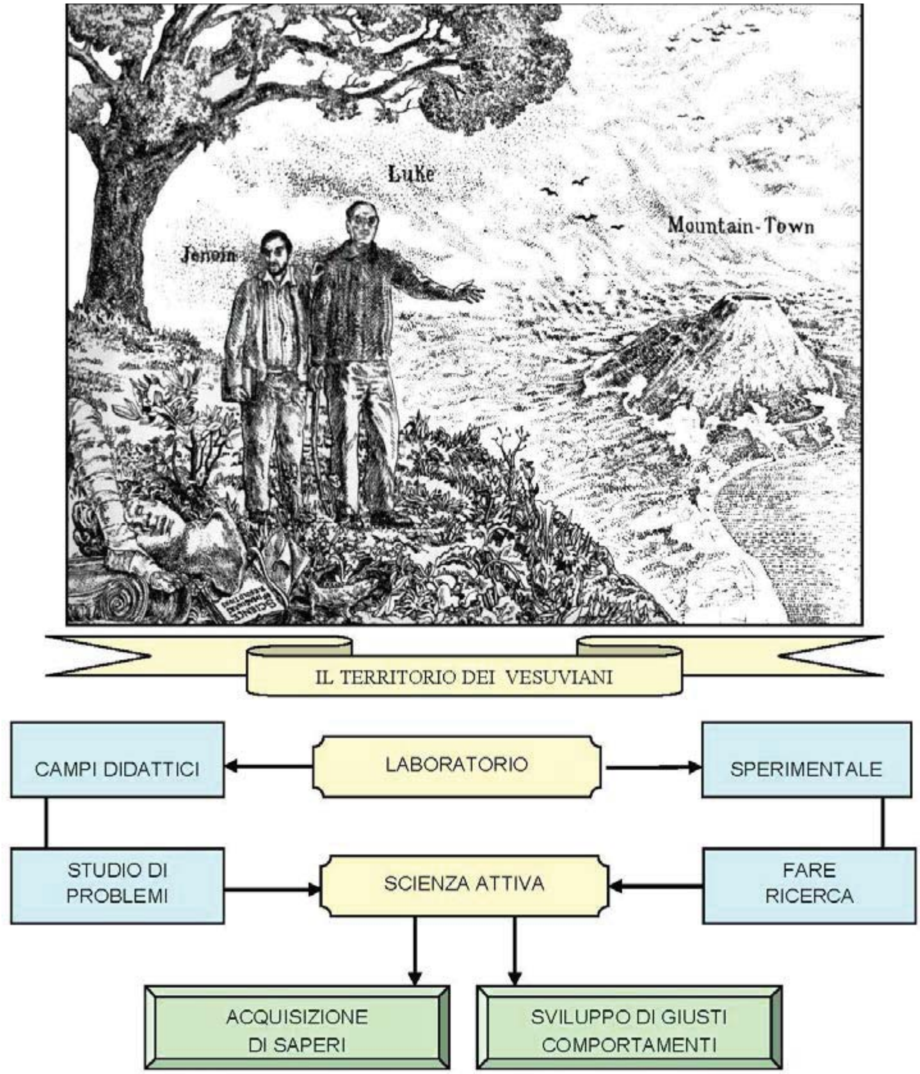

Figura 1. La metodologia riguarda la didattica concepita come ricerca.

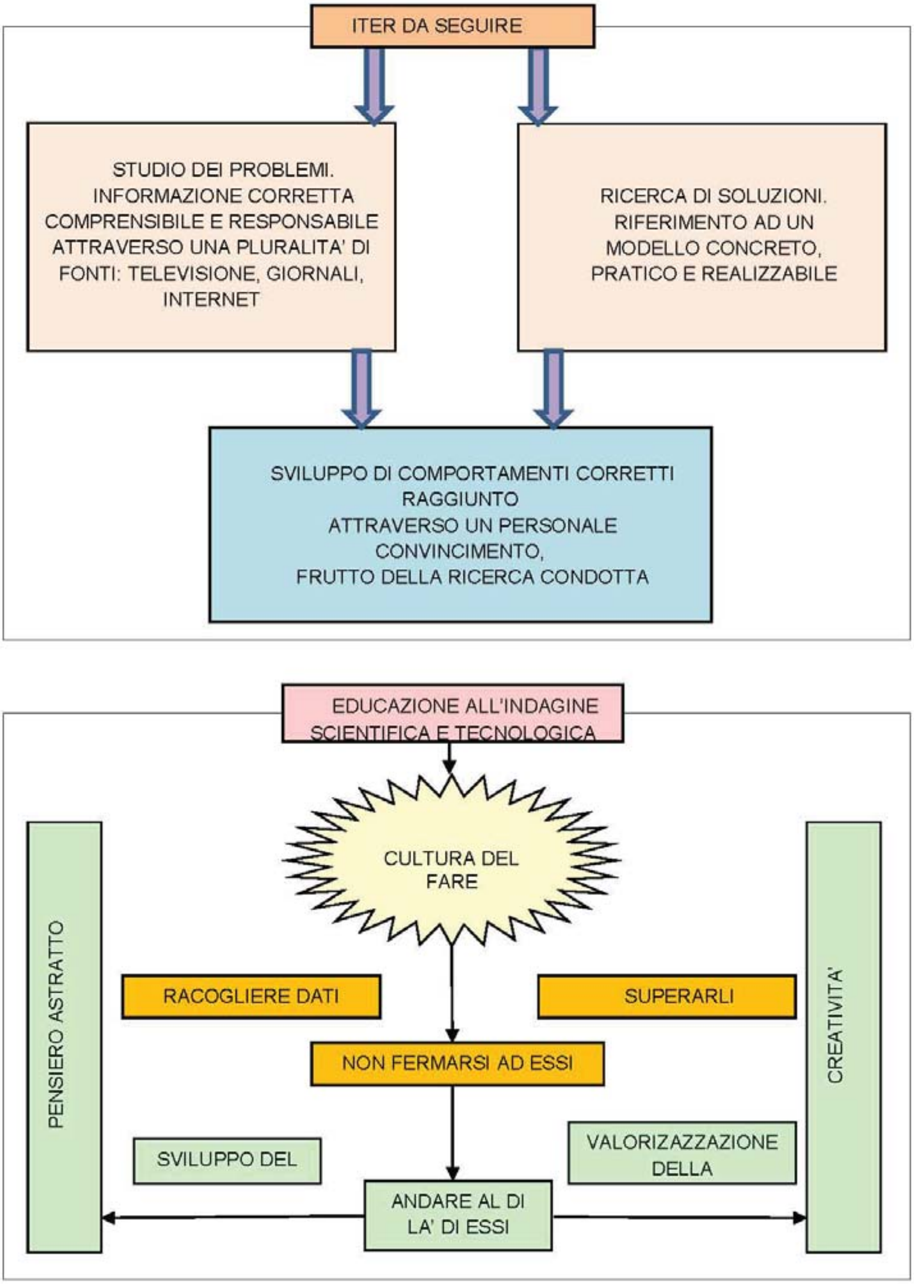

Figura 2. La problematizzazione dei fenomeni naturali ai fattori socio culturali ed economici.

2.4 Modalità di valutazioni, di documentazione e durata del progetto

Le modalità di valutazioni del progetto sono stati gli allievi di varie classi, frequenza, modifiche del comportamento nel laboratorio, eventuali modifiche del comportamento in classe, validità e coerenza: Progetto → Prodotto, utilità per l'orientamento, legami con altri progetti, possibilità di programmare il progetto in più esercizi finanziari.

Le modalità di documentazione comprende report in itinere di tutti gli indicatori, report finale di tutti gli indicatori, e la verifica orientata sul campo metodologico ed operativo. La durata del progetto era di nove mesi con gli elementi riportati nella Tabella 1.

Tabella 1. Risultati attesi e tempistica (Planning). I prodotti sono il testo Il Vulcano Ingabbiato e il CD multimediale.

Mese/Azione	9	10	11	12	1	2	3	4	5
Impianto laboratorio					x				
Modulo 1	Curricolari Corso A e F	x	x	x					
Modulo 2					x	x	x	x	x
Report in itinere M1			x						
Report in itinere M2						x			
Report finale				x					x
Test di gradimento									
Acquisto atrezzature					x				

2.5 Risorse umane

Le risorse umane sono i docenti per attività didattiche, per coordinamento e tutor, l'esperto umano, studenti e i loro genitori, e la responsabilizzazione per affettuare il progetto come riportato nella Tabella 2. Delle risorse umane fanno parte: Dirigente Scolastico Pasquale Bosone; 1° Modulo: Docenti (Maddaluno, Scorza, Gambardella); 2° Modulo: Docen-ti (Bosso, Capogrossi, Caputo, Scorza, Veneruso, Gambardella, Maddaluno + 2 docenti di sostegno + esperto esterno Architetto L. Scognamiglio. Il 1° Modulo viene svolto nelle ore curricolari (Corso A e Corso F) e il 2° Modulo nel Gennaio/Maggio. Il finanziario consiste: 1° Modulo con costo 0€, 2° Modulo con costo 270 h (30h x 9 docenti), attività di coordinamento di 60h (20h x 3 docenti), e acquisto materiale 500€.

3. Il risultato

Il risulato del lavoro è riporato nel volume Il Vulcano Ingabbiatto (Figura 3) e la sua struttura comprende una parte introduttiva a cui è affidato il compito di fornire in modo semplice e diretto le conoscenze generali sui vulcani. Il tema successivo è *Il vulcano più famoso del mondo: il Vesuvio* con le sue grandi eruzioni.

Tabella 2. La responsabilizzazione consiste di che cosa fare, chi lo deve fare e quando.

Che cosa fare	Chi lo deve fare	Quando
Attività di coordinamento	Maddaluno, Scorza, Gambardella	In itinere e a conclusione
Attività di ricerca	Tutti i 9 docenti	Intera durata del progetto
Produzione di materiale didattico	Maddaluno, Scorza, Gambardella	Febbraio, Maggio
Produzione di testo e CD	Maddaluno, Scorza, Gambardella	Maggio
Collaborazione e testi	Bosso, Capogrossi, Caputo, Veneruso + 2 docenti di sostegno	In itinere
Convegno	Tutti i 9 docenti	Maggio
Drammatizzazione	Tutti i 9 docenti	Maggio
Ideazione e conduzione esperimenti	Maddaluno, Scorza, Gambardella	In ittinere
Relazioni con enti esterni	Maddaluno, Scorza, Gambardella	In ittinere

L'obiettivo è di *non perdere la memoria storica, di comprendere l'importanza di vivere in un territorio a così alto rischio e di sentirne la responsabilità.* Così calati nel vivo della realtà del proprio Paese, si è pronti a considerare il vulcano anche come un grande creatore e quindi a percorrerne i sentieri per conoscere i vari ecosistemi ed i loro aspetti "dinamici". Vengono via via descritti animali, piante, paesaggi tra quelli più tipici e conosciuti. Ci si imbatte anche in personaggi fiabeschi come la strega ammaliatrice Amelia ed il suo simpatico corvo Gennarino. Nell'ultimo capitolo si prende coscienza di situazioni di squilibrio ambientale provocate dall'intervento dell'uomo.

Il testo è corredato di vari disegni scientifici, fotografie e poesie e per creare un legame emotivo tra i ragazzi e l'ambiente circostante è stato utilizzato il Vesuvio come *laboratorio a cielo aperto*, il che ha suscitato entusiasmo, curiosità e desiderio di oltrepassare i limiti del già noto. Attraverso il disegno naturalistico inteso come strumento scientifico e come mezzo di apprendimento, sono stati analizzati gli ecosistemi vesuviani e quelli urbani. Ne sono nate discussioni e riflessioni sul territorio: come era, come è, come dovrebbe essere. La Figura 4 riporta gli studenti e insegnanti del Laboratorio Ambientale[*].

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[*]Il disegno di copertina Il Vulcano Ingabbiato è di Gianfranco Gambardella. La carica delle 101 case vesuviane viene rigettata simultaneamente dal vulcano in una sorta di colata di magma edilizio che, sorprendentemente, quasi emula il colore rosso fuoco dell'autentica lava attraverso quei suoi tetti tenaci quanto invadenti che, data la circostanza, improvvisano scudi di spioventi tegole anticenere. Il confronto sarà impari: il Vesuvio, feroce drago addormentato, fiera sputafuoco ingabbiato nella soffocante prigione di cemento e di incessante e sconsiderata umana azione volta alla avida conquista, alla sopraffazione e, spesso, alla crudele e ottusa distruzione del proprio stesso bene, si sveglierà ed ahimé … Sbadiglierà. E si sa: meglio tenersi alla larga, a debita distanza dall'eventuale, indesiderato atto involontario di un drago che per un così lungo lasso di tempo è rimasto addormentato! Questa la sintesi che il disegno di copertina del libro ha inteso giocare nel suo duplice dinamismo grafico: la morale di una *fiaba dell'ambiente* che i ragazzi di un appassionato Laboratorio hanno saputo e voluto svelare tra le righe del loro avvincente racconto Il Vulcano Ingabbiato.

Figura 3. Il volume *Il Vulcano Ingabbiato* è stato realizzato nella Scuola Media Statale Scotellaro-Ungaretti di Ercolano e grazie a un contributo del Parco Nazionale del Vesuvio.

4. Conclusioni

E', questo un esempio di insegnamento mirato all'acquisizione di una importante **consapevolezza del rischio vulcanico** e, insieme a tanti altri lavori didattici che vengono realizzati a scuola, si spera possa giovare alla **mitigazione del pericolo**, nel tempo, con graduali miglioramenti verso un minore insediamento di popolazione. E' scuola che, attraverso tali attività didattiche, vuol raccogliere dei risultati concreti anche -relativamente- a lungo termine, restituendo ai giovani cittadini quel senso assopito dell' istinto di conservazione sia della vita, sia dei beni culturali di appartenenza alla propria terra. Lo stimolo alla difesa dei valori della vita e dell'arte, in seno all'acquisizione di una forte cognizione di quanto ruota e gioca nella sfera della propria mutevole realtà ambientale, donerà loro la forza di migliorare, ridisegnare, da politici del domani ed anche da semplici cittadini, i progetti che prediligono una vita contrassegnata dalla SICUREZZA**,** quella più vicina a garantire vera serenità.

Figura 4. Studenti e insegnanti del Laboratorio Ambientale con Gianfranco Gambardella nella prima fila.

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Insegnamento del rischio vulcanico a Castellammare di Stabia e Gragnano

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Riassunto. Sono riportati in questa relazione due esempi di lavori degli studenti delle scuole superiori di Castellammare di Stabia e Gragnano che sono stati coinvolti nella valutazione di due diverse strategie di mitigazione del Rischio Vesuvio. Gli studenti hanno affrontato questo compito attraverso la consultazione di documenti e interviste a scienziati e ad autorità, e hanno quindi raggiunto le loro conclusioni sull'adeguatezza delle diverse strategie di riduzione del rischio vulcanico. La prima strategia, promossa dal governo, richiede il trasferimento in tutta Italia di un milione di persone in caso di ripresa dell'attività vulcanica, mentre la seconda strategia non richiede enormi dispersioni di persone e promuove la creazione di un'area partenopea resiliente e sostenibile alle future eruzioni. Nel secondo lavoro, attraverso la Divina Commedia di Dante, gli studenti hanno collocato il Piano di Evacuazione del Vesuvio nell'Inferno e nel Purgatorio, e la strategia di resilienza e sostenibilità di VESUVIUS 2000 in Paradiso.

Parole chiave: Rischio vulcanico, Vesuvio, educazione

1. Introduzione

Risulta facile trovare, anche nelle occasioni ordinarie di lezione con gli studenti, l'occasione per approfondire e sviluppare la tematica del rischio ambientale e, nel contempo, approntare le possibili ed eventuali soluzioni.

In merito al rischio Vesuvio, di cui mi sono principalmente occupata, capita che, leggendo articoli di giornale, commentando fatti di cronaca o programmi televisivi, si trovi l'occasione per focalizzare l'attenzione sulla tematica in questione. Ad esempio, quando si è trattato di commentare qualche autorevole documentario televisivo o si è letto qualche articolo sull' argomento in merito alle polemiche sorte sull'efficacia del piano di evacuazione, ho notato che gli alunni mostrano interesse ad approfondire gli argomenti ed anzi a formulare degli spunti di riflessione talvolta anche critici. Questo, nel corso del mio lungo periodo di insegnamento, ha dato luogo allo studio e alla compilazione di lavori interessanti e proficui. In questa relazione voglio analizzare due, tra i tanti lavori fatti dai miei alunni sul rischio vulcanico sul territorio.

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2. Analisi e risultati

Il primo dei lavori si intitola "Verso la cultura della sicurezza", svolto nell'anno scolastico 1998/99 da alunni dell'ITC L. Sturzo di Castellammare di Stabia. Tale lavoro era il risultato di tanti stimoli forniti sul tema da: documenti storici, articoli di giornale, programmi televisivi, seminari con esperti e discussioni in classe [1]. Tutto ciò per avere una visione a largo raggio della tematica senza preclusione alcuna. Il tema della mitigazione del rischio vulcanico è alla base del progetto.

Questo argomento è di notevole rilevanza per gran parte della popolazione residente in prossimità del vulcano, ma pochi sono in grado di valutare obiettivamente cosa ciò implica per loro e quali sono le conseguenze dello scegliere uno schema piuttosto che un altro.

Il piano di evacuazione del Vesuvio [2] e' il piano ufficiale dei vulcanologi e propone l'evacuazione della gente in caso di emergenza. É controverso per quanto riguarda la questione della previsione delle eruzioni, del funzionamento del sistema dei trasporti e telecomunicazioni, della disponibilità della gente ad abbandonare le proprietà e gli amici e ad essere spostata in province italiane distanti, della speculazione che verrebbe attuata nei territori abbandonati e del rientro dopo l’eruzione. VESUVIUS 2000 [3] è un quadro non ufficiale di mitigazione del rischio e non prevede un’evacuazione di massa. Questo quadro prevede un’opera di prevenzione a lungo termine e richiede una collaborazione interdisciplinare per raggiungere gli obiettivi che si propone.

Durante gli anni scolastici 1997-1998 e 1998-1999, due classi del secondo anno della scuola Luigi Sturzo hanno partecipato ai seminari sul Vesuvio tenuti da diversi esperti, hanno ascoltato i dibattiti tra gli esperti, hanno intervistato le autorità della protezione civile, hanno studiato le anomalie associate ai diversi progetti di mitigazione del rischio e hanno confrontato i progetti sulla base delle rispettive modalita' soluzioni, risultati e conseguenze [1].

Con questo lavoro gli alunni, circa 20 anni fa, auspicavano un cambiamento e, pur avendo capito quanto fosse importante informare ed educare, prevenire oltre che prevedere un evento emergenziale, non sempre hanno ritrovato all’esterno la medesima percezione del rischio. Anzi gli enti preposti hanno sempre fornito un modello rassicurante di orientamento quasi a voler affermare che tutto era sotto controllo e che tutto il possibile da fare era stato fatto.

Il secondo esempio di progetto sul rischio Vesuvio è il lavoro prodotto nel 2014 dalla classe VC del Liceo Scientifico Don Milani di Gragnano, lavoro intitolato La Commedia Vesuviana ... fino a quando? [4]. In questo ricco e fantasioso lavoro gli alunni hanno associato alcuni versi della Commedia di Dante a riflessioni e considerazioni relative alla storia contemporanea del Vesuvio. In particolare modo si mettono in evidenza le differenze esistenti tra il piano di evacuazione emanato nel 1995 e l’aggiornamento fatto nel 2014, entrambi prevedono l’evacuazione e lo spostamento della popolazione. Il progetto VESUVIUS 2000 [3] e il suo omologo VESUVIUS PENTALOGUE [5] sono progetti che perseguono obiettivi di sostenibilità e sviluppo compatibile con salvaguardia dell’ambiente, dei beni culturali, dell’economia, nonchè della popolazione.

Inferno

Per me si va ne la città dolente,
per me si va ne l'etterno dolore,
per me si va tra la perduta gente.
Giustizia mosse il mio alto fattore;
fecemi la divina podestate,
la somma sapienza e 'l primo amore.
Dinanzi a me non fuor cose create
se non etterne, e io etterno duro.
Lasciate ogni speranza, voi ch'intrate.
Dante, Inferno III

L'eruzione vesuviana del 1944 ha segnato la fine di un duraturo ciclo di attività vulcaniche cominciato nel 1631 e l'inizio di uno sviluppo edilizio e civile nell'area limitrofa al vulcano. L'esigenza di una sistemazione induce il popolo napoletano ad investire nella zona vesuviana approfittando del boom economico registratosi negli anni del dopoguerra. La crescita urbanistica determina quel fenomeno passato alla storia come "abusivismo di necessità": si costruisce sottovalutando eventuali pericoli naturali, facendo crescere, di conseguenza, il rischio.

Ma lo stato di "quiescenza" del Vesuvio ha accompagnato la diffusione di un'evidente "quiescenza morale". L'uomo ha abusato della latenza del vulcano costruendo sulle pendici dello "sterminator Vesevo" accantonando così nella dimenticanza la sua potenza distruttrice.

Considerate la vostra semenza:
fatti non foste a viver come bruti,
ma per seguir virtute en canoscenza.

Dante, Inferno XXVI

Nel 1995, ritenuto un punto di partenza poichè per la prima volta l'uomo inizia a prendere consapevolezza del rischio con cui convive, i vulcanologi italiani, assieme alla protezione civile, hanno redatto il primo piano di emergenza per il rischio vulcanico nell'area campana. Questo piano segna una svolta cruciale nella gestione del rischio Vesuvio. Tuttavia, essendo concentrato essenzialmente sulle eventuali vie di fuga per la popolazione, su improbabili forme di evacuazione della stessa e su un'azzardata tempistica previsionale dell'evento (capacità di prevedere l'eruzione con tre settimane di anticipo), la stessa sconfessata dall'attuale aggiornamento del piano, risulta chiaro che il suddetto piano è da definire vago, superficiale e poco attuabile. Come si è potuto pensare che l'eruzione potesse essere prevista con ben tre settimane di anticipo?

Purgatorio

Per correr miglior acque alza le vele
omai la navicella del mio ingegno,
che lascia dietro a sè mar sì crudele;

e canterò di quel secondo regno
dove l'umano spirito si purga
e di salire al ciel diventa degno.

Dante, Purgatorio I

Nel febbraio 2014 è stato firmato l'Aggiornamento del Piano Nazionale di Emergenza per il Vesuvio che ha apportato modifiche al Piano Nazionale stilato nel 1995. Ma quali modifiche? Quali PROGRESSI?

	Piaano Nazionale d'Emergenza 1995	Aggiornamento del Piano Nazionale d'Emergenza 2014
Zona rossa	18 comuni	25 comuni
Previsione eruzione	20 giorni	72 ore
Modalità e tempi d'evacuazione	Mezzi propri, trasporti pubblici, navi. Circa 7 giorni per evacuare 600 000 persone.	Mezzi propri, trasporti pubblici, navi. Circa 72 per evacuare 1 000 000 persone.
Fasi di allontamento della popolazione	Spostamento nelle regioni gemellate (fase unica)	1 fase: spostamento in aree di prima assistenza 2 fase: trasferimento nelle regioni gemellate

Il piano Nazionale di Emergenza per l'Area Vesuviana è un oggetto di valore, ma *inutile e ingombrante*, perchè ha un valore molto basso per la popolazione dell'area vesuviana. Il piano infatti esclude il reale protagonista, la *popolazione* dell'area. Difatti, gli abitanti non sanno come muoversi in caso di eruzione, i sindaci non hanno mai avuto un contatto con le regioni gemellate e addirittura si dice che *il discorso del gemellaggio operativamente deve essere ancora costruito*; nè le aree di prima accoglienza sanno in che modo accogliere la popolazione che giungerà terrorizzata. Quando sarà il momento opportuno per informare i Vesuviani?

L'evacuazione proposta *distrugge la cultura* dell'area interessata e apre le porte al *ripopolamento abusivo* dopo l'eruzione. Ciò è ***inaccettabile*** e la popolazione dell'area dovrebbe decidere per un piano *sostenibile* in modo da salvaguardare le generazioni future.

Come le pecorelle escon del chiuso
a una, a due, a tre, e l'altre stanno
timidette atterrando l'occhio e il muso;
e ciò che fa la prima, e l'altre fanno,
addossandosi a lei, s'ella s'arresta,
semplici e quete, e lo 'mperchè non sanno;
si vid'io muovere a venir la testa
di quella mandra fortunata allotta,
pudica in faccia e nell'andare onesta.

Dante, Purgatorio III

Come le "pecorelle" si fidano ciecamente di chi le guida, allo stesso modo fa la popolazione vesuviana vivendo fiduciosa ma all'oscuro della reale situazione di rischio. Le due foto evidenziano come, in circa 60 anni, il rischio Vesuvio sia stato sottovalutato: è stato concesso un ulteriore incremento demografico della zona fino alle pendici del "Formidabil Sterminator Vesevo".

Paradiso

Infino a qui l'un giogo di Parnaso
assai mi fu; ma or con amendue
m'è uopo intrar ne l'aringo rimasse
dove l'umano spirito si purga

Dante, Paradiso I

Il mitico monte Parnaso, sede delle Muse e di Apollo, aveva due cime. In questa terzina Dante, invocando l'aiuto di entrambe, cerca e richiede l'ispirazione, così come gli uomini, facendo riferimento alle due esperienze precedenti (rispettivamente dell'Inferno e del Purgatorio) ed essendosi trovati prima nel buio della disinformazione relativa al rischio Vesuvio e poi passando attraverso il momento della presa di coscienza, giungono a uno spiraglio di salvezza: VESUVIUS 2000.

Ma cos'è VESUVIUS 2000?

Si tratta del progetto, elaborato nel 1994, dal professor Flavio Dobran, che mira alla prevenzione di una catastrofe nell'area vesuviana, e gli obiettivi centrali proposti da tale progetto sono i seguenti:

- Definizione del sistema vulcanico del Vesuvio e dell'eruzione del 1631, in particolare, al fine di sviluppare un modello fisico-matematico-informatico del vulcano capace di valutare eruzioni future e i loro effetti sul territorio (Simulatore Vulcanico Globale);
- Valutazione della vulnerabilità della popolazione, delle importanti strutture ed infrastrutture industriali-culturali (Scavi di Pompei, Oplonti, Ercolano) e delle telecomunicazioni nell'area a rischio per stabilire le zone più vulnerabili rispetto a diversi scenari eruttivi;
- Produrre un ambiente resiliente dalle eruzioni con nuove norme di costruzione;
- Sviluppo di una corretta metodologia educativa fondamentale per stabilire nuove abitudini mentali, finalizzate alla creazione della cultura della sicurezza, fondamentale per affrontare future eruzioni.

Beatrice in suso, e io in lei guardava.

Dante, Paradiso II

Un'altra importante peculiarità del progetto VESUVIUS 2000 è l'intenzione di agire e di perseguire i sopracitati obiettivi in termini di sostenibilità, ovvero una forma di sviluppo compatibile con la salvaguardia dell'ambiente, dei beni culturali, dell'economia, nonchè della popolazione.

Ecco perchè la Beatrice cantata da Dante può rappresentare il concetto di sostenibilità, in quanto volge il suo sguardo alla salvezza; l'uomo vesuviano, invece, in questo caso rappresentato da Dante che guarda Beatrice, ripone la sua speranza nello sviluppo sostenibile tanto inneggiato da VESUVIUS 2000.

Ma non eran da ciò le proprie penne:
se non che la mia mente fu percossa
da un fulgore in che sua voglia venne.

Dante, Paradiso XXXIII

Ed è per questo che l'uomo, seppure intimorito dall'oscurità dell'ignoranza che fino a questo momento ha attanagliato la sua mente, può ravvisare nel progetto VESUVIUS 2000 il soddisfacimento delle proprie aspettative che si concretizzano nelle competenze, nella buona informazione e nella piena tutela dell'uomo e del suo ambiente.

Ma non eran da ciò le proprie penne:
se non che la mia mente fu percossa
da un fulgore in che sua voglia venne.

Dante, Paradiso XXXIII

Ormai Dio, primo motore e primo amore, muoveva la mia sete di conoscenza e l'ansia delle mie volontà, proprio come un motore che gira in maniera uniforme in ogni punto.

Ma già volgeva il mio disio e 'l velle,
sì come rota ch'igualmente è mossa,
l'amor che move il sole e l'altre stelle.

Dante, Paradiso XXXIII

3. Conclusioni

Nonostante il lavoro fatto nelle scuole, perdura ancora oggi la sconcertante differenza tra le richieste delle nuove generazioni in termini di prevenzione e di sostenibilità e le risposte che ricevono dall'esterno che sono ancora poco chiare e coerenti. La scuola fa la sua parte e, di certo, non può abdicare a quelli che sono doveri istituzionali di formazione del cittadino, ma, almeno per me insegnante, è stato ed è ancor oggi molto difficile conciliare questi contrasti. Difatti è veramente spiazzante non poter dare esempi applicativi di buone e geniali idee progettuali di quanti profondono energie nel campo della ricerca e sperimentazione.

Anche limitandosi al loro contesto territoriale, i giovani si accorgono che non è facile tradurre la pur corretta argomentazione teorica sulla sicurezza in pragmatismo articolato e sistemico finalizzato al bene della collettività. Questo è un passaggio cruciale perchè una buona educazione al rischio dovrebbe prevedere un sincronismo di interventi e di azioni tra tutte le parti del sistema sociale ed evitare che quanto appreso dagli alunni a scuola resti una sterile conoscenza senza riscontro alcuno nel proprio territorio.

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Attività di educazione ed informazione delle popolazioni esposte al rischio vulcanico

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Riassunto. L'area vesuviana è considerata una delle più pericolose del pianeta e il Liceo Villari confina con la zona orientale della città in cui si trovano i quartieri vicini al Vesuvio. Nella scuola abbiamo svolto una indagine campionata su una popolazione di 325 persone, di diverse età e tutte abitanti nell'area metropolitana di Napoli. A tutti i soggetti coinvolti è stato somministrato un questionario, costituito da una serie di domande, che hanno voluto accertare la percezione del Vesuvio in termini di benefici e di rischi, di timori per un'eruzione immediata e, più in particolare, delle conseguenze che potrebbero derivare da essa. I risultati suggeriscono che la popolazione percepisce il rischio del Vesuvio in maniera molto superficiale, sia per un approccio fatalistico alla vita che per il basso livello di informazione scientifica. Gli esiti di questa indagine ci permetteranno di definire un percorso didattico efficace, indirizzato agli studenti tra i 14 e i 18 anni, per una formazione culturale adeguato.

Parole chiave: Vesuvio, educazione, rischio vulcanico, sondaggio.

1. Premessa

Ogni napoletano nutre un amore quasi filiale per il Vesuvio, ostinandosi ad ignorarne, quasi, la pericolosità, ritenendolo un gigante buono, incapace di provocare danni in una popolazione che lo ama profondamente. Eppure quando in una meravigliosa giornata di fine agosto (forse di fine ottobre) del 79 d.C. il Vesuvio si risvegliò, dopo una quiescenza di oltre 300 anni, non risparmiò danni a Pompei, Ercolano, Oplonti e Stabia, con un tributo notevole di vittime. Analogamente nel 1631, una violenta eruzione, a carattere sub-pliniano, colse del tutto impreparata la popolazione, che abitava le pendici del Vesuvio, provocando oltre 6000 morti e la distruzione della quasi totalità degli edifici eretti in quell'area.

Erano 500 anni che il Vesuvio era inattivo e, nella memoria collettiva, non si avvertiva affatto la preoccupazione di abitare alle falde di un vulcano. La popolazione

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era talmente tranquilla che non fu data la giusta considerazione a quei fenomeni, che pure furono osservati (scosse sismiche, vistose deformazione del suolo, rumori sordi, ecc.), ma valutati come "cose passeggere" e non come segnali di una imminente eruzione [1].

La popolazione non seppe interpretare quegli "avvertimenti", che avrebbero permesso di risparmiare molte vite umane.

Il comportamento eruttivo del Vesuvio, nel corso dei secoli, ha sempre alternato periodi di attività eruttiva a condotto aperto, che hanno avuto carattere effusivo non violento, ad altri, dopo periodi di quiescenza che hanno ostruito il condotto, cui hanno fatto seguito eventi esplosivi a carattere violento e distruttivo. Questa "intermittenza" ha prodotto lunghi periodi di apparente calma, che hanno fatto perdere la "memoria" degli eventi distruttivi, documentati durante il corso dei secoli.

L'eruzione del 1944, ultima in ordine di tempo, è considerata dai vulcanologi la fine di un'attività a condotto aperto e l'inizio di un'attività a condotto ostruito del vulcano, che al momento sembra non dimostri una imminente ripresa dell'attività: non sembrano esserci, infatti, accumuli di magma considerevoli nei primi 10 km di crosta.

A distanza di circa 70 anni, da questa ultima eruzione, ci siamo chiesti qual è il rischio che viene percepito dalla popolazione napoletana, soprattutto nei quartieri centro-orientali della città (Vasto, Vicaria, Poggioreale) e dei paesi limitrofi (Casoria, Casalnuovo, Volla, ecc.), da cui provengono la grande maggioranza degli studenti del Liceo P. Villari di Napoli e che risultano essere tra quelli a maggiore rischio, nel caso si verificasse un'eruzione del Vesuvio.

Il gigante si è addormentato: i napoletani possono dormire sonni tranquilli?

2. L'indagine

Conoscere la storia eruttiva del Somma-Vesuvio è molto importante, fondamentalmente per due motivi: (1) la valutazione della sua pericolosità si basa sull'ipotesi, secondo il principio dell'attualismo, che gli eventi futuri saranno simili a quelli del passato; (2) la popolazione tende a dimenticare che quella meravigliosa "montagna" è, in realtà, un vulcano tra i più pericolosi del pianeta.

La percezione del rischio può permettere di acquisire indicazioni importanti, per implementare una più efficace azione di prevenzione e di attenuazione, degli effetti disastrosi di un evento naturale, quale può essere un'eruzione vulcanica, permettendo, altresì, di mettere a punto delle appropriate attività educative, nella popolazione residente nell'area a rischio.

Alla luce di queste considerazioni, è stato messo a punto un questionario, che ci ha permesso di "misurare" la percezione del rischio da parte dei cittadini di diverse età, cultura, estrazione sociale, ecc. Negli studi di popolazione, come è noto, con il questionario si mira a descrivere, confrontare e spiegare le dinamiche comportamentali, gli atteggiamenti, nonché il sistema di norme, conoscenze, credenze propri del campione di soggetti intervistati [2-4].

Il questionario rimane, in questi casi, lo strumento più efficace nell'indagine su campioni di cittadini, soprattutto per i caratteri della strutturazione e della standardizzazione: lo stimolo deve essere somministrato, preferibilmente, utilizzando quesiti di tipo chiuso, secondo modalità di risposta predefinita (questionario a risposta multipla), in modo uniforme a tutti gli intervistati.

La realizzazione di un questionario ex novo è un'operazione molto impegnativa ma necessaria, per le notevoli potenzialità e l'ampio campo di applicazione di tale strumento, e va concepita ogniqualvolta la ricerca di un'informazione approfondita e l'originalità dei dati ricavabili ne giustificano realmente il ricorso.

Per la nostra indagine abbiamo scelto un metodo di tipo descrittivo, con domande "non dirette", che potessero determinare stati d'ansia nei nostri interlocutori, come di solito suscitano domande troppo dirette quali "Ti spaventa pensare ad un'eventuale prossima eruzione?" oppure "Quante vittime potrebbero esserci se il Vesuvio eruttasse?" oppure "Come ti comporteresti se il Vesuvio eruttasse?", che avrebbero prodotto, a nostro avviso, risposte prevedibili, scontate.

La scelta dei quesiti ha avuto anche lo scopo di raccogliere informazioni utili per la progettazione di un percorso didattico sull'educazione al rischio vulcanico.

Le domande proposte sono riconducibili all'esplorazione di tre grandi dimensioni:

- proprietà socio-grafiche(età, professione, quartiere/comune di residenza, ecc.);
- preconoscenze (tipo di vulcano, zone a rischio, possibili danni, norme e piani di evacuazione, gestione del rischio);
- comportamenti, soprattutto in riferimento ad atteggiamenti.

La verifica dell'efficacia dello strumento di rilevazione messo a punto è stata effettuata attraverso un pre-test, su un campione ristretto, prima di cominciare la campagna di rilevazione vera e propria, con l'obiettivo di :

- verificare la comprensibilità delle domande da somministrare;
- verificare la loro struttura logica;
- controllare i tempi di rilevazione, valutando la rilevazione più idonea.

Per la somministrazione del test, tra le possibili alternative (face to face, intervista telefonica, ecc), sono state utilizzate modalità on line, perché veloci e poco onerose, che hanno previsto l'utilizzo del sito web del nostro liceo, per la partecipazione della nostra comunità scolastica e delle loro famiglie, e dei social (WhatsApp) per coinvolgere nell'indagine altri cittadini, non in diretta relazione con la nostra scuola.

Le modalità scelte per la somministrazione hanno voluto garantire, inoltre, che non potessero esserci influenze e condizionamenti dell'intervistato da parte dell'intervistatore, riducendo in questo modo fattori di distorsione durante il setting di rilevazione.

3. Il questionario: domande e risultati

La numerosità del campione è N= 325 soggetti coinvolti, che hanno risposto alle domande del questionario articolato in 26 domande a risposta multipla presentate di seguito:

(1) In quale delle seguenti fasce è compresa la tua età?		
	N	Percentuale
Da 0 a 20 anni	189	58,2
Da 20 a 40 anni	52	16
Da 40 a 60 anni	69	21,2
Oltre i 60anni	15	4,6
	325	100

I soggetti sono stati divisi in quattro fasce d'età: la frazione maggiore (58,2%) è costituita da giovani di età compresa tra i 16 e i 18 anni.

(2) Abiti a			
Napoli		Provincia	
N	%	N	%
217	68	102	32

I soggetti interessati sono stati divisi in 2 fasce: abitanti in quartieri napoletani o in paesi della provincia.

(3) Qual è la tua professione?		
	N	%
Studente	208	64
Docenti	21	6,5
Impiegati	19	5,8
Disoccupati	17	5,2
Operai	8	2,5
Pensionati	5	1,5
Artigiani	3	0,9
Libero professionista	11	3,4
Dirigente aziendale	2	0,6
Dirigente pubblico	1	0,3
Artista	1	0,3
Altro	22	6,8

La maggior parte dei soggetti (64%) è rappresentata da studenti o da lavoratori in attività, dati che suggeriscono un buon livello di scolarità nella popolazione coinvolta.

(4) In quale quartiere di Napoli/comune abiti?		
	N	%
Quartieri S. Lorenzo/ Vicaria /CDN	84	26
Quartieri Poggioreale/Via Stadera/Arpino	45	13,9
Quartiere S. Carlo all'Arena	44	13,6
Quartieri Ferrovia/Mercato	16	5
Quartieri Capodichino/Secondigliano	13	4
Quartieri S. Giovanni/Barra	6	1,9
Quartieri Vomero/Posillipo/Fuorigrotta	17	5,3
Comune di Casoria	36	11,1
Comune di Casalnuovo	8	2,5
Comune di Volla	3	0,9
Altro	49	15,2

La maggior parte dei soggetti proviene dai quartieri S. Lorenzo Vicaria, di Napoli est (Poggioreale, S, Giovanni, Barra) e dei paesi di Casoria e Casalnuovo.

(5) Sai che tipo di vulcano è il Vesuvio?					
Quiescente		Attivo		Spento	
N	%	N	%	N	%
209	64,7	104	32,2	10	3,1

La maggior parte dei soggetti sa che il Vesuvio è un vulcano quiescente ma il 3,1% lo ritiene spento.

(6) Sai in che zona vulcanica ricade il tuo comune/quartiere?							
Zona rossa		Zona gialla		Zona non a rischio		Non lo so	
N	%	N	%	N	%	N	%
209	64,7	104	32,2	63	19,5	90	27,9

Il 27,9% dei soggetti non sa se il proprio quartiere/paese appartiene ad una zona di pericolosità.

(7) Sai in base a quali criteri sono state individuate le zone di rischio Vulcanico?			
SÌ		NO	
N	%	N	%
156	48	169	52

Più della metà dei soggetti (52%) ignora i criteri con cui vengono stabilite le zone di pericolosità al rischio Vesuvio

(8) Quanto sei preoccupato per il rischio Vesuvio ?							
Molto		Abbastanza		Poco		Per niente	
N	%	N	%	N	%	N	%
46	14,2	148	45,7	33,3	108	22	6,8

Il 33,3 % dei soggetti si dice poco preoccupato per il rischio di un'eventuale eruzione, mentre il 6,8% non avverte nessuna preoccupazione.

(9) Fra quanto tempo pensi sia possibile un'eruzione del Vesuvio?							
1 anno		20 anni		100 anni		Più di 100 anni	
N	%	N	%	N	%	N	%
11	3,4	152	47,1	107	33,1	53	16,4

Il 47% dei soggetti pensa possa avvenire una prossima eruzione del Vesuvio fra circa 20 anni.

(10) Quanto ti ritieni preparato ad un affrontare un'emergenza Vesuvio?							
Poco		Per niente		Abbastanza		Molto	
N	%	N	%	N	%	N	%
150	46,2	138	42,5	31	9,5	6	1,8

La stragrande maggioranza degli intervistati si sente poco (46,2%) o per niente preparato (42,5 %) ad un'emergenza Vesuvio.

(11) Quanto tempo prima si riuscirebbe a prevedere un'eruzione?							
6 mesi		1 mese		1 settimana		2-3 giorni	
N	%	N	%	N	%	N	%
42	13	76	23,5	100	31	105	32,5

Il 32,5% dei soggetti pensa sia possibile prevedere un'eruzione vesuviana solo 2-3 giorni prima.

(12) Quali sono le misure più efficaci per prevedere un'eruzione?		
	N	%
Reti di monitoraggio ambientale	102	31,5
Studi mediante l'uso di modelli matematici o probabilistici basati sul cosiddetto intervallo di riposo	66	20,4
Osservazione diretta del Vulcano, Rigonfiamento del vulcano	134	41,4
Altro	22	6,8

Il 41,4 % dei soggetti ritiene che un'eruzione si possa prevedere osservando eventuali rigonfiamenti del vulcano.

(13) Sai quanto sarebbe grande, secondo studi scientifici, l'area interessata dai detriti prodotti dell'eruzione?					
500 km2		50 km2		10 km2	
N	%	N	%	N	%
141	43,8	160	49,7	21	6,5

Circa la metà dei soggetti (49,7%) ritiene che, in base alle previsioni degli esperti, l'area interessata alla ricaduta di materiali piroclastici non superi i 50 km^2.

(14) Sai quante persone si dovrebbero evacuare in caso di eruzione?									
700.000		250.000		100.000		10.000		Non so	
N	%	N	%	N	%	N	%	N	%
8 9	27,5	68	21	27	8,3	7	2,2	133	4 1

Il 41% non conosce le dimensioni della popolazione, residente nelle aree a rischio, da evacuare.

(15) Quali sono le politiche e i programmi che si stanno attuando per la valutazione/gestione del rischio vulcanico?		
	N	%
Mappatura del rischio	30	9,3
Monitoraggio regolare	90	27,8
Simulazione di evacuazioni della popolazione residente	30	11,1
Valutazione dei flussi automobilistici nel sistema viario delle zone a rischio	7	2,2
Decongestione abitativa della fascia costiera e circumvesuviana	6	1,9
Corsi di educazione ambientale sul rischio vulcanico	21	6,5
Non saprei	134	41,4

Il 41,4 % dei soggetti non è informato sulle politiche e sui programmi che si stanno attuando per la valutazione e la gestione del rischio vulcanico.

(16) In caso di eruzione, pensi siano adeguate le misure di prevenzione che sono previste sul territorio?					
Sì		In parte		Per niente	
N	%	N	%	N	%
150	46,2	138	42,5	31	9,5

La maggioranza degli intervistati ritiene adeguate solo in parte (42,5 %) o per niente (9,5 %) le misure di prevenzione previste in caso di eruzione.

(17) Se consideri una possibile eruzione, quali sarebbero i principali danni socio-economici?		
	N	%
Perdita di vite umane	145	44,8
Perdita nelle attività produttive	15	4,6
Danni alla proprietà	6	1,9
Migrazione definitiva	12	3,7
Spopolamento di vaste aree dei territori interessati	47	14,5
Migrazione per mancanza lavoro	0	0
Gravi danni alle infrastrutture (scuole, ospedali, strade etc. con ingenti problemi economici per lo stato)	84	25,9
Distruzione di siti archeologici (Pompei, Ercolano, Oplonti, ecc.)	11	3,4
Altro	4	1,2

Il 44,8 % dei soggetti prevede che i danni socio-economici maggiori sarebbero in termini di perdita vite umane, che non si riuscirebbero a sottrarre all'eruzione.

(18) Se consideri una possibile eruzione, quali sarebbero i principali danni ambientali che potrebbero accompagnarsi ad essa?		
	N	%
Deforestazione	62	19,2
Cambiamento climatico persistente	67	20,7
Cambiamento della linea di costa	17	5,3
Variazione nei livelli delle falde freatiche	38	11,8
Scarsità d'acqua	14	4,3
Degradazione dei suoli	83	25,7
Altro	42	13

La degradazione dei suoli (25,7%), il cambiamento climatico persistente (20,7%) e la deforestazione(19,2%) sono stati indicati come danni ambientali più probabili prodotti da un'eruzione.

(19) Pensi che il tuo/a quartiere/città sarebbe interessato/a in maniera significativa dall'eruzione?		
	N	%
No	30	9,2
Sì, con danni limitati	136	41,8
Sì, con danni notevoli	86	26,5
Sì, con danni enormi	28	8,6
Non saprei	42	12,9

Il 41,8% dei soggetti prevede danni limitati, mentre il 9,2% ritiene che, in caso di eruzione, non si dovrebbero registrare danni nel proprio Quartiere/Comune.

(20) Sai che esistono dei piani di evacuazione predisposti dai comuni?			
SÌ		NO	
N	%	N	%
240	74,5	82	25,5

La maggioranza dei soggetti (74,5%) sa che i comune hanno previsto piani di evacuazione in caso di emergenza.

(21) Sai se nella tua zona di residenza è stato predisposto un piano di evacuazione?			
SÌ		NO	
N	%	N	%
58	18	264	82

La maggioranza dei soggetti (82 %) non sa se il quartiere/comune di residenza abbia predisposto un piano di evacuazione.

(22) Se esiste un piano di evacuazione, nella tua zona di residenza, sai come ti dovresti comportare in caso di emergenza?			
SÌ		NO	
N	%	N	%
37	11,6	281	88,4

La maggioranza dei soggetti (82 %) non sa come comportarsi in caso di emergenza.

(23) Sai in quanto tempo i piani di evacuazione prevedono che possano attuarsi le operazioni di allontanamento rapido della popolazione?		
	N	%
1 mese	23	7,2
1 settimana	54	16,9
2-3 giorni	58	18,1
Non saprei	185	57,8

Il 57,8% dei soggetti non conosce quanto tempo sarebbe necessario a permettere l'allontanamento rapido della popolazione in caso di eruzione.

(24) Tu e la tua famiglia avete mai concordato un piano di emergenza in caso di pericolo?			
SÌ		NO	
N	%	N	%
45	13,9	278	86,1

La grande maggioranza dei soggetti (86,1%) non ha mai concordato a livello familiare un piano di emergenza da adottare in caso di pericolo

(25) Hai mai fatto pratica su situazioni di emergenza a scuola?		
	N	%
No, mai	116	35,9
Sì, meno di sei mesi fa	120	37,2
Sì, un anno fa	43	13,3
Sì, più di 5 anni fa	20	6,2

Solo il 37,2% dei soggetti ha partecipato negli ultimi 6 mesi ad un'esercitazione su situazioni di emergenza.

(26) Hai mai partecipato a corsi, convegni, incontri, lezioni sui vulcani e sulla gestione del rischio vulcanico?		
	N	%
No, mai	229	70,7
Sì, organizzati dalla scuola	78	24,1
Sì, organizzati dal Comune	1	0,3
Sì, organizzati dalla Regione	3	0,9
Sì, organizzati dalla protezione civile	3	0,9
Sì, organizzati da Enti privati	3	0,9
Sì, organizzati da associazioni culturali	7	2,2

La maggioranza dei soggetti (70,7%) non ha mai partecipato a corsi, convegni, incontri sulla gestione del rischio vulcanico.

4. Discussione e Conclusioni

La nostra indagine ha dimostrato come sia poco percepito nella popolazione il rischio vulcanico. Molti dei soggetti che hanno partecipato al nostro sondaggio dimostrano di non avere conoscenze adeguate, per definire i livelli di pericolosità al rischio vulcanico del territorio in cui vive e si dichiarano poco o per niente preparati ad un'eruzione. Molto variegata è la conoscenza delle dimensioni del fenomeno in termini di danni socio-economici e ambientali e delle ricadute che un'eruzione vulcanica possa avere sull'area vesuviana. La quasi totalità delle persone vive il "problema Vesuvio" con molta superficialità, si aspetta di essere avvisata in tempo utile, se si dovesse "risvegliare" il vulcano, ma pochi sanno che "allo stato attuale delle conoscenze, nessuno è in grado di dire con certezza se un vulcano tornerà o meno in attività, se lo farà nel giro di poche ore o attraverso fasi di avvertimento più o meno lunghe" [5].

Dall'analisi delle risposte emerge, poi, una palese contraddizione: la maggioranza dei soggetti coinvolti afferma di non conoscere le iniziative, che si stanno attuando per la gestione del rischio vulcanico, ma ritiene poco adeguate le misure di protezione civile previste in caso di eruzione. Altro aspetto negativo è rappresentato dalla mancanza di partecipazione a corsi di formazione per la gestione del rischio vulcanico e ad esercitazioni di simulazioni in situazioni di emergenza, pure appartenendo a quartieri della città o a comuni che sono inclusi nelle zone di pericolosità. I cittadini coinvolti ritengono, probabilmente, che solo lo Stato abbia la responsabilità di proteggere la popolazione in caso di eruzione. Attualmente, oltre all'organizzazione di sporadici incontri, dibattiti ecc. sul tema Vesuvio, che coinvolgono solo marginalmente la popolazione residente, l'unica risposta che le Istituzioni (Stato, Regione, Provincia, Comune) sembrano in grado di attuare, in caso di emergenza vulcanica, sia una complessa operazione di evacuazione dell'area minacciata, peraltro, molto problematica in un'area come quella vesuviana ad alto indice abitativo.

I risultati di questa nostra inchiesta hanno confermato, quindi, la necessità assoluta di sensibilizzare tutti i cittadini, e in particolare i giovani, sulla consapevolezza e sulla conoscenza dei rischi derivanti da calamità naturali, che si possono verificare nel proprio territorio. L'educazione al rischio vulcanico a Napoli e nei comuni limitrofi deve, perciò, prevedere un percorso di formazione sistemico, da attuare nelle scuole: la scarsa consapevolezza del rischio unita all'elevata presenza demografica incrementano sensibilmente la vulnerabilità del territorio [2,3,6-8]. Ogni abitante dovrebbe essere sensibilizzato e partecipare attivamente, in prima persona, nella mitigazione del rischio vulcanico: Bob Tilling, Vice presidente della IAVCEI (International Association of Volcanology and Chemistry of the Earth Interior), nel convegno"Napoli 91", affermava: "una riduzione significativa del rischio non può essere raggiunta senza il dialogo attivo fra scienziati, autorità e popolazione".

I risultati del nostro sondaggio sono pienamente coerenti con gli obiettivi di VESUVIUS 2000 e confermano in buona parte quanto era emerso dai lavori del sondaggio GVES. La popolazione dell'area vesuviana desidera rimanere sul territorio o nelle vicinanze ed è consapevole che il Vesuvio è pericoloso, ma che è possibile conviverci, così come hanno fatto le precedenti generazioni.

I proposti piani di evacuazione non tendono alla formazione di una solida coscienza vesuviana e alla salvaguardia della cultura locale, bensì allo sradicamento delle radici e alla dispersione delle risorse umane dell'area vesuviana. VESUVIUS 2000, per converso, promuove l'individuo favorendo la conservazione della cultura e degli affetti sul territorio, riorganizzando lo stesso a difesa dell'intera comunità esposta. E' chiaro che l'approccio vulcanologico classico per la riduzione del rischio vulcanico deve essere abbandonato a favore di iniziative concrete per la gente [3].

Alla luce di queste considerazioni, la nostra proposta è quella di istituire curricula scolastici che, partendo dalla conoscenza dei fenomeni naturali e più in particolare dei vulcani, porti ad una conoscenza approfondita del territorio della nostra regione e dell'area napoletana, compresa nel "recinto" rappresentato dal sistema Somma-Vesuvio, dall'area dei Campi Flegrei e da Ischia. Il progetto interdisciplinare VESUVIUS 2000, presentato nel territorio napoletano in 1995 e la sua estensione per l'area flegreia VESUVIUS-CAMPIFLEGREI PENTALOGUE per produrre l'area resiliente e sostenibile, ha anche sottolineato questa necessità [6,9].

L'intervento più significativo dovrebbe essere rivolto agli studenti dei primo biennio della scuola secondaria di secondo grado e poi proseguire negli anni successivi. Questo percorso non potrà prescindere dalla trattazione di alcune aree tematiche, che dovrebbero contribuire a colmare le lacune manifestate dai nostri intervistati, quali:

- conoscenza della realtà vulcanica della Campania e degli inevitabili rischi derivanti da un territorio così complesso
- conoscenza delle realtà operanti sul territorio per la gestione delle attività di controllo scientifico e di protezione civile
- conoscenza delle procedure e dei comportamenti da assumere in condizioni di emergenza
- conoscenze delle possibili reazioni emotive in caso di evento naturale (eruzione) e come controllarle

La conoscenza favorisce la riflessione e l'interazione tra allievi e docenti può stimolare percorsi di coinvolgimento più ampi, che partendo dall'ambito scolastico, possano contribuire alla formazione di una coscienza collettiva, in gruppi sempre più numerosi di cittadini napoletani. La consapevolezza scientifica e una più adeguata informazione dovrebbero imporre l'acquisizione di norme e l'assunzione di comportamenti, che possano garantire in ogni momento, anche nel caso in cui si dovesse verificare un'eruzione, l'economia ma soprattutto l'incolumità delle persone residenti in quel territorio: si può vivere in un'area a rischio ma solo nell'assoluto rispetto della natura che ci circonda. La relazione tra uomo ed ambiente non può prescindere dal principio che una eruzione vulcanica, un terremoto, un'alluvione sono eventi naturali, che diventano catastrofici solo se gli esseri umani continuano ad ignorarli o sottovalutarli, in un'ottica di gestione dell'ambiente troppo "antrocentrica" e non come dovrebbe essere, rigorosamente e "naturalmente ecocentrica".

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Etica ambientale: educazione alla responsabilità ed alla consapevolezza

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Riassunto. Questo lavoro affronta l'etica ambientale non come scienza astratta, ma nelle sue possibili applicazioni pratiche alle scelte di vita quotidiana. In tale contesto siamo tutti chiamati a raccordare ragione e sentimento, di fronte alla Natura intesa quale valore da difendere in una prospettiva di difesa della propria e dell'altrui vita. Talvolta il nostro pianeta è percepito come separato da noi e di qui il suo impoverimento, causa di svariate forme di rischio ambientale. L'etica ambientale si fonda sul raggiungimento della virtù ambientale e richiede che assumiamo la sana abitudine di relazionare con rispetto con la terra, sempre.

Keywords: Educazione, scuola, etica ambientale

1. Introduzione

È possibile scoprire le radici della *virtù ambientale* nella filosofia greca. Per dirla con i filosofi greci si tratta di acquisire il senso della Virtù in una relazione di circolarità dialettica con il Bene, la Felicità, l'Utile collettivo. Virtuosa può definirsi una persona responsabile che esprime i propri valori attraverso scelte e decisioni applicate alla vita quotidiana al fine di raggiungere obiettivi di benessere di dimensione oggettiva, universale [1].

Alcuni esperti di etica [1-2] asseriscono che "la crisi ambientale è talmente grave da dover creare un nuovo approccio alle virtù umane. Re-immaginare le classiche virtù cardinali in un contesto ambientale è cosa buona, ma non abbastanza per affrontare le sfide di oggi. Il rapporto tra la moderna società umana e la natura è così fuori equilibrio che deve essere proposta una nuova serie di atteggiamenti, un nuovo approccio alle virtù". Si tratta di promuovere una crescita ed una formazione graduali della persona guidandola a cogliere gli aspetti valoriali del nostro vivere sul Pianeta terra.

Tommaso d'Aquino, rappresentante della filosofia cristiana, ha elaborato le quattro virtù cardinali: giustizia, prudenza, temperanza e fortezza le quali, indipendentemente dal proprio credo religioso, possono essere una buona base per una corretta interpretazione del discorso ambientale [3].

La *Giustizia* ci guida a riconoscere ad ogni creatura il diritto di vivere una vita piena nel mondo considerando, al contempo, i propri doveri in rapporto ad esso. Quindi è il caso di interrogarci sui nostri obblighi etici verso il mondo naturale, sulla

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necessità di preservare diritti reciproci nella difesa di una vita sicura e dignitosa per tutti e nella difesa del Pianeta terra che ci ospita ed è prodigo di doni.

La *Prudenza* può essere intesa come l'abitus intellettuale di colui che valuta con saggezza i mezzi necessari per raggiungere significativi fini esistenziali. In tale prospettiva necessita formulare giudizi sul principio della sostenibilità. Sostenibilità significa soddisfare i bisogni dell'attuale generazione con lungimiranza, senza compromettere quelli delle generazioni future (e riprenderò questo tema più avanti) .

La *Temperanza* può essere intesa come la capacità di vivere con consapevolezza il proprio ruolo culturale, sociale ed economico senza lasciarsi condizionare dall' attaccamento a valori materiali di tipo personalistico.

La *Fortezza* altro non è se non il coraggio nell'attuare cambiamenti ambientali positivi alla luce delle informazioni che gli scienziati ci forniscono attraverso i loro studi sul precario stato del pianeta.

L'etica delle virtù ci incoraggia ad andare oltre i nostri sentimenti egoici e/o negativi ed a mettere a fuoco il nostro compito di difesa ambientale con cura, impegno ed amore verso il Pianeta che è la nostra casa. Le azioni buone sviluppano buone pratiche e queste accrescono il desiderio per il Bene comune; al contempo il desiderio di realizzare tale Bene tende ad accrescere il bisogno di tramutare la virtù in azione.

In tale contesto mi piace riportare il pensiero di Emmanuel Kant che, alla fine del XVIII sec nella sua opera *Critica del Giudizio* [4], nell' analizzare il Bello come valore universale caratterizzante la natura, ce ne presenta il livello superiore, il Sublime, distinguendolo in sublime matematico ed in sublime dinamico.

Nell'interpretare la nostra condizione emozionale suscitata dal Sublime che è in Natura, Kant sostiene che di fronte al sublime matematico (es. il cielo o il mare non racchiudibili in confini spaziali per la loro sconfinata estensione) il nostro animo prova un sentimento di compiaciuta soddisfazione nel riconoscerci le uniche creature in grado di entrare in contatto con la Bellezza della natura e di emozionarci al suo cospetto: di qui un profondo sentimento di gratitudine nei confronti del Creatore che ci ha resi capaci di una tale percezione.

Di fronte al Sublime dinamico, rappresentato dalle forze endogene, il sentimento rilevante è la paura, nella consapevolezza di non poter contrastare e/o dominare l'impato della Natura, ma … nonostante il terrore e la disperazione … emerge la gratitudine nei confronti di chi ci ha resi capaci di una tale percezione di fenomeni naturali grandiosi, anche se distruttivi.

La nota più interessante ed emozionante, a mio avviso, sta nella riflessione con la quale Kant sostiene che se siamo capaci di cogliere la Bellezza fuori di noi ciò accade perché la Bellezza è dentro di noi, il che significa che siamo naturalmente predisposti a provare la Bellezza ed il sentimento del Bello nella sua dimensione universale e non limitato dal bello o piacevole per me.

Ed allora, se è vero che siamo animali che hanno in sé la Bellezza e che sono in grado di osservarla ed incontrarla fuori di sé, se possiamo ritenere che la virtù alla greca sia dentro di noi, perché non rispettiamo la Natura che ne è portatrice e rappresentante? Perché non siamo in grado di difenderla e di preservarla per noi e per i posteri in tutta la sua Bellezza e la sua magnificenza?

Questo tipo di ragionamento è anche associato alle categorie etiche come comandamenti, leggi, diritti e giustizia. In termini di etica ambientale, forse il

Kantiano imperativo categorico "Tu devi" che anima la nostra coscienza, capace di gestirsi eticamente in maniera autonoma e responsabile, può essere tradotto in uno dei comandi classici di tutta l'etica: "Non causare danno. Sfuggi all'utilitarismo di dimensione soggettiva … cura il Bene comune …"

Questa modalità di ragionamento etico ci invita ad una attenta e onesta riflessione su noi stessi a livello sia individuale sia di gruppo.

Credo si tratti della volontà di avere *cura* del mondo che ci circonda e nel quale viviamo. Per questo mi piace fare riferimento al pensiero di Heidegger, esponente dell'esistenzialismo, corrente filosofica sviluppatasi tra le due guerre e nel del 2° dopoguerra, il quale ci presenta l'*Ente* come principio, l'*ente* come esistente, l'*essere* che vive "gettato" nel mondo da "deietto", destinato ad una vita inautentica e senza consapevolezza di sé e delle sue possibili scelte, l'*esserci* chiamato a vivere una vita progettuale, autentica, responsabile, caratterizzata dalla cura e dall'attenzione ai progetti di vita personali e comunitari [5].

Ciò che suscita particolare interesse è, infatti, la concezione della cura intesa non solo in senso individualistico come tensione al raggiungimento dei propri obiettivi e del proprio progetto di vita, bensì anche come cura rivolta a preservare il progetto di vita altrui.

2. L'ambiente naturale

È, dunque, indispensabile impegnarsi a difendere l'ambiente naturale del quale noi stessi siamo parte. Dobbiamo crescere nella volontà di comprendere, in termini di resilienza, che è necessario armonizzarci ed integrarci in maniera consapevole con i cambiamenti ambientali nel rispetto delle categorie spazio-temporali della Natura senza stravolgerle e violarle con il risultato di danneggiare la nostra e l'altrui vita. Dobbiamo comprendere che le leggi della natura sono le stesse che regolano la nostra stessa vita e che violare le une significa violare anche le altre.

Nel corso degli anni '80 del XX sec., il filosofo tedesco Hans Jonas ha sviluppato ulteriormente tali implicazioni etiche introducendo nel contesto il *principio di precauzione* [6]. Jonas ha sostenuto che, nell'antichità, gli esseri umani sentivano di essere parte integrante della natura e non agivano deturpando gravemente l'ambiente. La rivoluzione scientifica dell'età rinascimentale, la successiva risoluzione dell'Illuminismo nella scienza, nella tecnologia e nell'economia ed il Positivismo teso ad esaltare la ragione scientifica, hanno prodotto progresso ma anche sconvolgimenti, dissesti ambientali, danni irreversibili per l'ambiente e per la salute dell'umanità e questo richiede una riflessione etica più profonda da parte di ciascuno di noi. Secondo Jonas esiste un rapporto inversamente proporzionale tra le nostre capacità tecnologiche e la nostra responsabilità morale e decisionale di fronte ai rischi ambientali in difesa di ogni forma di vita e del massimo benessere delle generazioni future. È quindi una forma di etica conseguenzialista, il che significa che la moralità di un'azione è determinata dal suo esito. L'utilitarismo collettivo o universale può essere definito dalla frase: "Impegniamoci a costruire il più grande bene nel mondo per il maggior numero di persone …".

Si tratta, dunque, di saper vivere all'interno dell' intera comunità umana.

In una prospettiva storica, ritorniamo al concetto di prudenza in S. Tommaso d'Aquino ed anche in Aristotele che, nell'Etica Nicomachea [7], con il termine phronesis, indicava prudenza e saggezza pratica al servizio dell'intelligenza: phronesis indica, infatti, "… ciò che è giusto, bello e buono per ciascun essere umano".

3. L'etica ambientale

In maniera provocatoria oserei parlare anche di una nuova Metafisica incentrata sul rispetto delle categorie strutturali del pianeta terra in tutte le sue manifestazioni ambientali e delle leggi che lo muovono. Ma si può ancora fare riferimento alla Metafisica del volto del filosofo Levinas [8], autore del XX sec., per il quale questa Scienza prima, che secondo la tradizione dell'occidente cristiano ci porta alla contemplazione di Dio, deve concretamente guidarci a cogliere Dio o il senso del divino nel volto del nostro prossimo la cui vita va difesa e protetta. E qui ritorna fortemente l'importanza dell'etica ambientale.

In tema di Etica ambientale appare chiaro, alla luce delle riflessioni filosofiche oggetto della mia relazione, che il problema della difesa del pianeta non è soltanto degli Stati, dei governi, delle multinazionali, ma tocca ciascuno di noi in quanto cittadini del proprio Paese e del mondo, cittadini fruitori di tutti i doni di cui il Pianeta terra è prodigo.

A questo punto mi limiterò a considerare velocemente e senza approfondimenti di tipo scientifico-tecnico, in quanto non è questo il mio ambito professionale, alcuni dei rischi ambientali da limitare.

Nei decenni passati, e purtroppo ancora oggi, il mondo naturale non è stato sempre considerato di rilevanza etica in quanto l'etica è stata calata unicamente nei rapporti sociali ed interpersonali.

Questo atteggiamento ha reso possibile minimizzare gli effetti dannosi per l'ambiente causati, ad esempio, dalla ciminiera di una fabbrica o da una discarica per lo smaltimento dei rifiuti o dalla fruizione indiscriminata delle risorse naturali.

L'etica ambientale [9] ci invita a guardare lontano nello spazio e nel tempo ai luoghi naturali lontani da noi … alla terra, all'acqua, all'aria … al fine di percepire e considerare gli effetti non immediati delle nostre azioni: l'olio motore esausto, ad esempio, versato giù per lo scarico delle nostre cucine finisce nelle condutture, viaggia per chilometri e arriva, attraverso i corsi d'acqua, fino al mare, inquinandolo e così pure al mare arrivano la plastica ed i detersivi non ecologici, danneggiando la biodiversità marina.

Ogni nostra azione può avere effetti lontani dal luogo in cui hanno avuto origine e va anche considerato che la nostra azione isolata potrebbe verificarsi all'interno di un sistema biologico già esistente, interconnesso ad altri sistemi, causandone alterazioni negative e/o nocive.

Allo stesso modo il disboscamento delle foreste è risultato essere mezzo di sussistenza economica per il commercio del legno e della legna che se ne ricava senza considerare gli effetti negativi.

Il diboscamento è da evitare:

- per ragioni di bellezza e valorizzazione degli alberi in se stessi;
- per preservare l'habitat naturale in connessione con altri esseri viventi;
- per evitare e/o contenere le frane, il dissesto dei costoni montani e collinari, il dissesto idrogeologico;
- per favorire la messa in atto di possibili e non ideali piani di evacuazione, quando la resilienza e la sostenibilità non si possono effettuare;
- per il bene comune in termini di etica ambientale e di etica sociale.

E che cosa dire della continua cementificazione che ha sottratto a noi umani polmoni verdi, suolo ed ha favorito una densità demografica eccessiva in spazi a rischio ambientale, come quelli che insistono alla base del Vesuvio, … rendendo impossibile o lenta l'attuazione dei piani di evacuazione …

Lo sconvolgimento del nostro clima globale per cause antropiche rappresenta una delle minacce più gravi per il genere umano e l'ambiente [10], pertanto l'elaborazione di adeguate soluzioni su una questione così complessa richiede un forte impegno a livello di istituzioni sociali, politiche ed economiche per ridurre o evitare terribili conseguenze per la vita sul pianeta che è un grande valore e merita protezione.

E ancora, i gas serra prodotti in Europa e Nord America, gli scarichi industriali, i gas tossici, l'agricoltura industriale, sono i principali responsabili dell'aumento della temperatura media globale con effetti sulla biosfera, su tutti gli ecosistemi e con l' alterazione dei parametri fisico-chimici di acqua, aria, suolo: la lotta al cambiamento climatico ed ai suoi effetti di distruzione della biodiversità vegetale ed animale richiede una forte cooperazione internazionale.

Nel corso degli ultimi due secoli i paesi industriali avanzati hanno creato una sorprendente ricchezza di energia con conseguente sovrapproduzione di anidride carbonica, mentre i paesi più poveri del mondo non riescono a copiarne il modello di sviluppo economico [10].

Molti processi industriali nel creare beni di consumo continuano a generare grandi quantità di rifiuti e di sostanze chimiche tossiche e vi è una maggiore possibilità che queste danneggino maggiormente le comunità svantaggiate rispetto a quelle ricche.

Il problema è anche quello di mettere a confronto gli stili di vita dell'intera popolazione del pianeta con un riesame del principio di sostenibilità. Gli stili di vita dei membri più ricchi e più poveri della famiglia umana rappresentano la principale minaccia per l'integrità dei sistemi di vita della Terra, ma per ragioni diverse.

I più ricchi consumano molte più risorse di quanto loro spetterebbe, più di quello che il pianeta può offrire per tutti, senza "precauzione". I più poveri, circa un terzo della popolazione umana, non hanno altra alternativa se non quella di utilizzare le risorse in modo miope, per sopravvivere; ad esempio, tagliare gli alberi per farne legna da ardere [10].

Con il Trattato europeo di gestione del Mare del Nord nel 1987 e, successivamente, con il Trattato dell'Unione europea (noto anche come *Trattato di Maastricht* [11]), Carta dell'Unione europea del 1992, tale principio è stato posto all'attenzione come di fondamentale importanza.

La Dichiarazione di Rio sull'ambiente e lo sviluppo (1992) fornisce una definizione comunemente utilizzata [11]: "Al fine di proteggere l'ambiente, gli Stati applicheranno largamente, secondo le loro capacità, il *principio precauzionale*. In caso di rischio di danno grave o irreversibile, l'assenza di certezza scientifica assoluta non deve servire da pretesto per differire l'adozione di misure adeguate ed effettive, anche in rapporto ai costi, dirette a prevenire il degrado ambientale" (Principio 15).

Tuttavia la *governance* adottata dagli Stati Uniti e dall'Europa in materia di tutela ambientale e di regolamentazione diverge circa il raccordo precauzione-gestione del rischio.

Un altro fattore chiave nel discorso etico ambientale è il ruolo svolto da*: rischio, incertezza, probabilità e previsione* in quanto va considerato che gli ecosistemi terrestri possono essere spesso incomprensibili così da impedire previsioni accurate il che, in termini etici, richiede di interrogarsi sulla qualità delle prove utilizzate per la valutazione del rischio in fase previsionale, nella prospettiva del benessere, della sicurezza ambientale e della salute della comunità globale [11].

4. L'etica della sostenibilità

La sostenibilità è un tema scottante che estende il concetto di giustizia verso il futuro. Essa può essere definita come il modo di soddisfare i bisogni dell'attuale generazione senza compromettere la capacità delle generazioni future di soddisfare i propri [11]. Ci sono molte risorse che oggi consumiamo o degradiamo come i minerali, i combustibili fossili, l'acqua, il legno e la legna, più velocemente di quanto possano essere ripristinate naturalmente, il che significa che non saranno rinnovabili e disponibili in futuro immediato.

Altre risorse, come il vento e le piante, traendo la loro energia dal sole, possono essere adeguatamente gestite in modo da fornire una continua fonte di beni.

Un approccio etico alla sostenibilità suggerisce che la società ha l'obbligo di limitare lo spreco delle risorse naturali tra i paesi ricchi, ma ha anche l'obbligo di promuovere lo sviluppo economico tra i poveri, il tutto avendo cura della protezione ambientale delle risorse.

La sostenibilità non è una condizione assoluta, ma sempre parziale; essa così come la giustizia ambientale di cui gi Stati Uniti si sono fatti promotori a partire dagli anni '80 del XX sec. (posizione attualmente discutibile e/o disattesa) è un continuum e il suo stile è la *moderazione*.

Sono in gioco, come vediamo, i principi di giustizia, di precauzione e di responsabilità in quanto si pone, alla base dei trattati e dei regolamenti nazionali ed internazionali, la necessità di bilanciare equamente le esigenze di chi vive oggi (ricchi e poveri) con la presa in carico delle esigenze delle generazioni future. Quindi, l'etica ambientale assume il carattere fondamentale di *equità* e lo estende fino ad includere gli svantaggiati e coloro che devono ancora nascere secondo un principio di *sufficienza* per il quale tutte le forme di vita hanno diritto alla disponibilità dei beni sufficienti per vivere e prosperare.

In un'economia globalizzata e partecipativa a livello internazionale, in cui beni e servizi vengono forniti anche da varie parti del mondo, devono vigere le leggi della solidarietà, della collaborazione e della partecipazione all'interno dell'intero ecosistema-mondo.

Va considerato che moltissimi problemi ambientali derivano da decisioni prese dai governi, da privati o da multinazionali con implicazioni di vasta portata che non considerano il consenso pubblico.

Il principio etico della partecipazione impone di riconoscere tutti i soggetti decisionali; una reale partecipazione richiede trasparenza, nel senso che ogni individuo deve avere accesso alle stesse informazioni ed avere voce di fronte a decisioni che implicano effetti che incideranno sempre più profondamente sulla vita dell' umanità nei prossimi decenni.

L'etica della sostenibilità si è sviluppata al di fuori dell'etica ambientale. Nel 1987 la World Commission on Economic Development (Commissione Mondiale per lo Sviluppo Economico) ha dato all'idea di sostenibilità una portata globale e le Nazioni Unite hanno promosso lo studio del rapporto tra sviluppo economico e ambiente, pubblicato col titolo *Our Common Future* [12, e conosciuto anche come *Rapporto Brundtland* caratterizzato da tre pilastri, anche noti come "Tre E" di sviluppo sostenibile (environmental, economic, equity), ossia tutela dell'ambiente globale, sviluppo economico ed equità sociale.

Questa posizione etica afferma che ogni individuo ha il diritto all'aria pulita, al'acqua non inquinata, ai prodotti agricoli coltivati in terreni non tossici, al cibo a sufficienza, alla casa, alle risorse naturali e questi non sono privilegi, ma diritti che tutti, dai governi ai gruppi decisionali, dalle catene economiche al singolo cittadino, abbiamo la responsabilità di proteggere.

Tutti dobbiamo prendere parte, in quanto cittadini del mondo, alle decisioni dei vari governi relative all'utilizzo del suolo e delle risorse della terra.

5. Conclusione

Da docente ritengo che ogni insegnante debba perseguire obiettivi di formazione e di cittadinanza attiva, prima degli specifici obiettivi relativi alla propria disciplina. Insegnare Filosofia e Storia mi consente di sviluppare con faciltà interventi etici, discussioni e riflessioni che arricchiscano i giovani a me affidati e li guidino a ricercare il proprio corretto orientamento nel mondo.

Essi si fanno, a loro volta, promotori di sensibilizzazione e di correttivi comportamentali presso le rispettive famiglie.

In classe si valutano le risposte ed i miglioramenti messi in atto o da attivare. I dati raccolti vengono registrati mediante questionari mirati e presentazioni power point.

Ravviso, in conclusione, la necessità di porci tutti delle domande fondamentali:

- Che cos'è per noi la Natura e quale rapporto emozionale viviamo con essa?
- Proviamo "amore" per il nostro Pianeta? In che misura lo difendiamo? Ne abbiamo cura?
- Viviamo nella Natura e nel mondo soltanto come uomini e donne tecnologici, trascinati dal fiume del progresso ad oltranza, in un rapporto da ospiti estranei e/o di passaggio?

- Quale ruolo ha svolto l'educazione ricevuta in famiglia ed a scuola sulla costruzione, nel tempo, del nostro rapporto con la natura, con il pianeta che ci ospita?
- Quale Natura, quali ecosistemi lasceremo in dotazione ai nostri posteri?

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Indicazioni nazionali e nuovi scenari: cittadinanza attiva e sostenibilità nel Curricolo di Scuola

Mobilizzare la scuola per produrre cittadinanza attiva e sostenibilità

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Riassunto. Il presente lavoro prende le mosse dall'analisi del documento di lavoro "Indicazioni nazionali e nuovi scenari", di cui alla nota MIUR prot. n. 3645 del primo marzo 2018, alla luce del testo "Trasformare il nostro mondo: l'Agenda 2030 per lo sviluppo sostenibile", programma d'azione per le persone, il pianeta e la prosperità, sottoscritto dall'Assemblea Generale delle Nazioni Unite nel settembre del 2015, per analizzare in che modo la scuola può contribuire, nel quadro di una complessità crescente, per il sovrapporsi di problematiche di ordine sociale, culturale, economico e ambientale, a sostenere un modello di sviluppo sostenibile a tutti i livelli. Dalla lettura integrata delle Indicazioni e dei dieci target dell'Agenda emerge il ruolo cruciale assegnato alla scuola nella partita dell'educazione sostenibile: la scuola è, infatti, luogo privilegiato di prevenzione delle disuguaglianze e di realizzazione dell'equità grazie all'ingresso precoce nel sistema di istruzione, al contrasto della dispersione, alla promozione dell'inclusione, alla costruzione delle premesse per l'esercizio di una robusta cittadinanza sostenuta dalla qualità degli apprendimenti conseguiti.

Parole chiave: Educazione, scuola, curricolo, cittadinanza, sostenibilità

1. Introduzione

Il dinamismo caotico all'interno del quale si muovono le nuove generazioni impone alla scuola un'attenta e costante rilettura non solo dei contesti di riferimento più prossimi, ma anche dei mutamenti più ampi che investono la società, la cultura, l'economia, l'ambiente. La scuola è, infatti, il primo luogo in cui si produce il corto circuito tra le generazioni che si avvicendano e gli incessanti mutamenti cui assistiamo e l'aula rappresenta lo spazio in cui è possibile comprendere le tendenze, interrogare le trasformazioni, maturare un atteggiamento mentale di apertura verso le novità, verificare la capacità degli individui di far fronte a difficoltà e sfide, manifestando quell'adattamento funzionale, più noto come resilienza.

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Si rende pertanto necessario e urgente transitare verso un modello in grado di garantire il benessere di tutti gli individui, verso un modello di sviluppo sostenibile da intendersi come un processo di crescita capace di rispondere ai bisogni del presente senza compromettere la capacità delle future generazioni di soddisfare le proprie esigenze, e in grado di armonizzare tre elementi fondamentali: la crescita economica, l'inclusione sociale e la tutela dell'ambiente [1].

Un modello sintetizzato dal programma ambizioso varato con l'Agenda 2030 che prevede 17 Obiettivi di Sviluppo sostenibile – Sustainable Development Goals (SDGs) – articolati in ben 169 traguardi, interconnessi ed indivisibili, secondo una prospettiva universale, trasformativa, rivoluzionaria: porre l'Agenda al cuore delle discussioni sul futuro delle nazioni e del pianeta [2].

Gli SDGs si basano sugli Obiettivi di Sviluppo del Millennio e perseguono la prospettiva di liberare l'umanità dalla povertà, dalla malattia, dalla tirannia, dalle discriminazioni, garantendo sicurezza, libertà, accesso equo all'istruzione, all'assistenza sanitaria, al lavoro, alla realizzazione personale e sociale [3].

In questa cornice, quale ruolo è assegnato alle istituzioni che si occupano di istruzione e formazione? "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all", fornire un'educazione di qualità, equa ed inclusiva e opportunità di apprendimento per tutti: questo il quarto obiettivo dell'Agenda, che indica la direzione verso la quale deve tendere l'impegno globale in campo educativo e, che più direttamente, chiama in causa il mondo della scuola.

I target ad esso collegati precisano quali siano i traguardi attesi entro il 2030:

- accesso generalizzato a cure e istruzione pre-scolastica, ad un'istruzione primaria e secondaria in grado garantire apprendimenti adeguati e concreti, ad un'istruzione terziaria di qualità a costi accessibili e adeguata ad incrementare l'occupabilità;
- superamento delle disparità di genere nell'accesso all'istruzione e alle professioni e realizzazione di una piena inclusione;
- generalizzazione dell'alfabetizzazione strumentale;
- acquisizione delle conoscenze e competenze necessarie a promuovere lo sviluppo sostenibile, la promozione di una cultura pacifica e non violenta, la valorizzazione delle diversità;
- realizzazione di ambienti di apprendimento sicuri, inclusivi ed efficaci per tutti;
- incremento del numero di borse di studio a disposizione di studenti dei paesi in via di sviluppo;
- sviluppo della formazione degli insegnanti in particolare nei paesi in via di sviluppo.

Una sfida enorme, strumentale alla realizzazione delle più ampie aspirazioni dell'Agenda [4].

2. Il ruolo della scuola

2.1 Le sfide pedagogiche lanciate al mondo della scuola

Nel ruolo della scuola [5,6] c'è una sfida che riguarda *la qualità degli apprendimenti* [7,8] che si esprime nella necessità di garantire una formazione significativa, basata su competenze durature, trasversali e funzionali ad ulteriori apprendimenti, in cui la responsabilità del singolo si esplica anche nella manutenzione dei propri saperi.

C'è una sfida che riguarda *l'inclusione e la lotta alla dispersione scolastica e al fallimento formativo* che si traduce nel contrasto ai fenomeni quali l'uscita precoce dal sistema di istruzione, l'assenteismo, il deficit nelle competenze di base, alla base di diverse condizioni di esclusione educativa e universalmente riconosciuti quali ostacoli all'esercizio di una piena cittadinanza e allo sviluppo personale e sociale [9].

C'è una sfida che riguarda *l'orientamento e l'apprendimento permanente*, che si sostanzia nella promozione di competenze chiave in grado di alimentare l'attitudine alla conoscenza continua, di orientare gli apprendimenti futuri, le scelte di tipo formativo e professionale, la capacità di essere flessibili e resilienti in uno scenario in continuo mutamento non più rinviabile.

2.2 Gli obiettivi prioritari per la scuola in questo nuovo scenario

"Insegnare a ricomporre i grandi oggetti della conoscenza … in una prospettiva complessa, volta cioè a superare la frammentazione delle discipline e a integrarle in nuovi quadri d'insieme. Promuovere ... la capacità di cogliere gli aspetti essenziali dei problemi; di comprendere le implicazioni, per la condizione umana, degli inediti sviluppi delle scienze e delle tecnologie; di valutare i limiti e le possibilità delle conoscenze; di vivere e di agire in un mondo in continuo cambiamento. Diffondere la consapevolezza che i grandi problemi dell'attuale condizione umana … possono essere affrontati e risolti attraverso una stretta collaborazione non solo fra le nazioni, ma anche fra le discipline e fra le culture" [3,10].

Queste le rinnovate e più incisive curvature da conferire al curricolo a livello d'istituto, secondo la lettura incrociata dei documenti finora citati. Nuovi punti di attenzione che possono alimentare e caratterizzare l'impalcatura dell'offerta formativa.

2.3 Cittadinanza attiva e sostenibilità nel curricolo verticale

Un primo snodo cardine può trovarsi nel promuovere *un'educazione al pensiero critico e riflessivo*, tesa a promuovere la reazione al conformismo, a reagire al pensiero ricorrente, all'identificazione di massa. Tale profilo si sostanzia nell'educare a interrogarsi sulla validità di una qualunque affermazione, nello stimolare l'analisi, la sintesi e la valutazione delle informazioni raccolte, nel promuovere l'incontro con questioni in grado di stimolare la ricerca della conoscenza, il confronto con diverse ipotesi interpretative, nel sollecitare la dimensione euristica, la discussione, l'argomentazione, il dialogo [11-15].

Un secondo snodo è da rintracciarsi nell'*educazione al pensiero progettuale e creativo,* esercitando l'atteggiamento investigativo e proattivo, intervenendo attivamente sulla realtà, prefigurando situazioni e soluzioni, dando spazio alla creatività e all'esercizio della responsabilità.

Un terzo snodo è situato nell'*educazione al pensiero globale e solidale,* investendo nel superamento dell'individualismo culturale, nella maturazione di una prospettiva olistica nell'analisi dei grandi problemi dell'umanità e del pianeta, nell'educazione interculturale, nell'assunzione dell'interdipendenza come canone delle scelte, individuali e collettive, sulla ricerca dell'equità e della giustizia come vincoli al benessere comune.

Un curricolo così orientato, teso allo sviluppo delle competenze per la cittadinanza attiva e la sostenibilità può rispondere alla domanda educativa del nostro tempo e impegnare le comunità professionali in un protagonismo di senso in grado di dispiegare i suoi effetti nel prossimo futuro [16].

3. Conclusioni

Dall'analisi del quadro all'interno del quale si muove il mondo della scuola risulta facile prefigurarsi le sfide che poniamo al cittadino di oggi e di domani.

Occorre superare individualismi, pensare e operare secondo una logica di interdipendenza planetaria. Per superare la visione "al singolare" dell'esistenza, occorre entrare in contatto con l'altro da sé, se necessario anche scontrarsi, attraversando le questioni del nostro tempo, sperimentando quanto le scelte dei singoli incidano sul destino di ciascuno.

La scuola deve farsi promotrice di un approccio ai problemi che sia sostenibile non solo a livello ambientale, ma anche economico e sociale, sostenendo la maturazione negli individui della responsabilità di una equità di tipo intergenerazionale, con una capacità potenziale di intervento che orienti le scelte personali e le proietti nel futuro dei propri simili.

Ancora, occorre operare per il superamento delle disuguaglianze e agire per la coesione sociale. In questa sfida c'è la necessità di investire molto in termini di acquisizione di dati, informazioni, quadri storici al fine di esercitare un pensiero globale e interculturale, capace di cambiare le prospettive e di guardare alle situazioni da diversi punti di vista.

Infine, è ineludibile la cura della democrazia, in tutte le sue forme ed espressioni. In questo caso, la sfida sta nel trasformare il contesto scolastico in un vero e proprio incubatore di democrazia, il che significa strutturare spazi, tempi, l'intera organizzazione, in modo che sia visibile il modello di riferimento.

In questo modo il curricolo diventa effettivamente un laboratorio permanente di ricerca-azione, percorso dinamico e aperto, nel quale la comunità educante può riconoscersi, crescere e contribuire alla prosperità della vita sociale.

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Promozione della conoscenza e della educazione del rischio nell'area napoletana

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Riassunto. La promozione della conoscenza e della educazione del rischio nell'area napoletana è una parte integrante del progetto interdisciplinare VESUVIUS 2000 e la realizzazione di un'efficace campagna di informazione e una strategia di preparazione attiva della popolazione nelle zone intorno ai vulcani di Somma-Vesuvio e dei Campi Flegrei portano alla resilienza ed alla sostenibilità del territorio. Con numerosi collaboratori, dal 1995 stiamo perseguendo questo obiettivo lavorando con gli insegnanti delle scuole per poter produrre una più proficua conoscenza del territorio degli studenti e, con i numerosi seminari al pubblico, stiamo operando per produrre una più ampia cultura della sicurezza, dove i cittadini sanno come leggere il territorio e partecipano allo sviluppo sostenibile. In questo lavoro riportiamo alcuni momenti di queste attività educative e concludiamo che la imposta cultura di emergenza, promossa dai piani di evacuazione per i vulcani napoletani, sta rallentando questo sviluppo.

Parole chiave: Educazione, scuole, Vesuvio, Campi Flegrei, cittadinanza, area napoletana

1. Introduzione

Con la fondazione della GVES nel 1994 abbiamo sollecitato dai ricercatori europei una collaborazione interdiciplinare e transdisciplinare per presentare un progetto alla Unione Europea, volto allo studio della fattibilità per la riduzione del rischio nel territorio intorno al Vesuvio. Abbiamo riunito più di 60 studiosi, nominato il progetto VESUVIUS 2000, e lo abbiamo presentato nel 1995 per il finanziamento [1], per poter completarlo entro il 2000. Il progetto non fu finanziato e, non avendo ricevuto una spiegazione professionale, abbiamo chiesto al Parlamento Europeo di fornire le ragioni. Anche la risposta del Parlamento Europeo [2] è inadeguata perchè è stata prodotta, per giustificare le esigenze di lobbisti, dai geologi, non affronta professionalmente le debolezze desunte della proposta e si sforza di diminuire la professionalità degli autori di VESUVIUS

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2000 attraverso false dichiarazioni. Invece di sostenere lo sviluppo della resilienza e della sostenibilità nell'area napoletana, come richiede VESUVIUS 2000, la Unione Europea ha preso una strada opposta: sostenere l'inaffidabile Piano di Emergenza dell'Area Vesuviana [3].

Nonostante ciò, con i collaboratori, abbiamo continuato a lavorare per sviluppare uno dei più importanti obiettivi di VESUVIUS 2000: promozione della conoscenza e della educazione del rischio nell'area napoletana. Fruitori di questa iniziativa sono stati educatori, politici, amministratori, ricercatori e cittadini dell'area vesuviana. Soprattutto l'iniziativa era volta a formare una coscienza e una migliore conoscenza delle problematiche connesse alla convivenza col vulcano e, attraverso la collaborazione di validi educatori, il progetto VESUVIUS 2000 entrò direttamente nella programmazione annuale di alcune scuole partenopee. Nel corso degli anni sono state attivate, nelle scuole aderenti, numerose iniziative volte alla cultura della sicurezza e destinate ad alunni, docenti e alla comunità adulta del territorio. Si sono sviluppati diversi metodi educativi indirizzati alla conoscenza del rischio Vesuvio al fine di informare e di formare i giovani ad assumere un atteggiamento nuovo rispetto, non solo ad una eventuale emergenza vulcanica, ma anche a problemi inerenti ad ambiti diversi e più ampi per formare cittadini consapevoli dei punti di forza e di debolezza del territorio in cui vivono [4, 5]. Solo con una corretta informazione, infatti, si è capaci di incidere sulla realtà territoriale per non subirla e, anzi, per cambiarla in positivo.

Numerosi gli obiettivi che le scuole si sono posti: acquisizione del concetto del rischio Vesuvio, la conservazione della memoria storica degli eventi eruttivi del passato, la conoscenza degli organismi responsabili istituzionalmente del rischio Vesuvio, la conoscenza del piano inaffidabile di emergenza esistente [6], la cognizione della pluralità di informazioni riguardanti il rischio Vesuvio e lo sviluppo di metodologie volte ad educare gli alunni alle problematiche relative alla sicurezza nel territorio vesuviano. Tali obiettivi sono stati perseguiti attraverso le seguenti strategie: proiezioni audiovisive, ricerche scientifiche e storiche sulle conoscenze fondamentali del problema, plastici e cartelloni, partecipazione alle manifestazioni annuali promosse dalla GVES, visite guidate sul territorio (Pompei, Ercolano, Stabia, Vesuvio, Osservatorio Vesuviano), attività seminariali; allestimento di un laboratorio-Vesuvio. Le attività promosse hanno portato gli alunni ad assumere un ruolo centrale nel processo di insegnamento-apprendimento e hanno favorito lo sviluppo di svariate iniziative che sono sfociate in una consistente produzione di lavori. Con seminari (comuni, chiese, organizzazioni, incontri con organizzazioni professionali locali), presentazioni del progetto agli scienziati negli incontri professionali mondiali e produzione del materiale educativo, la GVES ha cercato di promuovere un percorso verso la sostenibilità, non solo dell'area vesuviana, ma anche verso quella di tutto il territorio napoletano.

In questa relazione riportiamo alcuni lavori sull'educazione al rischio Vesuvio nelle scuole e con seminari al pubblico, promossi dai soci e collaboratori della GVES. Partendo da un inizio ottimistico, dove abbiamo raccolto i migliori educatori che lavoravano sul rischio nel territorio vesuviano, siami arrivati, in anni recenti, in una situazione dove la istituzionalizzazione dei piani di emergenza del Vesuvio e dei Campi Flegrei vuole imporre solo la cultura di emergenza e soffocare quella della sicurezza e della prosperità. Questo è inaccettabile e dobbiamo, quindi, muovere nuove forze per superare gli ostacoli.

2. Primi lavori

2.1 Il programma

Quando avviammo il progetto interdisciplinare VESUVIUS 2000 allo scopo di prevenire una futura catastrofe nell'area vesuviana, ci rendemmo immediatamente conto della difficoltà di trasmettere gli obiettivi di tale iniziativa alla popolazione, dal momento che cira l'80% di essa non era informata sul rischio vulcanico [7]. Con seminari nelle scuole, comuni e luoghi pubblici abbiamo cercato di migliorare la conoscenza vesuviana di questa popolazione. Abbiamo rilevato che le scuole di quest'area sono più ricettive a indagare, porsi domande e sperimentare nuove idee e, spesso, ci siamo meravigliati del fatto che, pure avendo grandi potenzialità, queste istituzioni non sono state pienamente utilizzate per creare un cittadino che sappia come dovrebbe comportarsi durante un futuro risveglio del vulcano. È sorprendente che troppe scuole dell'area vesuviana stiano perdendo una grande opportunità educativa, nella quale l'arte e le scienze potrebbero così bene armonizzarsi con le potenzialità socio-economiche del territorio. I costi della mancanza di educazione al rischio vulcanico, in termini di ignoranza delle possibilità di esperienze umane, sono incalcolabili e dolorosi e, se non si riduce questa condizione, sarà impossibile per la popolazione valutare i meriti di qualsiasi iniziativa avviata a ridurre il rischio vulcanico e a favorire lo sviluppo sostenibile del territorio. Le scuole dell'area vesuviana non solo hanno il difficille compito di formare i cittadini produttivi del domani, ma anche individui con la coscienza vesuviana. Per realizzare quest'ultimo obiettivo è necessario che gli educatori comprendano pienamente le loro responsabilità e si preparino all'assalto al gigante addormentato prima che si risvegli con tuoni e furia e in pochi secondi cancelli una generazione, una cultura e una ignoranza delle possibilità non-realizzate.

Nel maggio del 1997 convocammo alcuni Presidi di scuole dell'area vesuviana nella S.M.S. F. d'Assisi di Torre del Greco [4] allo scopo di definire un progetto che potesse aiutare gli educatori dell'area nel loro compito di formare meglio le future generazioni sul rischio vulcanico. A tal proposito si decise di: (1) invitare le scuole dell'area a fornire lavori connessi all'educazione al rischio Vesuvio, (2) raccogliere i lavori in un volume, (3) sperimentare i contenuti di questo volume sul territorio, (4) aggiornare il volume con nuove informazioni e (5) divulgare il risultato del progetto sul territorio durante l'anno scolastico 1998-1999. I lavori raccolti nel volume rappresentano la positiva risposta e dovrebbero essere visti come un'informazione iniziale di diverse esperienze educative al rischio Vesuvio nel territorio, alcune delle quali abbiamo noi promosso come parte del progetto VESUVIUS 2000.

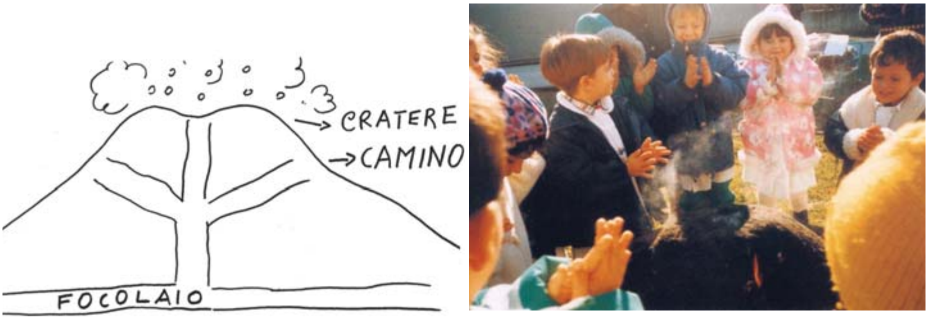

Figura 1. Esempio della didattica seguita nella scuola Materna IV Circolo di Portici. Saper ascoltare e comprendere contenuti (sinistra). Problematizzare la realtá con "fumo" del Vesuvio (destra) [8].

Dai lavori ricevuti fu possibile strutturare il volume durante un secondo incontro delle scuole interessate, nell'ottobre del 1997, presso l'I.T.C. Sturzo di Castellammare di Stabia [4], dividendo il volume in tre parti: (1) vulcanesimo e il Vesuvio, (2) territorio, e (3) educazione al rischio Vesuvio. Per una più completa comprensione della dimensionalità del problema Vesuvio abbiamo anche sollecitato i contributi di alcuni esperti in merito all'attività vulcanica, previsione, gestione e prevenzione dell'emergenza e aspetti socio-economici dell'area. Qui di seguito riassumeremo alcuni di questi lavori educativi per fornire uno spessore delle problematiche trattate.

2.2 Esempi dei lavori educativi

Nel lavoro intitolato *L'educazione al rischio nella Scuola dell'Infanzia* [8], la docente Annamaria Trotta della Scuola Materna IV Circolo di Portici pone l'importanza dell'informazione e della formazione dell'individuo già nell'età prescolare (3-6 anni). Lo scopo è che i bambini conoscano, senza provocarli, i pericoli ambientali che sono la parte integrante del bagaglio culturale di ogni individuo. Questo percorso è stato seguito lasciando i bambini ad illustrare le proprie conoscenze dell'ambiente, canalizzando la loro attenzione sull'ambiente più caratteristico della montagna, sollecitando bambini a disegnare gli elementi presi dall'ambiente in esame e costruendo cartelloni. Perseguendo questo itinerario si portano i bambini a canalizzare l'attenzione su una *montagna particolare* a loro vicina, a impegnarsi nella ricercara di materiali, ad analizzare e rifflettere, ad assumere informazioni, a problematizzare la realtà partendo da un "fumo" del Vesuvio (Fig. 1), e ad utilizzare il corpo per rappresentare la realtá.

Una delle scuole più attive sul territorio sul Rischio Vesuvio è la Scuola Paritaria Bambi posta solo ad alcuni chilometri dal cratere Vesuvio e diretta da Ciro Formisano. Questa scuola é sempre stata una preziosa collaboratrice e attraverso gli anni, gli alunni, con la guida delle insegnanti, hanno prodotto lavori ricchi e fantasiosi. Il Gigante Vesuvio è uno di tali progetti dell'anno scolastico

2012-2013 dove il vulcano è minacciato dalla pressione demografica produce la eruzione per ricominciare una nuova vita in sintonia coll'ambiente (Fig. 2). Altri significativi lavori degli alunni sono: l'intervista a nonno Gennaro sulla ultima eruzione del 1944 e la intervista allo scienziato Flavio Dobran (Fig. 3).

Figura 2. Il Gigante Vesuvio della scuola d'infanzia Bambi di Ercolano racconta una difficile coabitazione del vulcano con l'uomo.

Coll'articolo *Vesuvio a scuola* [9] gli insegnanti della Scuola Media Statate R. Scotellaro di Ercolano svilupparono un più complesso percorso educativo indirizzato alla conoscenza del rischio vulcanico riportato nella Fig. 4. Iniziando con un atteggiamento conoscitivo, per recuperare una visione integrale dell'ambiente, si è perseguito con confroni e riflessioni che portarono alla classificazione, conoscenza, mappa del rischio, recupero delle radici e la creatività di un "cubo magico", di canzoni, d'interpretazioni pittoriche, di recite e poesie in cui l'interiorizzazione dei contenuti è evidente (Fig. 5).

Da una educazione mitica del rischio nella scuola materna e una educazione romantica nella scuola media siamo arrivati a una educazione al rischio Vesuvio interdisciplinare e multidisciplinare riportato nel lavoro di Carmela Sorrentino di I.T.C. L. Einaudi di San Giuseppe Vesuviano [10]. I principali obiettivi di questo progetto intitolato *Un percorso sull'educazione al rischio Vesuvio in una scuola superiore* e, ricco di bibliografia, sono: conoscenza del territorio tramite gli eventi naturali (terremoti, eruzioni, inondazioni, frane), sviluppo di una men-

Figura 3. Alunni della scuola Bambi che hanno intervistato nel 2013 lo scienziato Flavio Dobran sul rischio Vesuvio.

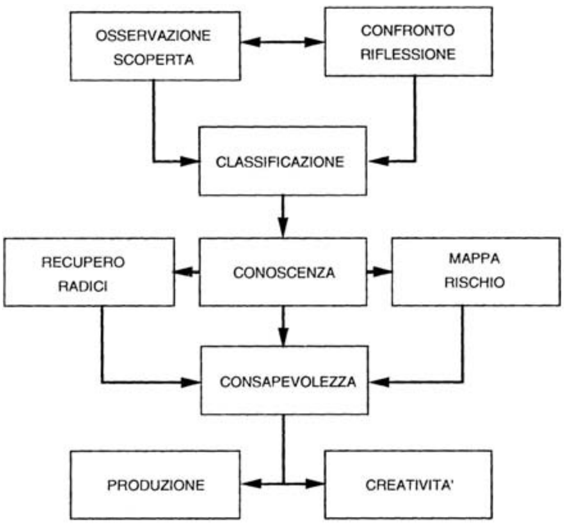

Figura 4. Sintesi delle fasi educative sviluppate nella scuola S.M.S. R. Scotellaro [9].

Figura 5. Cubo magico sviluppato nella scuola S.M.S. R. Scotellaro [9].

talitá che permette di allargare il panorama delle conoscenze del territorio al di fuori dell'ambito scolastico e testi e leggere il territorio anche nei suoi aspetti antropici, acquisto del dubbio, considerazione critica delle informazioni provenienti dai nezzi di comunicazione e acquisire capacità di organizzazione interpersonale e di gruppo. Questo metodo di educare gli allievi attraverso i vari aspetti della realtà ha la capacità di formare giovani capaci di affrontare meglio le problematiche del territorio e partecipare attivamente per produrre un territorio resiliente e sostenibile.

La disinformazione della popolazione sul rischio vulcanico nell'area napoletana è troppo elevata e all'inizio del millennio fu circa del 80% [7] e questo ci ha spinto non solo ad avviare seminari nelle scuole, ma anche nei luoghi pubblici e ad organizzare ogni anno manifestazioni delle scuole sul rischio per incentivare insegnanti e studenti a lavorare sulle problematiche del loro territorio [11]. In questi incontri i problemi dei vulcani napoletani vengono trattati in tutti i loro aspetti: scientifici, geografici, sociali, economici e culturali. Per uscire fuori dalla cultura della emergenza, promossa dai piani di evacuazione del Vesuvio e dei Campi Flegrei, e lavorare verso una cultura della prevenzione, fu necessario avviare anche le iniziative scientifiche con convegni nel territorio, diffondere il progetto VESUVIUS 2000 nell'ambito internazionale e definire meglio gli obiettivi del progetto.

3. Riflettendo e spingendo nel millennio

La promozione della conoscenza e della educazione del rischio nell'area napoletana nel terzo millenio dovrebbe portare ad una più grande comprensione nella popolazione partenopea, che *l'appartenenza al posto* è uno dei pilastri fondamentali della sostenibilità [12] e il progetto VESUVIUS 2000 é consistente con questo requisito. In parallelo con i seminari nelle scuole e nel pubblico e le manifestazioni annuali delle scuole, promossi dalla GVES, abbiamo anche organizzato, negli ultimi due decenni, tre incontri scientifici e divulgato il progetto negli incontri scientifici internazionali [13]. Gli obiettivi di VESUVIUS 2000 sono stati riassunti in cinque obiettivi principali inglobando anche il vulcano dei Campi Flegrei. Questo nuovo quadro della resilienza e della sostenibilità dell'area napoletana comprende non solo le eruzioni pliniane del Vesuvio ma anche le eruzioni pliniane e super pliniane dei Campi Flegrei, che sono 10-100 volte più forti.

Il volume *VESUVIUS: Education, Security and Prosperity* [14] è il risultato di una conferenza internazionale e interdisciplinare tenutasi a Villa Campolieto a Ercolano, dal 2 al 3 settembre 2004 e comprende i lavori sul progetto VESUVIUS 2000, come insegnare il Vesuvio nelle scuole, le realtà sociali ed economiche del Vesuvio, gli scenari sismici e vulcanici e la modellizzazione dei processi vulcanici.

In seguito, il volume *Vesuvio a Scuola* [5] riporta non solo i lavori più recenti degli educatori nel territorio vesuviano, ma anche strumenti cognitivi e metodologie educative applicabili a varie fasce di età degli alunni delle scuole materne, elementari, medie e superiori. I lavori sulla educazione degli allievi da notare in questo volume sono quelli della scuola elementare V Circola Didattico di Torre del Greco, della Scuola Media Statale O. Comes di Portici, dell'Istituto Comprensivo Statale D. d'Assisi di Torre del Greco e dell'Istituto Tecnico Commerciale L. Sturzo di Castellammare di Stabia.

Maria Aurelia, Colomba Balbi e Maria Gargiulo del quinto circolo di Torre del Greco, hanno avviato il progetto *Andar per ... Alla scoperta del territorio* con 30 alunni e articolato in IV fase: formazione rivolta a genitori, docenti ed alunni tramite gli esperti in vulcanolgia, ambiente, biologia, protezione civile e ideatore di VESUVIUS 2000, raccolta dei dati del territorio, conoscenza della città della scuola e la ricerca sulla sua trasformazione nel tempo.

Presso la scuola Comes di Portici Annamaria Imperatrice e i collaboratori Nicola Ciobbo, Giuseppina Donatiello e Franca Vigiliante hanno insegnato agli allunni il Rischio Vesuvio dal 1995. Insieme agli studenti hanno partecipato a diverse initizative nel territotio napoletano, visitato le rovine di Pompei ed Ercolano, promosso la cultura della sicurezza nella scuola e fatto capire agli studenti che consuetudini negative, clientelismo, conformismo e crimine non portano allo sviluppo sostenibilie del loro territorio. Nelle immaginazioni degli studenti, nel fumetto *Il mio viaggio ... al Vesuvio* [14], il vulcano e eventi importanti accaduti durante gli ultimi due millenni nel territorio vengono rappresentati dal punto di vista storico, scientifico, geografico e culturale e culminano con l'ultima eruzione del vesuvio nel 1944 e il Piano di Evacuazione del Vesuvio, di scarsa utilità. Gli insegnanti sostengono che attraverso il fumetto gli studenti sono guidati alla scoperta delle loro radici e della loro precaria coabitazione col vulcano.

Gelsomina Sorrentino (Fig. 6) e i suoi colleghi all'I.C. d'Assisi di Torre del Greco hanno insegnato "Rischio Vesuvio" dall'inizio della presentazione del progetto VESUVIUS 2000 nel territorio. Questi insegnanti hanno compreso che prima di rendere consapevoli gli studenti dei problemi posti dal vulcano era necessario rendere se stessi consci di una *nuova consapevolezza* come cittadini che

Figura 6. Gelsomina Sorrentino con gli studenti dell'I.C. d'Assisi di Torre del Greco.

vivono e lavorano sui piedi del vulcano. Dal loro impegno è sorto un *vulcano laboratorio* a scuola e, quindi, una consapevolezza della natura pluridimensionale del vulcano e del suo ambiente. Il progetto "Il Vesuvio: alla ricerca delle radici tra storia, natura ed economia" degli alunni intorno ai 10 anni d'età era rivolta a prepararli a occuparsi del loro ambiente e a renderli osservatori obiettivi nel territorio.

Nella scuola superiore I.T.C. Sturzo di Castellammare di Stabia si nota un livello piu sofisticato o filosofico nell'insegnamento degli studenti. Ida Mascolo ha guidato due classi di studenti sul tema della mitigazione del rischio vulcanico, dove gli studenti hanno esaminato le teorie e le loro anomalie, hanno intervistato degli esperti, portato avanti delle ricerche e si sono formati le loro opinioni relativamente a due diversi schemi: Piano di Evacuazione e VESUVIUS 2000 riportati nella Fig. 7.

Dalla conferenza internazionale tenuta a Castellamare di Stabia nel 2014 (Fig. 8) è uscito VESUVIUS PENTALOGUE – un riassunto degli obiettivi principali del progetto VESUVIUS 2000 [15]. Questo quadro richiede di raggiungere cinque obiettivi della resilienza e della sostenibiltà per l'area vesuviana, con il quarto obiettivo che richiede campagne effettive per la informazione e la educazione. VESUVIUS PENTALOGUE é recentemente stato modificato per inserire il vulcano dei Campi Flegrei, nominato VESUVIUS–CAMPIFLEGREI PENTALOGUE, e richiede che la informazione e la educazione al rischio vulcanico dovrebbe coinvolgere tutto il territorio napoletano [16]:

A. La realizzazione di un'efficace campagna di informazione e una strategia di preparazione attiva della popolazione nelle zone dei nuclei di esclusione, delle cinture delle resilienza e in quelle di sostenibilità intorno al Somma-Vesuvio e Campi Flegrei;
B. In tutte le scuole delle zone sopra indicate si dovrebbe realizzare un Programma di Educazione alla Sicurezza per il Rischio Vulcanico.

Figura 7. Confronto tra Piano di Evacuazione del Vesuvio e VESUVIUS 2000, realizzato nella scuola superiore L. Sturzo di Castellammare di Stabia [5].

Figura 8. Partecipanti al covegno di Castellammare di Stabia nel 2014. Da sinistra a destra: G. Gambardella, O. Colucci, M. Di Lascio, M. Giordano, D. Trezza, B. De Vivo, A. Lima, G. Rolandi, A. Marturano, M. Indirli, F. Dobran, E. Cubellis, A. Vella, G. Luongo, A. Imperatrice, I. Mascolo.

4. Conclusione

Nonostante il nostro sforzo per ridurre il rischio nell'area napoletano le autorità italiane e quelle della Unione Europea sembrano non avere le capacità di promuovere resilienza e sostenibilità e si nascondono dietro gli inaffidabili piani di emergenza e finanziano per decenni i loro promotori. Questa cultura di emergenza fallirà e lascerà una machia nera nella storia partenopea, grazie alla istituzionalizzazione della ignoranza.

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THEME

Pathways and Resilience to Sustainability of Cities in Hazardous Environments

Percorsi e resilienza alla sostenibilità delle città in ambienti pericolosi

From left to right and top to bottom. Maurizio Indirli, Rohit Magotra, Maria Pilar Ortiz, Andrea Young, Flavio Dobran, Alessio D'Auria, Grazia Paolella, Annarita Ottaviano, Bartolomeo Sciannimanica, Nicola Chieffo, Mathieu Augustin, Franco Vaccari, Annamaria Imperatrice, Cristina Lara Correa, Lyuba Albouf. The images in the last row correspond to a workshop on robotics coordinated by Lyuba Albouf.

Sustainable and Disaster Resilient Urban Development, India: A Comparative Study of 10 Cities to Draw Lesson for South Asia

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Abstract. The International Panel on Climate Change established a strong link between climate change and extreme weather events, like storms, cyclones, floods, heat waves, etc., and forecasted considerable increases in frequency of such events that can produce disasters. During the last thirty years India has been subjected to many environmental disasters and with the Disaster Management Act of 2005 its government recognized the importance of resilience of cities and awarded a study on Sustainable and Disaster Resilient Urban Development, India, to assess the state of resilience of 10 cities: Ahmedabad, Bhopal, Bhubaneshwar, Dehradun, Guwahati, Hyderabad, Pune, Shillong, Srinagar, and Vishakhapatnam. The study adopted a holistic methodology by incorporating factors that give local and regional diversification and flexibility to be customised for use in other cities and regions. A comparative study of vulnerability was carried out on the aspects of hazards vulnerability of the cities, existing critical infrastructure, recovery and response systems of city governance, and socio-economic status of the population. A detailed case study for the city of Guwahati is presented using the Geographic Information System (GIS) tools, like Digital Elevation Model (DEM) maps, to study the regional topography and identify low-lying vulnerable zones within the cities. Integrated Land-Use-Vulnerability maps helped developing appropriate strategies for risk reduction and mitigation, and building a robust knowledge base on different components of the risk function: hazards, exposure, vulnerability, and resilience. The study has also considered certain aspects of the United Nations' Sendai Declaration, such as the reduction of socio-economic losses, damage to critical infrastructure and basic services, along with increasing the access to multi-hazard early warning systems and disaster risk information.

Keywords: Climate change, city vulnerability, disaster/hazard resilience, GIS

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1. Introduction

During the last thirty years India has been subjected to unplanned urbanization and increased vulnerabilities that produced 431 disasters and affecting nearly 1.5 billion people, great damage to the property, and uprooting of some 2.3 million people [1,2]. With the Disaster Management Act of 2005, the government of India has recognized the importance of resilience of cities [3] in the event of disasters and awarded a study on Sustainable and Disaster Resilient Urban Development, India, to assess the state of resilience in selected 10 cities: Ahmedabad, Bhopal, Bhubaneshwar, Dehradun, Guwahati, Hyderabad, Pune, Shillong, Srinagar, and Vishakhapatnam, across India.

With the increasing unplanned urbanization, the impacts of cities are increasing, which is primarily associated with poorly planned and unmanaged urban development, degraded ecosystems, and poverty [4]. The unplanned urbanization increases the vulnerability of cities to natural and anthropogenic hazards and according to the 2011 census 31% of India's population live in urban areas (GoI). According to a survey reported in the UN State of the World Population report of 2007, 40.76% of country's population is expected to reside in urban areas by 2030, and according to another United Nations study almost 890 million people (60%) across the globe live in cities that are at risk from at least one major natural disaster, including floods, droughts, cyclones, or earthquakes. In 2011, 80% of global disaster-related economic losses occurred in the Asia and Pacific regions, and nearly 40% of all the disasters triggered by natural hazards in the world occur in Asia, with 88% of the people being affected in this region [5].

Disaster is defined as an event or series of events which gives rise to casualties and damage or loss of properties, infrastructure, environment, essential services or means of livelihood on such a scale that is beyond the normal capacity of the affected community to cope with. Disaster is also sometimes described as a "catastrophic situation in which the normal pattern of life or ecosystem has been disrupted and extraordinary emergency interventions are required to save and preserve lives and or the environment" [6].

The "smart cities" effort, in 100 cities across India, aims to create urban spaces where green, high-tech initiatives bring more efficient management of resources, including water and energy, and better services to citizens. To make cities disasters resilient right at the inception stage, an efficient urban planning can have a major impact on communities' preparedness and capacities to recover. Smart growth strategies like creating flexible land-use policies, targeting public investment, and engaging the entire community in making decisions can help the community to recover from a disaster, rebuild according to a shared community vision, and be better prepared for a disaster.

The government of India recognizes the importance of resilience of cities across India in the event of disasters. Disaster resilient cities can be achieved through multi-sectoral and multi-stakeholder approaches along with policy level interventions. It is always required that the preparedness (resilience) of the cities should be such that minimum time is taken in response, recovery and risk reduction measures. The Disaster Management Cycle [7] (Fig. 1) is an ongoing process by which governments, businesses, and civil society plan for and reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after the disaster.

These phases do not always, or even generally, occur in isolation or in this precise order; often they overlap and the length of each phase greatly depends on the severity of the disaster.

Figure 1. Disaster management cycle.

2. Scope and Methodology

2.1 Scope and Study

In order to produce a concrete roadmap to disaster resilience IRADe conducted a study on Sustainable and Disaster Resilient Urban Development, India, for the Ministry of Urban Development (MoUD), under the Comprehensive Capacity Building Programme, and assessed the state of resilience of selected cities across India with diverse physiographic/topographic characteristics. The cities were selected (from among Jawaharlal Nehru National Urban Renewal Mission (JnNURM) cities) in a manner that there is regional variation, covering a wide range of parameters, such as city natural hazards, infrastructure, land use, city management, and governance profiles. The 10 cities selected for the study are: Ahmedabad, Gujarat; Bhopal, Madhya Pradesh; Bhubaneshwar, Orissa; Dehradun, Uttarakhand; Guwahati, Assam; Hyderabad, Telangana; Pune, Maharashtra; Shillong, Meghalaya; Srinagar, Jammu & Kashmir; Vishakhapatnam, Andhra Pradesh; and their locations is shown in Fig. 2.

Figure 2. Locations of 10 cities for the resilience study.

2.2 Methodology

The relation between disaster risk assessment and resilience to different parameters related to infrastructure, governance, hazards, and socio-economic factors is a known fact. Since the definition of disaster resilience is highly contextual and also governed by the local and regional factors, the methodology adopted gives due consideration to the local and regional parameters. IRADe has attempted to adopt a holistic methodology by incorporating factors that give local and regional diversifications and flexibilities to be customised for use in other cities and regions, and assessed the disaster resilience based on the following aspects:

- **Hazard vulnerability:** List of hazards and their frequencies and magnitudes of impacts (on socio-economic fabric, infrastructure, and human life);
- **Evaluation of existing critical infrastructure**: Based on the above mentioned disaster proneness;
- **Governance:** Response and recovery system and evaluation of city management and governance in the context of disaster proneness. Comments on the financial resources of the Urban Local Body (ULB) are available for disaster management and on the structure of the disaster response system;
- **Socio-economic status:** Slum population, population below poverty line, availability of basic services to urban poor.

To understand and analyse climate resilient measures in India's urban centres, a framework has been designed based on four themes: (1) Hazards, (2) Infrastructure, (3) Governance, and (4) Socio-Economic characteristics (HIGS), which are determined on the basis of the city's characteristics like location, economic, and geographical parameters to determine the exposure to hazards. The framework was made dynamic by adding more parameters and was evaluated by developing a matrix to represent resilience.

The data collected for 10 cities' governance, ULBs performance, preparedness, financial indicators, and Service Level Benchmarks (SLB) were gathered during the visits to the cities, which were subsequently analysed to develop a vulnerability assessment matrix for these cities (Fig. 4). A spatial analysis utilizing GIS was carried out to identify critical urban hotspots in the cities which are highly susceptible to disastrous impacts of hazards. This is based on the concept of integrating the hazard assessment layer, which is derived from the hazard profile of the city, with vulnerable urban components that are exposed to these hazards. The disaster resilience at the city level was assessed through its socio-economic vulnerability in terms of population and slum population cover, vulnerability towards hazards like cyclones, urban flooding, heat waves, etc., current status of physical infrastructure and comparison with the national SLBs and their existing institutional frameworks and disaster mitigation preparedness and proposed recommendations for the same.

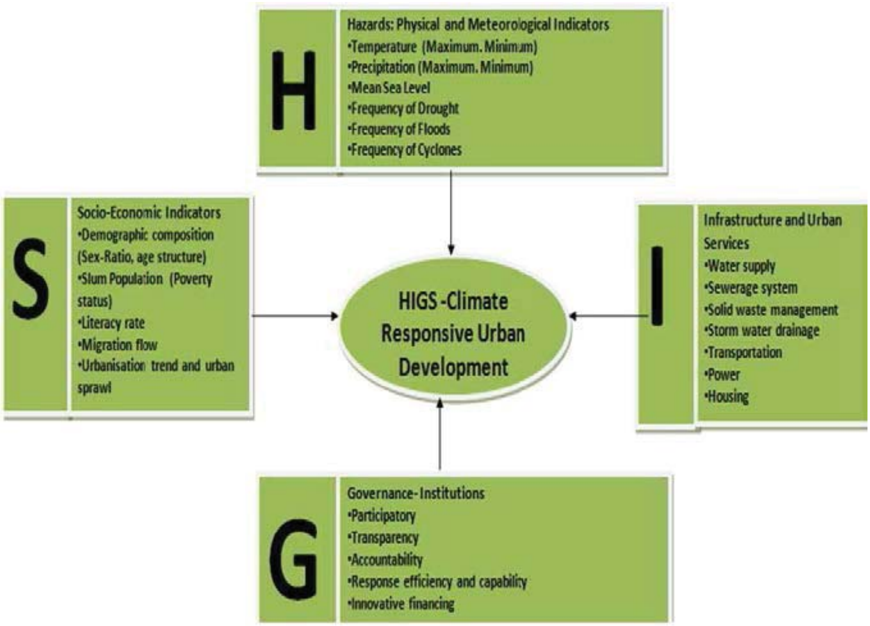


Figure 3. Hazards, Infrastructure, Governance, and Socio-economic (HIGS) characteristics for climate responsive urban development

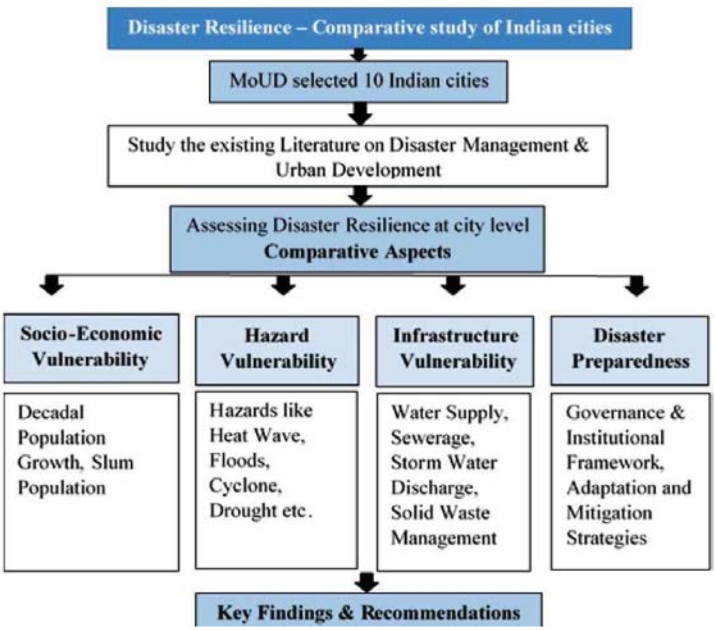


Figure 4. Study methodology.

3. Analysis

3.1 Hazard Vulnerability

The India's geo-climatic conditions as well as its high degree of socio-economic vulnerability, makes it one of the most disaster prone country in the world [8]. Indian cities are exposed to multiple natural hazards, such as earthquakes, tropical cyclones, urban floods, drought/water scarcity, landslides, heat and cold waves, etc. During the last thirty years, the country has experienced 431 major disasters resulting in enormous losses to life and property. According to the Prevention Web statistics, 143,039 people were killed and about 1.50 billion people were affected by various disasters in the country during these three decades [9]. The major disasters in India over the last 40 years are listed in Table 1.

India is one of the ten worst disaster prone countries of the world. The country is prone to disasters due to a number of factors, both natural and human-induced. Out of 35 states and union territories in the country, 27 of them are disaster prone. The percentage of land in India prone to various disasters is shown in Fig 5.

3.1.1 Floods

NIDM reports [12] over 40 million hectares (12%) of the land in India is prone to flood and river erosion. Urban floods are a result of inadequate or poor maintenance of storm water drains, improper planning, encroachment on drains and water bodies, occupation of low lying areas, modification of catchments, and climate change. This is becoming a regular event in Indian cities, as can be seen in Table 2.

Ahmedabad, Bhubaneshwar, Guwahati, Srinagar and Vishakhapatnam are highly prone to flood risks and fall into the severe risk zones (Fig.6). Their levels of vulnerability towards flood are high owing to their geographical locations along the coasts and nearness to catchment areas. However, cities like Dehradun, Hyderabad, Pune, and Shillong are at moderate risk levels. The increase in urban flooding in cities have resulted in the increases of vector and water borne diseases, high traffic congestions, chocking of drains, damage to public and private property, etc.

3.1.2 Earthquakes

As stated earlier, 58.6% of the land in India is prone to earthquakes ranging from moderate to very high intensity. The seismic zonation map shows that India is highly vulnerable for earthquake hazards. India has witnessed more than 650 earthquakes of Magnitude >5 during the last hundred years [14]. The increase of earthquake risk is due to a spurt in developmental activities driven by urbanization, economic development, and the globalization of India's economy. Some of the major earthquakes are summarized in Table 3.

As shown in Fig. 7, Dehradun, Guwahati, Shillong, and Srinagar lie in high risk zones (Zones IV and V) in terms of earthquakes. Ahmedabad, Pune and Bhubaneswar lies in moderate risk zone (Zone III). Ahmedabad, despite being in moderate risk zone, experienced huge loss of lives and property in 2001 Bhuj Earthquake. This stresses the need for adopting development regulations for earthquake resistant structures in all of the cities.

Table 1. Major disasters in India during the last 40 years [10].

Sl No.	Events	Year	States and Area	Fatalities
1	Drought	1972	Large part of the country	200 million people affected
2	Cyclone	1977	Andhra Pradesh	10,000 deaths, hundreds of thousands homeless
3	Drought	1987	15 States	300 million people affected
4	Cyclone	1990	Andhra Pradesh	967 people died, 435,000 acres of land affected
5	Latur Eartquakes	1993	Latur, Marathwada region of Maharashtra	7,928 people died 30,000 injured
6	Cyclone	1996	Andhra Pradesh	1,000 people died, 5,80,000 houses destroyed, Rs. 20.26 billion damage
7	Orissa Cyclone	1999	Orissa	Over 10,000 deaths
8	Earthquake	2001	Gujarat	13,805 deaths 6.3 million people affected
9	Tsunami	2004	Coastline of Tamil Nadu, Kerala, Andhra Pradesh, Pondicherry and Andaman & Nicobar Islands	10,749 deaths 5,640 person missing 2.79 million people affected 11,827 hectares of crops damaged 300,000 fisher folk lost their livelihood
10	Floods	2005	Maharashtra	1094 deaths 167 injured 54 missing
11	Earthquake	2005	Mostly Pakistan, Partially Kashmir	1400 deaths in Kashmir (86,000 deaths in total)
12	Flood	2008	North Bihar	527 deaths, 19,323 livestock perished, 2,23,000 houses damaged, 3.3 million affected
13	Cyclone Nisha	2008	Tamil Nadu	2004 deaths
14	Drought	2009	252 Districts in 10 States	-
15	Floods	2009	Andhra Pradesh and Karnataka	300 people died
16	Cloudburst	2010	Leh, Ladakh in J&K	257 people died
17	Earthquake	2011	North Eastern India with epicenter near Nepal Border and Sikkim	97 people died (75 in Sikkim)
18	Lanslides clouburst	2012	Uttrakhand in Himalaya	Hundreds died, huge economic loss
20	Flood	2012	Assam, Madhya Pradesh, Rajasthan etc.	Hundreds died and damage to property and agriculture.
21	Floods/ Lanslides	2013 [11]	Uttarakhand and Himachal Pradesh	4,094 people died
22	Floods/Cyc. Phailin	2013	Odisha and Andhra Pradesh	Hundreds died and huge economic loss
23	Cyclone Hud	2014	Andhra Pradesh & Odisha	Hundreds died, damage to property and agriculture.
24	Flood	2014	Jammu & Kashmir	Hundreds died, huge economic loss

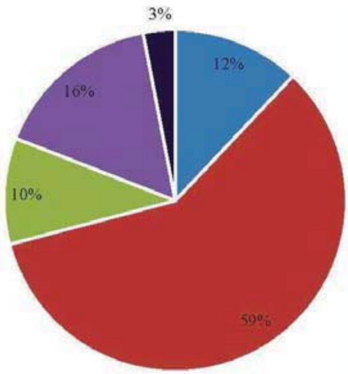


Figure 5. Percentage of land affected by Hazards (59% earthquakes, 12% floods, 16% drought, 10% floods, 3% landslides [11].

Table 2. Flooding events in India [13].

City	Flooding Years
Hyderabad	2000, 2001,2002, 2006 and 2008
Ahmedabad	2001
Delhi	2002 and 2003
Chennai	2004 and 2015
Mumbai	2005, 2007 and 2015
Bangalore	2005, 2009 and 2013
Surat	20060 and 2013
Kolkata	2007 and 2013
Jamshedpur	2008
Delhi	2009, 2010, 2013, 2016
Guwahati and Delhi	2010 and 2011
Srinagar	1992, 2014 and 2015

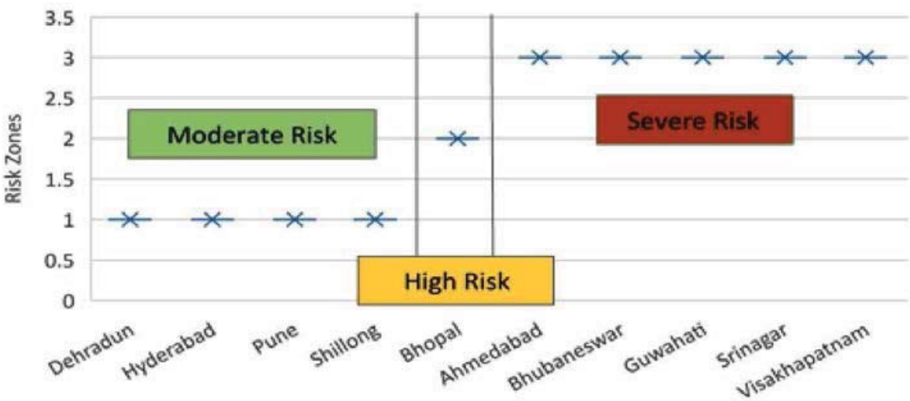


Figure 6. Flood vulnerability of cities.

3.1.3 Landslides

Landslides are simply defined as the mass movements of rocks, debris or earth down the slopes and have come to include a broad range of motions whereby falling, sliding, and flowing under the influence of gravity dislodges the earth material [15]. In the hilly terrain of India including the Himalayas, landslides have been a major and widely spread natural disasters that often strike life and property and occupy a position of major concern. Some of the landslide events are shown in Table 4.

Nearly 20 states of India fall under different landslide hazard categories. Cities like Dehradun and Srinagar are highly vulnerable to landslides and fall under the severe risk zones (Fig. 8). The increasing population has resulted in the development of residential areas on moderate to steep slopes. The construction activities on the hill slopes have increased the runoff of soil resulting in landslides.

Table 3. Earthquake events in India [14].

Place / Cities	Year	Fatalities
Indian Ocean	December,2004	>283,106
Kashmir	October, 2005	130,000
Bihar & Nepal	January, 1934	>30,000
Gujarat	January, 2001	20,000
Kangra	April, 1905	>20,000
Latur	September, 1993	>9,748
Assam	August, 1950	1,526
Assam	June, 1897	1,500
Uttarkashi	October, 1991	>1,000
Koynanagar	December, 1967	180

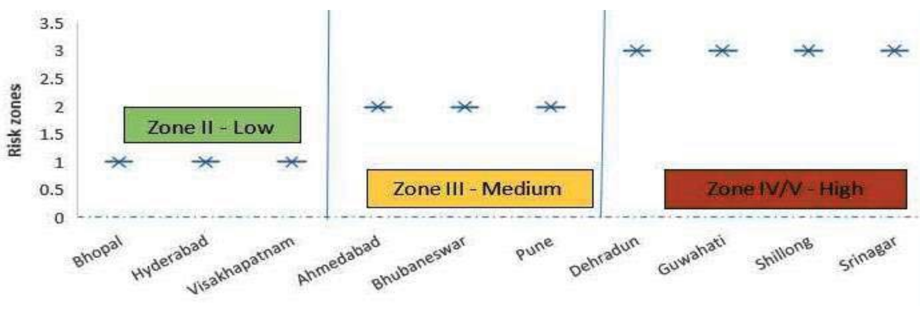


Figure 7. Earthquake vulnerability of cities.

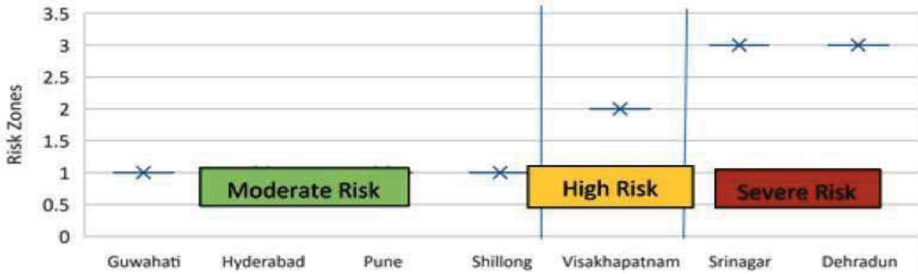


Figure 8. Landslide vulnerability of cities.

Table 4. Landslide events in India [15].

State, city	Year	Fatalities
Rajouri, Jammu & Kashmir	January, 2005	Ten people were killed and some others went missing after a house collapsed
Lachen river valley, Sikkim	September, 2012	21 deaths. Damage to the buildings and roads
Pelling, Sikkim	June, 2011	Damage to property and killed 16 people.
Kullu, Himachal Pradesh	February, 2014	Washing away roads and terraced fields.
Mandi, Himachal Pradesh	August, 2011	Blocked national highways
Dehradun, Uttarak-hand	August, 2014	7 deaths, concrete houses collapsed
Nainital, Uttarak-hand	July, 2013	6 deaths
Uttarakhand	June, 2013	5,700 deaths, Kaidarnath, Gaurikund, and market town of Rambada were washed
Maharashtra	July, 2014	Some 50 houses were buried and 134 died.

3.1.4 Cyclones and Wind Storms

The Indian sub-continent is the worst affected region of the world, having a coastline of 7516 km that is exposed to nearly 10% of the world's tropical cyclones [16]. The analyzed data for the period 1980-2000 show that on average 370 million people are annually exposed to cyclones in India. The major tropical cyclones which struck the coastal districts in India during the period 1891-2002 include Kerala (3), West Bengal (69), Karnataka (2), Odisha (98), Maharashtra (13), Andhra Pradesh (79), Goa (2), Tamil Nadu (54), Gujarat (28), and Pondicherry (8). Some of the cyclone incidences are listed in Table 5 [17].

Bhubaneshwar, Hyderabad, and Vishakhapatnam are highly vulnerable to cyclonic activities with wind velocity ranging between from 45 to 55 m/ sec, whereas Guwahati, Shillong, and Srinagar encounter wind storms (Fig. 9). The recurring cyclones and wind storms account for large number of deaths, loss of livelihood opportunities, loss of public and private property, and severe damage to infrastructure, thus seriously reversing the developmental gains at regular intervals.

Table 5. Cyclonic events in India [17].

States/ cities	Years	Fatalities
Cyclone Nilam, Tamil Nadu	October, 2012	20 deaths and the evacuation of 13,000 people
Cyclone Thane, Tamil Nadu	December, 2011	41 deaths, damage to standing crops
Cyclone Laila, Andhra Pradesh	May, 2010	32 deaths, evaluation of thousands of people, agricultural crops over 12,000 hectares destroyed.
Cyclone Aila, West Bengal	May, 2009	100 deaths

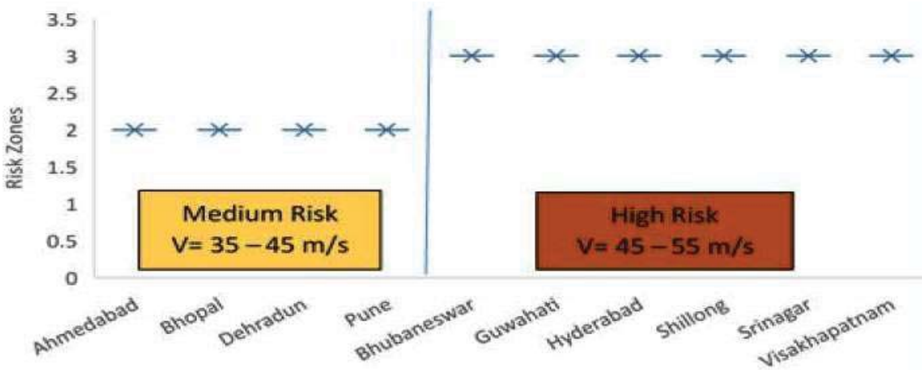


Figure 9. Cyclones and wind storms vulnerabilities of cities.

3..1.5. Heat Waves

The Climate Change Vulnerabilities (CVV) has given rise to heat waves[1] where there is 5-7^{0}C increase in average summer temperature. While India is accustomed to high temperatures, a large number of fatalities resulting from recent heat waves have highlighted the importance of this public health risk (Table 6). Heat stroke is the second most common contributing cause of accidental deaths due to natural causes. The country recorded a 61% increase in heat-related mortality between 2004 and 2013 [18].

[1] Heat wave is a period of abnormally high temperatures, more than the normal maximum temperature that occurs during the summer season. Heat waves typically occur between March and June, and in some rare cases even extend till July. The extreme temperatures and resultant atmospheric conditions adversely affect people living in such regions as they cause physiological stress and sometimes resulting in death.

Table 6. Heat wave fatalities [18].

Year	Fatalities
1992-2001	7,203
2002-2011	8618
2012-2015	6562

It has been found (Fig 10) that there is a significant warming trend over India in annual mean Temperature along with significant increasing trend during different seasons. It has also been reported that there is a substantial acceleration of warming in last three decades.

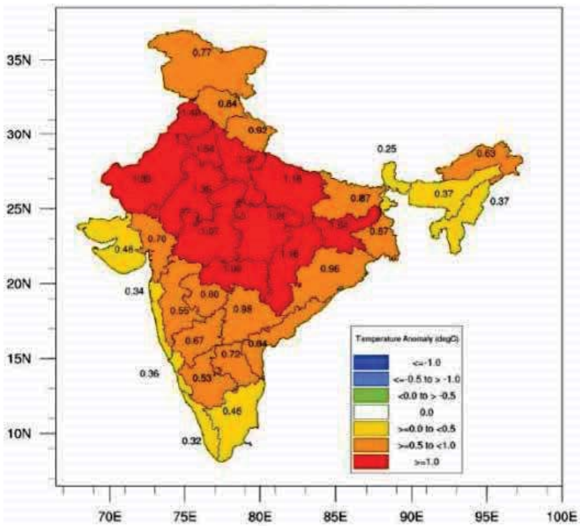


Figure 10. Annual mean temperature anomalies for the period 1901-2009 [19].

Ahmedabad, Bhopal & Bhubaneshwar are highly vulnerable to heat waves as temperatures sore above 40^{O}C in the summer, whereas Pune and Vishakhapatnam experience low temperature ranges (Fig. 11).

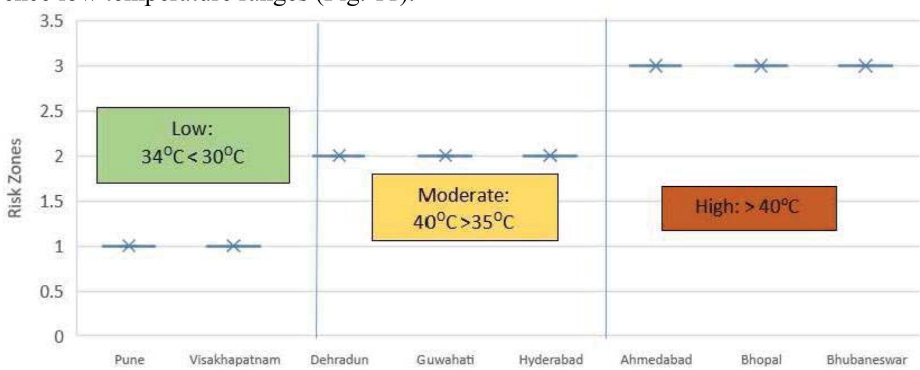


Figure 11. Heat wave vulnerabilities of cities.

The cities like Srinagar, Ahmedabad, Dehradun, Guwahati, and Visakhapatnam are among the most vulnerable cities exposed to numerous natural and man-made hazards (Fig. 12). Apart from the mentioned hazards there are certain other hazards faced by Indian cities, like the water scarcity or drought conditions, cold waves, and industrial hazards/fires. For instance, the water scarcity is a hazard waiting to become a disaster in Ahmedabad where the groundwater table has gone extremely low (90 m bgl). Cities with over a million people like Hyderabad, Pune, Bhopal, and Visakhapatnam are at risk of depleting groundwater if not managed. The industrial towns of Ahmedabad, Bhopal, Guwahati, Shillong, and Visakhapatnam are highly prone to industrial hazards. All the cities need to have stringent safety standards and quick responding emergency operating centers.

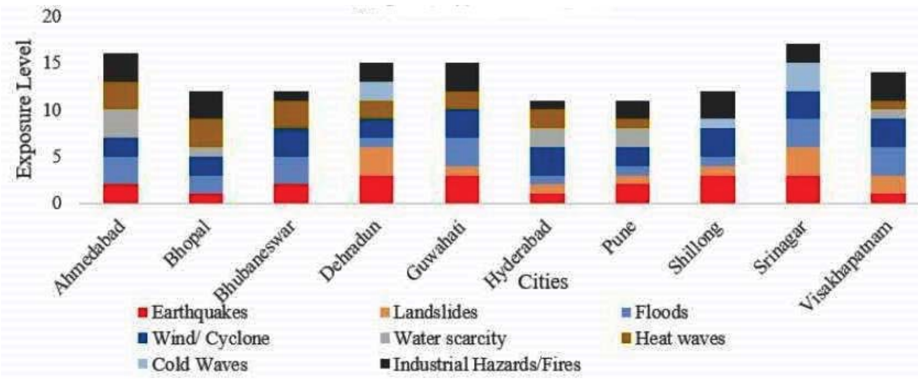


Figure 12. Exposure of cities to hazards.

The heightened vulnerabilities to disaster risks can be associated with the expanding population, urbanization and industrialization, development within high-risk zones, environmental degradation, and climate change. Along with the natural factors discussed in the preceding text, various human-induced activities like increasing demographic pressure, deteriorating environmental conditions, deforestation, unscientific development, faulty agricultural practices and grazing, unplanned urbanization, construction of large dams on river channels, etc. are also responsible for the accelerated impact and increase in frequency of disasters in the country.

3.2.1 Urban Population Growth

The population growth and distribution, and especially the increasing population density and urbanization, increase vulnerabilities and promote disasters [20]. The severity of any disaster is usually related to the population it affects, and the impact of natural disasters is always worse if the proportion of population affected by it is large. The high population density at any city makes the impact of the disaster disproportionately worse.

The population of India has increased by more than 181 million during the last decade 2001-2011 [21]. For the first time since Independence, the absolute increase in population has been more in urban areas than in rural areas. The level of urbanization has increased from 27.81% in 2001 Census to 31.16% in 2011 Census. The overall population growth rate of India has slowed down from 21.54% (1991-2001) to 17.64% (2001-2011) due to the sharp decline in the rural growth rate, whereas the urban growth rate remains almost the same (31.5-31.8%) (Fig. 13).

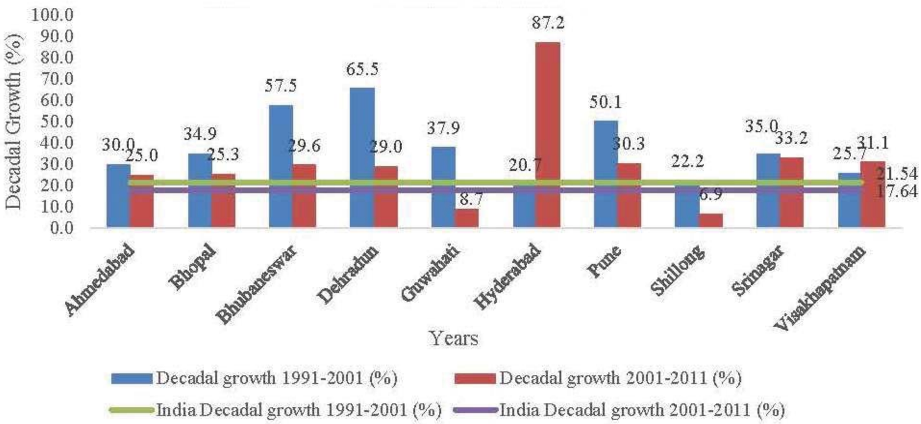


Figure 13. Decadal growth of population of 10 studied cities vs India (1991-2011).

Over the last decade the cities (except for Hyderabad and Vishakhapatnam) has projected a declining population growth. The increasing growth in the cities of Hyderabad (87.2%) and Vishakhapatnam (31.1%) was due to the increase in respective municipal areas. As compared to the national growth rate of 17.64%, all the cities expect Shillong and Guwahati experienced the least annual growth in population during the last decade. Hyderabad and Srinagar record higher growth rates of 87.2% and 33.2% when compared to the decadal urban rate of 31.8% for the year 2001- 2011. The populations of cities (urban) have decreased in all of them over the decade. This growing urban population increases the population exposed to disasters and it affects the changing demographic and socio-economic character of the city at large (Fig. 14).

3.3 Slum Population

Slums[2] have been a constant feature of urban landscape in India. Slums manifest the worst form of deprivation that transcends income poverty. Under Section 3 of the

[2] A Notified Slum is defined as a compact area of at least 300 people or about 60-70 households of poorly built congested tenements, in an unhygienic environment and usually with inadequate infrastructure and lacking proper sanitary and drinking water facilities. Identified Slums are compact areas of at least 300 people of poorly built congested tenements, in unhygienic environments and with usually inadequate infrastructure and lacking in proper sanitary and drinking water facilities. Recognized Slums are the ones which may not have been formally notified as slums under any act but are recognized by States, UTs, and local bodies.

Slum Area Improvement and Clearance Act of 1956, slums have been defined as mainly those residential areas where dwellings are in any respect unfit for human habitation by reasons of dilapidation, overcrowding, faulty arrangements and designs of such buildings, narrowness or faulty arrangement of streets, lack of ventilation, light, sanitation facilities or any combination of these factors which are detrimental to safety, health, and morals [22].

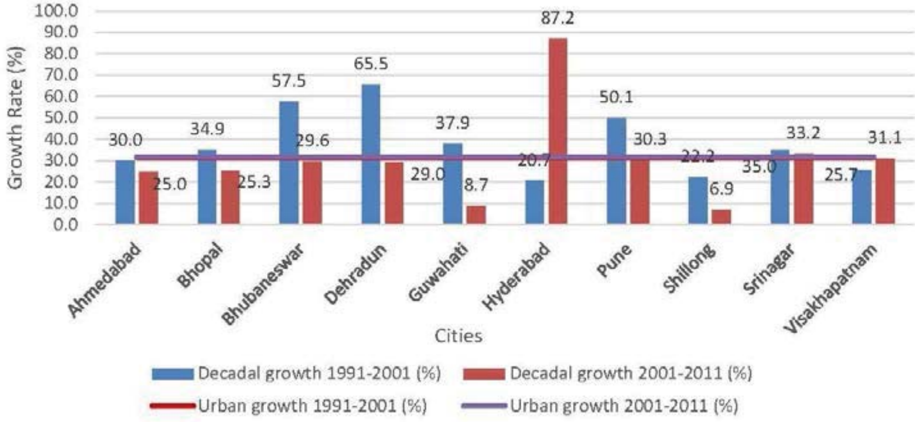


Figure 14. Decadal Growth: Cities & Urban Population (1991-2011)

The slum population in India has increased during 2001-11 (Fig. 15). Three types of slums have been defined in the Census 2011, namely, Notified, Recognized, and Identified. The census reports slum population of 65.49 million, including the slum population from the Notified, Recognized, and Identified slum pockets, with the total number of towns reporting slums being 2613. The highest slum population is recorded in the Identified slums (22.82 million).

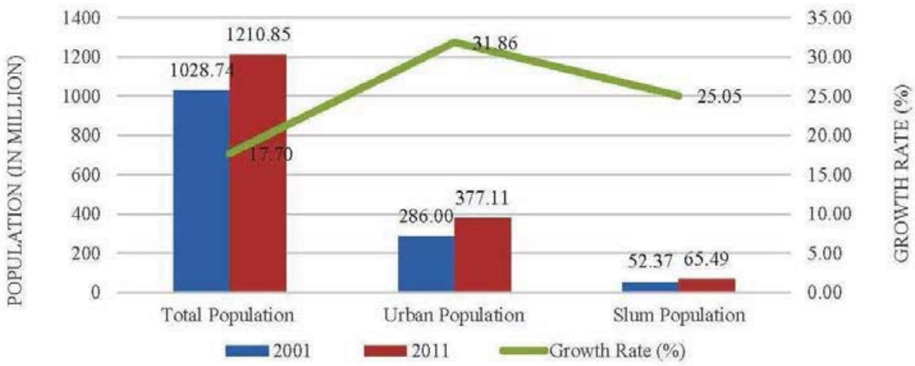


Figure 15. Comparison of urban and slum growth rates.

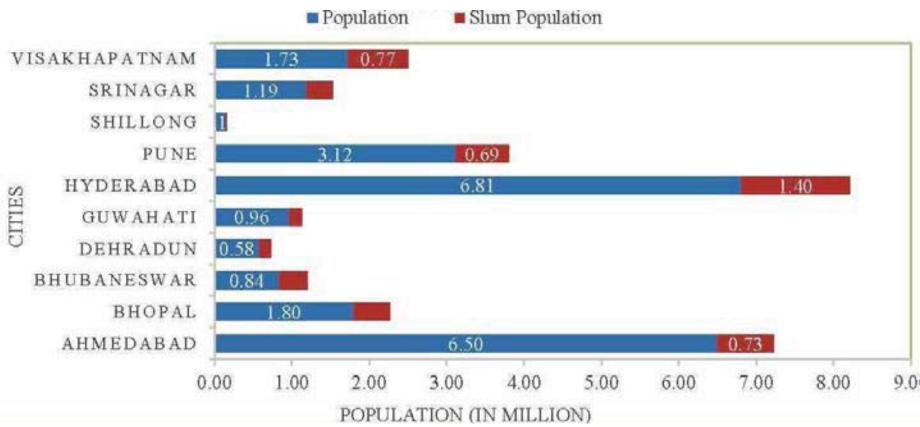


Figure 16. Comparative city and slum populations.

In India the population growth of the cities and slum expansions are co-related and play an important role in determining the vulnerability levels of cities towards the hazards. The slum population in India has increased during 2001-11, and nearly 17.34% of the urban population lives in the slums and slum-like conditions in India.

Rapid urbanization, industrialization, and the negative consequences of urban pull results in the upcoming of slums and have resulted in the metropolitan cities being more prone to conditions which can turn a hazard into a disaster. In absence of basic facilities, the slum population is the most vulnerable group at the time of a disaster.

Bhubaneshwar and Vishakhapatnam have the highest share of slum population to the total population of the cities (44% and 45%, respectively), whereas Bhopal (27%), Dehradun (26%), and Srinagar (29%) are not far behind (Fig. 16). The slums are usually located at low lying areas, with a housing shortage and critical inadequacies in public utilities, overcrowding, unhygienic conditions, etc. According to a report submitted by a technical committee to the Ministry of Housing and Urban Poverty Alleviation (MHUPA), India's urban housing shortage is estimated at nearly 18.78 million households in 2012 [23].

3.4 Urban Infrastructure

Urban Infrastructure and services serve as the basic foundation for city's economic, social, cultural, and environmental dynamics. The urban infrastructure provides a backbone for the functioning of a city and the cities preparedness towards disaster resilience is directly dependent on the present status of the physical infrastructure and services provided. However, the existing urban infrastructure is in a relatively poor state (especially in non-metropolitan cities) and various central and state government schemes have been adopted over the time to produce only the basic services.

The infrastructure and services that have been studied in detail against the MUD benchmarks, Service level Benchmarks (SLBs) are water supply, sewerage, solid waste management, and storm water drainage facilities within the selected cities. The benchmark encompasses 28 indicators (Table 7) reflecting multiple facets of service delivery performances [24].

Table 7. Indicators of water supply, sewage and solid waste management, and storm water drainage [24].

	Indicator	National Benchmark
	Water supply	
1	Coverage of Water Supply Connections	100%
2	Per capita availability of water at consumer end	135 lpcd
3	Extent of metering of water connections	100%
4	Extent of non-revenue water	20%
5	Continuity of Water Supply	24*7
6	Adequacy of Treatment and Disinfection and Quality of water supplied	100%
7	Efficiency in redressed of customer complaints	80%
8	Cost recovery in water supply services	100%
9	Efficiency in collection of water supply related charges	90%
	Sewage management	
1	Coverage of Toilets	100%
2	Coverage of Waste sewerage Network Services	100%
3	Collection Efficiency of Waste Water Network	100%
4	Adequacy of waste water treatment Capacity	100%
5	Quality of sewage Treatment	100%
6	Extent of reuse and recycling of sewage	20%
7	Efficiency in redressed of customer complaints	80%
8	Extent of cost recovery in sewage management	100%
9	Efficiency in collection of sewerage charges	90%
	Solid waste management	
1	Household level coverage of Solid Waste management services	100%
2	Efficiency of collection of municipal solid waste	100%
3	Extent of segregation of municipal solid waste	100%
4	Extent of Municipal solid waste recovered/recycled	80%
5	Extent of scientific disposal of municipal solid waste	100%
6	Efficiency in redressed of customer complaints	80%
7	Extent of cost recovery in solid waste management services	100%
8	Efficiency in collection of SWM charges	90%
	Storm water drainage	
1	Coverage of Storm Water Drainage Network	100%
2	Incidence of water logging/flooding	0%

3.4.1 Water Supply

The census of 2011 indicates that nearly 70% of the urban households have access to tap water, out of which 62% have access to the treated tap water. Thus, nearly 40% of urban households have no access to public water supply, and have to depend on other sources of water [25]. Moreover, not all households that have access to public supply have access to it within the premise, because only 49% of the households have access to piped water supply within their premises. Comparing the censuses 2001 and 2011, one can see that nearly 18 million additional households have obtained access to tap water, whereas the overall share across different water sources appears to have changed only marginally.

In 1951, the per capita water availability of portable water was about 5177 m^3. This has now been reduced to about 1545 m^3 in 2011 [26] and according to WRI India, almost 54% of India is facing high to extreme water stressed condition and more than 100 million people in India live in areas of poor water quality [27]. The problem has been compounded with increased concretization due to urban development that has choked ground water resources. Water is neither being recharged nor stored in ways that optimizes its use while retaining the natural ingredients of water.

In terms of the per capita water supply, most of the cities exceed the benchmark (SLB) set by MUD of 135 lpcd. However, the water received at consumer end is lower in many cities due to huge distribution losses; for instance in Bhubaneswar, per capita supply is 218 lpcd with 62% loss in distribution. Guwahati and Hyderabad are the other two cities with more than 30% distribution losses. Ahmedabad and Vishakhapatnam have more efficient networks with only 23% distribution losses (Figs. 17,18).

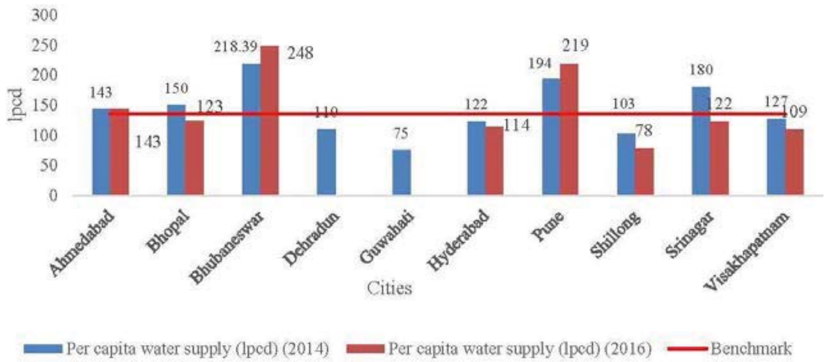


Figure 17. Per capita water supply of cities considered and comparison with the benchmark.

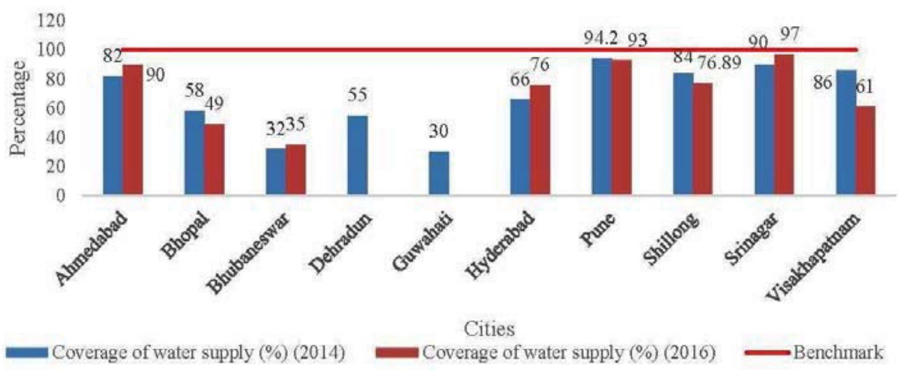


Figure 18. Coverage of water supply and comparison with the benchmark.

The 2016 [28] data indicates that the cities like Bhubaneshwar and Pune which were already providing water above the benchmark set at 135 lpcd have been successful to increase the per capita water supply to 248 lpcd and 219 lpcd, respectively. However, other cities have not shown any positive rise in the figures and their per capita water supply has decreased over the years.

While most of the cities have more than 80% coverage of water supply, against 100% benchmark set by MUD, the cities like Bhubaneswar and Guwahati have only 32% and 30% coverage, respectively. The coverage area has increased in the cities of Ahmedabad, Bhubaneshwar, Hyderabad, and Srinagar.

Metering of water supply is almost inadequate in all the cities and almost no city in India provides 24-hour water supply, with 4-5 hours being the norm [29]. The SLB data indicate that the duration of supply is only 2–3 hours on the average.

3.4.2 Sewage and Sanitation

As per the census of 2011, at the country level there is no drainage facility in 48.9% of the households, while 33% of the households have only open drainage systems [30]. According to a latest statement [31], only 3 Indian states meet their demand for sewerage treatment. The national average for waste treatment capacity as a proportion of sewage generated in urban India is around 38% (Fig. 19).

The National Family Health Survey-3 (2005-2006) reported that 52.8% of the households in urban areas have "improved sanitation", which means that their flush or pour toilet latrine are connected to piped sewer or septic or other systems, while 41% of the households still have no latrine within household premises, with 24.2% of them depending on public latrine and other 16.8% practicing open defecation. The bulk of the sewage treatment capacity exists in the metropolitan cities, with 40% of wastewater generation. The cities of Delhi and Mumbai generate some 17% of all the sewage in the country [32].

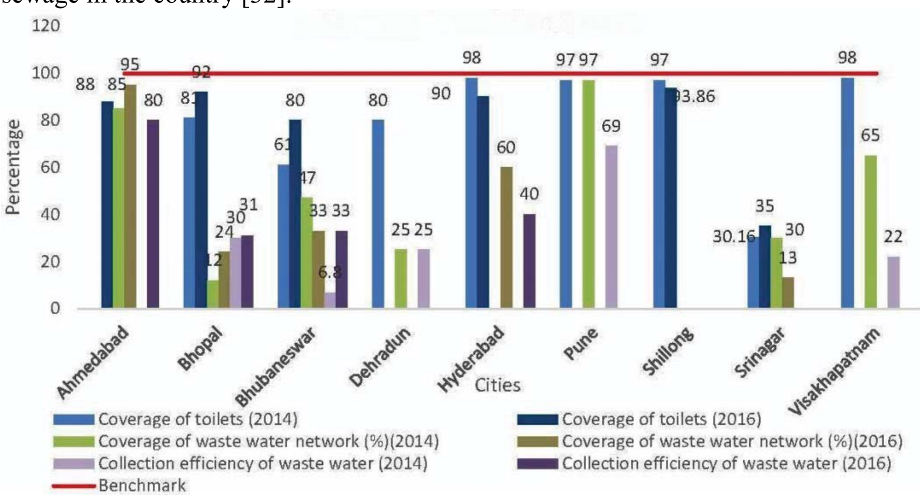


Figure 19. Sewage and sanitation status of cities for 2014 and 2016 and comparison with the benchmark.

In refernece to the coverage of toilets at household or community levels, Fig 19 shows that almost all the cities have tried to achive a target of 80% and above, expect for Sinagar (30.18% & 35%). None of the cities have been able to achive the SLBs of 100% in any af the categories. The cities have over the years not been able to achieve their targets of efficiently collecting the waste water and are only 30-40 effecient. However, Ahmedabad has shown improvements in sectors in achiving over 80% effciency.

3.4.3 Storm Water Drainage

In the today's urban Indian where water logging has become a frequent disaster, there is no city which has 100% coverage of storm water drainage. Urban storm water management is an important aspect of any urban area development, planning, and expansion. Urbanization of an area invariably leads to an increase in overall imperviousness of the area. When land becomes impervious, storm water stagnates on the surface and affects the infrastructure, transportation, and causes inconvenience to general populace. One way to minimize these effects is to provide a proper storm drainage system [33].

In 2010-2011 MUD surveyed 13 states for storm water drains and found that the coverage was below 50%, requiring an "immediate action for improvement" in 56 of 104 cities and in 745 of 1,383 urban areas that responded [34] (Fig. 20). Storm water drains which are designed to address high rainfall concentrations in a short period of time face clogging with garbage and sewage. In half of the 1,383 cities/towns that responded to the survey, the storm water drainage coverage was below 50% and in 1,142 it was below 75%. Odisha, Kerala, and Chhattisgarh were the worst among the states. Among the better ones, relatively speaking, were Maharashtra, Rajasthan, and Andhra Pradesh.

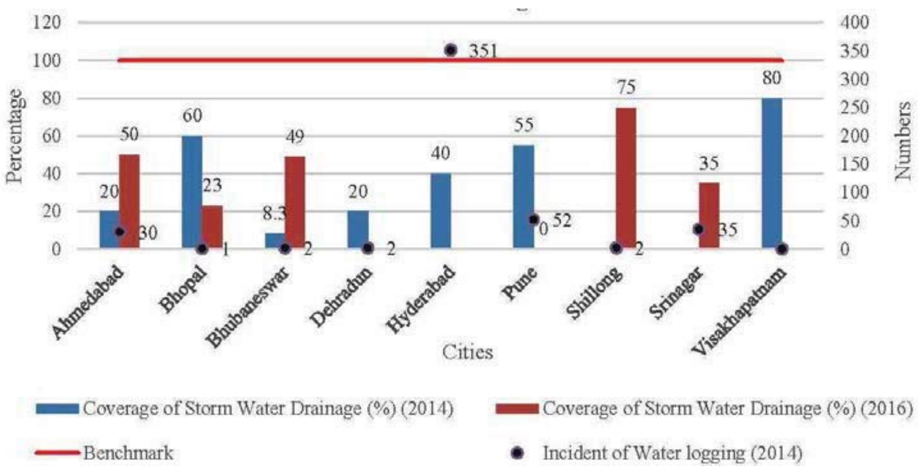


Figure 20. Storm water drainage status, 2014 and 1016, of cities and comparison with the benchmark.

Ahmedabad and Hyderabad being million plus cities need immediate attention as they are far behind in managing storm water, with Hyderabad recording as high as 351 incidences of water logging in the past decade. Storm water retrofit designs are required to overcome water logging and flooding situations and to achieve successful groundwater recharge.

Bhubaneswar and Dehradun at 8.3% and 20%, respectively, have the least network reach. However, in 2016 the cities of Bhubaneshwar and Ahmedabad have shown improvements with the storm water drainage coverage increasing to 49% and 50%, respectively. The cities like Guwahati, Shillong, and Srinagar were unable to provide optimal data for storm water managements for the year 2014. However, the 2016 data reveals that almost 75% of Shillong has a storm water drainage cover.

3.4.4 Solid Waste Management

Solid waste Management is defined as discarded solid fractions, generated from domestic units, trade centers, commercial establishments, industries and agriculture, institutes, public services and mining activities [35]. Urban areas in India generate more than 1,000,000 MT of waste per day [36].

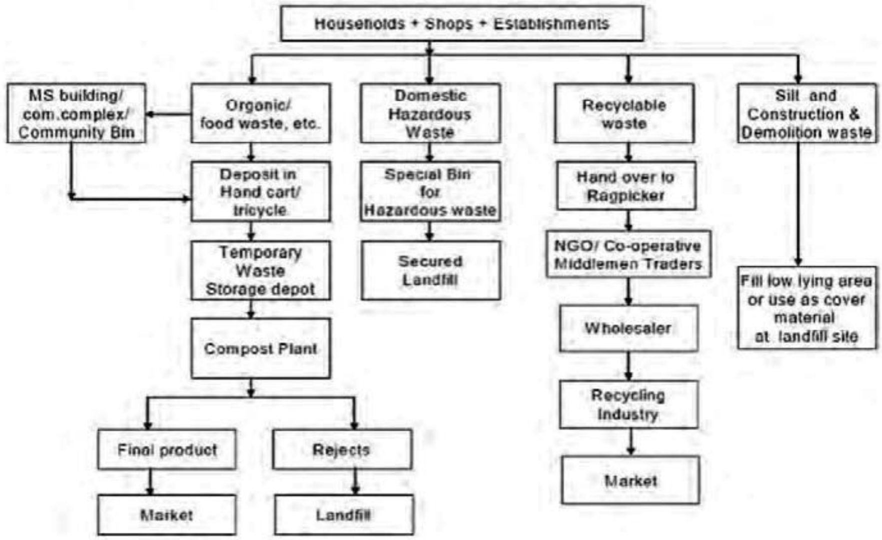
The Solid waste Management (SWM) system includes collection, segregation, transportation, processing, and disposal of waste, and is the responsibility of the urban local bodies in India (Fig. 21). The Municipal Solid Waste (management and handling) Rules of 2000 are applicable to all ULBs in India, and the appropriate systems and infrastructure facilities are required to undertake the enforcement of these rules. However, the ULBs are unable to provide the required services owing to technical, managerial, and financial deficiencies along with the lack of engagements from private sectors and local NGOs.

Large cities like Ahmedabad and Pune generate waste in the range of 1600-3500 MT per day [37]. The coverage of solid waste collection is almost 100% for Ahmedabad, whereas Pune shows 100% efficiency in the collection. The cities also show the above average efficiency in the collection of waste. The segregation of the waste collected at source is, however, plagued with insufficient data and appears absent in most of the cities.

3.5 Disaster Preparedness and Mitigation Strategies

The super cyclone in Orissa in October 1999 and the Bhuj earthquake in Gujarat in January 2001 underscored the need to adopt a multi-dimensional endeavor involving diverse scientific, engineering, financial, and social processes, or the need to adopt multidisciplinary and multi sectoral approaches and incorporation of risk reduction in the developmental plans and strategies [38].

During the last decades the natural disasters have killed some 70,000 people every decade, where 88% of all deaths occurred from the disasters. Similarly, the unnatural disasters have killed some 90,000 people during each decade. Nearly two-thirds of the people perished in these disasters are from the developing countries like India, with only 4% of the casualties being reported from highly developed countries [39].



Source: Cited in (Kurien, 2002) from (Supreme Court Committee Report, 1999)

Figure 21. National plan for municipal waste management of India.

In the implementation of various policy frameworks, the central and state governments, communities, urban local bodies, and media must play a key role in producing safer cities, and for reducing the vulnerability the rapid professional response to disasters, mitigation, and preparedness measures must work simultaneously.

Disaster preparedness needs to address planning and preparing the strategy to tackle and mitigate disasters in a responsible and effective manner. Almost all the cities being considered have established disaster response systems and management teams, within their existing governance and city institutional frameworks (Fig. 22). However, Bhopal remains highly vulnerable due to the unavailability of the proper governance for disaster response and management.

Cities like Dehradun has adopted optimal adaptation strategies through mock drills, capacity building of the officials, database updating, early warning and rehabilitation of the community pre- and post-disasters. Building codes have been provided to all cities for the current and future constructions, but the cities have not been able to implement these codes extensively as a part of mitigation for disasters.

3.6. Land Use and Hazard Vulnerability Assessment Using GIS Tool

Land use and urban planning are widely recognized as key non-structural risk mitigation measures with the potential to avoid exposure in the most hazardous zones and to decrease overtime exposure and vulnerability in already urbanized areas (UNISDR). The land use plans provide relevant information about the environmental features that include natural hazards and the areas that can be developed.

Land use and hazard vulnerability of each of the 10 cities were assessed to develop Integrated Land-Use-Vulnerability maps, which indicate precise locations of sites where people, the natural environment or property are at risk due to a potentially catastrophic events that could result in death, injury, pollution, or other problems. Figure 23 shows four examples of such integrated land use and hazard assessment maps for the cities of Srinagar, Bhopal, Shillong, and Ahmedabad.

Variables	Ahmedabad	Bhopal	Bhubaneswar	Dehradun	Guwahati	Hyderabad	Pune	Shillong	Srinagar	Visakhapatnam
Adaptation Strategies in the cities										
Prevention(preparedness drills/mock drills, regular training)		H		L	L	L	L	L	L	M
Human Resource-trained workforce for community interaction, community awareness initiative etc	L	H	L	L	L	M	L	L	L	M
Early warning system and rehabilitation	M	H	L	L	L	L	L	H	L	M
Updated previous disaster database	L	H	M	L	M	M	M	M	L	M
Mitigation Actions by Category										
Emergency Services- like dedicated control room for information dispensation and coordination and Necessary equipments in place and functioning	L	H	L	L	L	L	L	L	L	L
Natural Resource Protection				M	M			M	M	M
Building codes for current and future construction	L	H	L	L	L	L	L	L	L	H

Figure 22. Disaster preparedness and mitigation status of cities.

These maps can help planners and decision makers find appropriate strategies for risk reduction and mitigation, and build upon a robust knowledge base on different components of the risk function (hazards, exposure, vulnerability, resilience). These integrated maps can provide information that can lead to a reduction of disaster impact through safety and environmentally conscious land use management. Local authorities and planners can use the information to complement and improve their land use policies and practices and consider the vulnerability of areas such as coastal zones or locations with high numbers of residents.

4. Conclusions and Recommendations

The results from the analysis show that the cities like Srinagar, Ahmedabad, and Guwahati are among the most vulnerable, where Ahmedabad remains vulnerable to urban floods, heat waves and drought occurrences, Guwahati and Srinagar remain vulnerable to earthquakes, cyclones, and landslides. The natural hazards such as flood, drought, extreme temperature, storm surge, and cyclone already impact these cities and this impact will be further exacerbated by the climate change variability.

4.1 Disaster Risk Reduction (DRR)

The cost of ignoring disaster risks on long-term growth and development are substantial like the recent floods in Chennai, which reportedly caused $3 billion loss to the Indian economy. Therefore, the Disaster Risk Reduction (DRR) should be made an integral part of master/development plans.

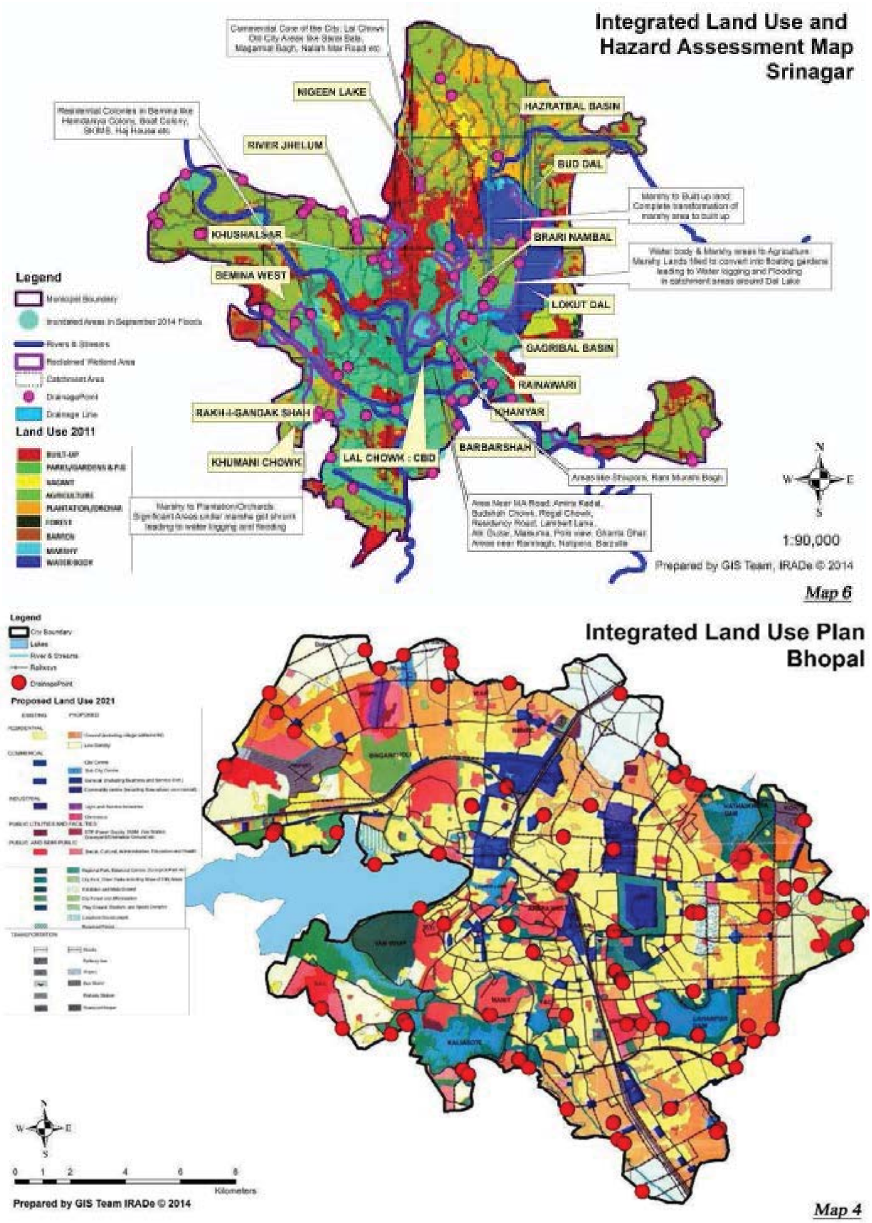


Figure 23. Integrated land use and hazard assessment maps for Srinagar and Bhopal.

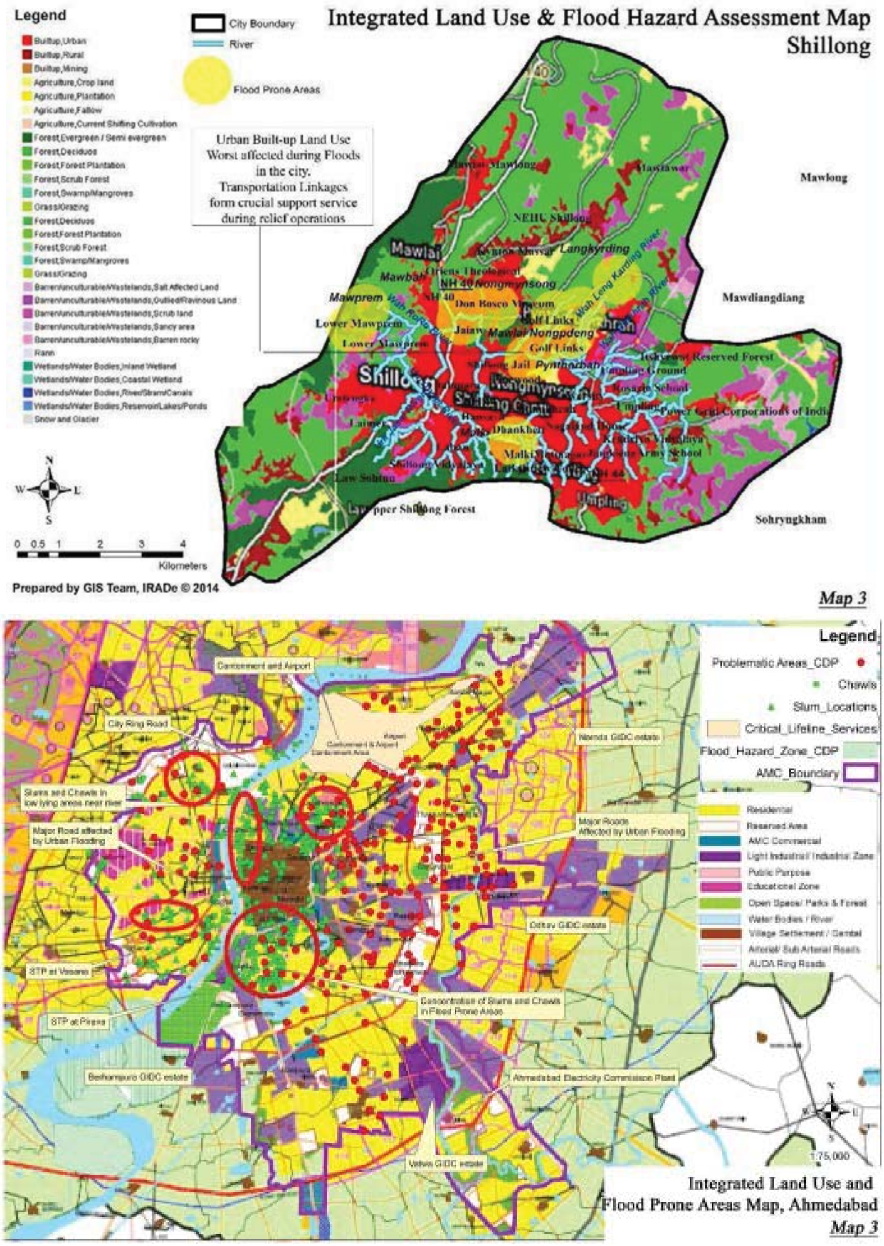


Figure 23 (continued). Integrated land use and hazard assessment maps for Shillong and Ahmedabad.

Using the GIS-assisted spatial analysis, the vulnerability assessment of a city that employs the hazard maps can be used as planning instruments for building the disaster resilience of the city. Vulnerability maps allow for improved communications about risks and what is threatened. They allow for better visual presentations and understanding of the risks and vulnerabilities. Vulnerability maps can be of use in all phases of disaster management: Prevention, mitigation, preparedness, operations, relief, recovery, and lessons learned

The Sendai Framework[3] [40] requires that the cities work towards reducing disaster mortality, socio-economic losses due to disasters, damage to critical infrastructure and basic services, and increase the access to the multi-hazard early warning systems and disaster risk information and assessments.

The use of indigenous knowledge, alongside the scientific knowledge, is being increasingly advocated to reduce the community vulnerability to environmental hazards [41], and a framework is required on how to identify this knowledge and integrate it to reduce the vulnerability of communities to these hazards. Using the GIS-assisted spatial analysis, the land use and hazard assessment maps can be used as planning instruments for building the disaster resilience of cities.

Reducing disaster risk and promoting a culture of disaster resilience requires knowledge of the hazards and physical, social, economic, and environmental vulnerabilities to disasters that most societies face, and of the ways in which the hazards and vulnerabilities are changing in the short- and long-term bases. The disasters can be substantially reduced if people are well-informed and motivated towards a culture of disaster prevention and resilience, which in turn requires the collection, compilation, and dissemination of relevant knowledge and information on hazards, vulnerabilities, and capacities [42].

4.2 Database Management

In Indian cities, the lack of reliable data often results in little/partial action towards establishing disaster resilience and mitigation plans. A database of history and management capacity needs to be maintained for all the disasters which may help in planning for future developments. Such a database can provide inundation information about the onset, duration, and passing of a hazardous event, which is critical for land-use planning, mapping evacuation routes, and for locating suitable emergency shelters.

City Disaster Management Plans (CDMPs) need to be prepared for cities like Bhopal and Hyderabad, which will not only provide the past data and information on the disasters in the city, but also a platform for a better governance and optimum available resource utilization. Efforts need to be made to incorporate risk and vulnerability assessment data into the National Urban Information System (NUIS) of Ministry of Urban Development to make this information accessible to all. The data available can easily be accessed by all government agencies and can be verified and updated on regular intervals.

[3]The Sendai Framework was adopted by UN Member States on 18 March 2015 at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan. This framework requires substantial reduction of disaster risk and losses in lives, livelihoods and health, and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries.

A team can be set up within the Municipal and Development Authority of the city for the collection and updating of such data at every stage of the crisis before, during, and after its occurrence. New application software can be incorporated to support the value-added data and information requirements for the disaster management unit and coordinator of disaster and relief.

4.3 Natural Resources Management Through Macro and Regional Planning

The cities are characterized by various natural resources which include water bodies, wetlands, forests, and rich biodiversity, and for sustainable use of these resources the city governments need to understand the types of resources available within a region, quality, and quantity, and how to manage them for a long time period.

The cities like Shillong, which had rich natural resources and biodiversity, a Natural Resource Plan can be drawn for the city that can not only upgrade the human index of the city but also make it resilient to disasters. A comprehensive plan can be drawn for the city for managing the natural resources of the city.

While the government schemes like JNNURM, Smart City Mission, and AMRUT deal with city level infrastructure and service development, the city level natural resource management and regional plans can make the city well-informed about the hazards. Such plans can serve as guides to government agencies, local government bodies, NGOs, businesses, and communities for timely actions for mitigating the effects of climate change and other hazards.

4.4 Governance and Institutional Framework

Urban local bodies, government organizations, and institutions play important roles in the disaster risk management, and the structures of individual institutions need to adapt to be able to pursue the disaster risk reduction more effectively. Policies and operational programes alike must be supported by the appropriate organizational structures, systems, and attitudes.

The ULBs need to develop financial independence and self-sustainability to achieve disaster resilience, and enhance the taxes at irregular intervals causing incontinence among the public. As the governance structure is multi-layered with overlaps and duplication of functions, there is a need for the well-coordinated disaster response system in the city among various departments.

Figure 24 illustrates the status of a governance and institutional framework in the cities and Fig. 25 the investment and intervention required to improve urban services.

The city like Bhopal is highly vulnerable because it lacks disaster resilience. The urban local body needs to assign responsibilities to update the disaster data with loss figures (impact), and the city has an urgent need to integrate disaster resilience into the Development Plans to increase the investment utilization efficiency and make the city more disaster resilient along with development. The city administration is also required to take different convergence programs with other departments and make them aware of the hazard proneness of the city.

As the governance structure is multilayered with overlaps and duplications of functions there is a need of a well-coordinated disaster response system in the city of Vishakhapatnam, among various departments. An integrated project management covering disaster resilience, adaptation, environment, and sustainability is highly recommended as the city is being upgraded on all fronts.

Figure 24. Governance and institutional framework of cities.

Variables	Ahmedabad	Bhopal	Bhubaneswar	Dehradun	Guwahati	Hyderabad	Pune	Shillong	Srinagar	Visakhapatnam
Governance and Institutional Framework										
Disaster response system	L	H	L	L	L	M	L	L	L	M
City Disaster Management department	L	H	L	M	L	M	L	L	M	H
Dedicated persons to handle and update Disaster Risk Reduction (DRR) data	L	H	L	H	M	M	M	M	M	M
DRR in urban planning	L	H	L	M	M	M	M	M	H	M
Top down approach or Bottom up approach	M	H	L	L	L	L	L	L	L	M

Figure 25. Investment and intervention required to improve urban services of cities considered.

For a strong institutional framework, the cities' Municipal Authorities, Development Authorities, and State Disaster Management Authorities are required to work in close collaboration. Efforts are required to strengthen the "institutional machinery" needed to ensure appropriate individual structures, mandates, roles and responsibilities, and encourage the communities to become more resilient to the hazards that threaten their development gains.

4.4 Technical Capacity at Urban Local Body Level (ULBs)

According to the United Nations International Strategy for Disaster Reduction (UNISDR) definition, the "c*apacity is the combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk or the effects of a disaster*". The capacity building is integral to disaster management, and the programs in disaster mitigation and recovery cannot be successful without building adequate capacities. Although the focus on capacity building has revived with the new vision on disaster management, the efforts towards building capacities have not been very systematic.

The city of Guwahati can strengthen its resilience by having a better financial health. The financial capacity of the ULBs should be strengthened through the capacity building programs for the ULB staff. The capacity building is required to efficiently track meteorological patterns, forecast impacts, and assess risks in order to make decisions and provide timely information. The City Disaster Management capacity also needs to be strengthened. The cities can build capacities at the grassroots level stakeholders in disaster management, and follow a comprehensive and scientific approach to achieve its goals. The capacity for monitoring and forecasting climate change can significantly affect the disaster response management[4].

4.5 Robust Infrastructure

The physical infrastructure development of a city should have a strong transportation system, water supply, sanitation, and power infrastructure with optimum physical resilience. Most of the Indian cities have inadequate and inefficient infrastructure. Storm water drains/water bodies encroached by garbage had resulted in water logging and flooding, and the unregulated development over catchment areas has led to obstructions of natural flows of streams. Storm water drainage systems and sewage managements can be improved by increasing the service capacities and delivery efficiencies. The cities are required to reconsider their urban designs and reinforce building construction codes and land-use plans to reduce building in risk-prone areas and to reinforce structures so that they can be made resilient to various hazards.

As shown in Fig. 26, the existing infrastructure conditions of considered 10 cities indicate that the city of Ahmedabad lacks a proper sewerage coverage and drainage network system, and it needs to manage its green areas and water bodies so that the effluents do not accumulate and the water quality is maintained. The rain water recharge can also be made mandatory to revive the depleting ground water. Bhubaneshwar is prone to heavy rains and needs to improve its rain management systems. Other cities like Guwahati, Shillong, and Srinagar also suffer from the inadequate provisions of basic services.

The important urban infrastructure needs to function before and after the natural and anthropogenic disasters to ensure a rapid recovery, whereas some infrastructure such as emergency response teams, hospitals and waste treatment and disposal facilities are required to deal with the consequences of disasters. The substandard construction practices have to be identified, and the city authorities have to provide incentives for enforcing building codes for reducing the post-disaster cost and strive towards designing and developing more sustainable infrastructure.

[4] On June 22, 2016, the Global Covenant of Mayors for Climate & Energy, representing 639 cities and 500 million people worldwide, declared that the "Cities are the drivers of progress and innovation, and through the Compact of Mayors can help nations set new, aggressive climate targets over the next year." Michael R. Bloomberg, UN Secretary-General's Special Envoy for Cities and Climate Change.

Variables	Ahmedabad	Bhopal	Bhubaneswar	Dehradun	Guwahati	Hyderabad	Pune	Shillong	Srinagar	Visakhapatnam
Infrastructure condition (basic services)										
Water supply (lpcd)	L	L		L	M	L	L	L	M	M
Sewerage system coverage	H	L	H	L	H	L	L	H	M	M
Solid waste management system coverage	L	M	H	M	M	M	M	H	H	M
Drainage (coverage & water logging incidences)	H	M	H	L	H	M	M	L	H	M

Figure 26. Infrastructure status of cities.

4.6 Improving Socio-Economic Conditions

The urban poor are more directly exposed to natural hazards compared to the other sectors of the society and the cities face problems with urban expansions and limited infrastructure. It has been observed over the times that the slum dwellers are one of the most vulnerable and marginal part of urban population, becasue are often located in places with high hazard risk and with less or no means to reduce its impact. The slums are particularly vulnerable to flooding, often due to clogged drains, land subsidence, heat waves, and increased health risks. In the cities like Bhopal and Bhubaneswar 26-44% of the urban poor dwell in the hazard prone, river banks, low lying areas and in poor housing conditions that make them exposed to the risks of floods and heat waves. Again in the cities like Ahmedabad the water logging in the low lying slum area has given rise to water borne diseases, and it hence becomes important to relocate these urban poor to more sustainable areas with affordable housing.

4.8 Investments and Intervention Through Public Private Partnerships

UNISDR's 2013 *Global Assessment Report on Disaster Risk Reduction: From Shared Risk to Shared Value, the Business Case for Disaster Risk Reduction,* stresses on the need of private sector investment in and consideration of disaster risk. Public-private partnerships (PPPs) have become a way for governments to engage private actors in the delivery of government infrastructure and services with the aim of increasing quality and providing better value for money. The corporate sector is one of the key stakeholders for providing involvements in disaster preparedness and mitigation.

Figure 27 shows that most of the cities analyzed remain highly vulnerable to the investment and intervention to improve urban services, such as the investment in basic services, dedicated budget allocation for DRR, incentives to businesses that comply with DRR, etc. It has become increasingly important for the disaster risk management to incorporate PPP with an effective coordination so that it can be implemented by city authorities and urban local bodies for effective investments and interventions leading to disaster resilience.

Adaptive Action Plans and Mitigation Strategies are essential for efficient governance, updated disaster database, early warning, and rehabilitation systems. The disaster communication systems need to be strengthened so that in the wake of a disaster the early warning pertaining to the disaster can reach all the citizens of the city well in advance.

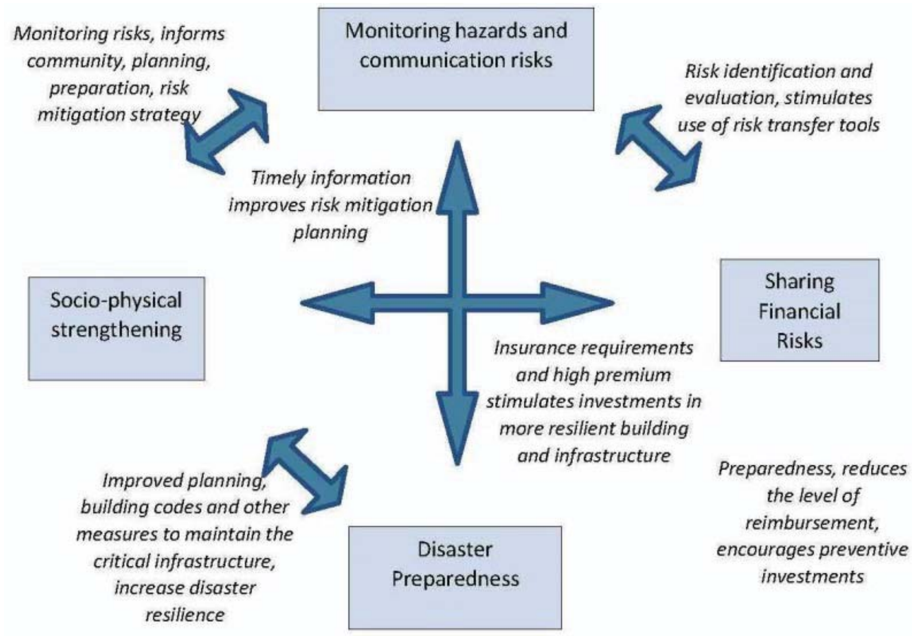


Figure 27. Virtual cycle of PPP consultation for disaster resilience. Adapted from: Dalberg Development Advisors in World Economic Forum, 2008

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Making Cities Transition Work: Searching Solutions to Urban Challenges Through Green Infrastructure and Ecosystem Services in Campinas (SP, Brazil)

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Abstract. The work reported in this paper was initially focused on identification, description, and quantification of a range of urban green infrastructure and ecosystem services in Campinas city, located in the Campinas Metropolitan Area of some three million inhabitants. However, the São Paulo state suggested the necessity of broader ecosystem integration to solve most of the challenging disaster risk reduction issues that could not be addressed by a single jurisdiction or from only one perspective. For this reason, we organized a MOVER workshop to mobilize different municipalities and spheres of São Paulo state and to focus our strategies on disaster risk reduction through a more comprehensive framework. It is important to highlight that a strategic approach based on green infrastructure is understood as an interconnected network of ecosystems that preserves natural ecosystem forms and functions, and that provides the associated benefits to disaster risk reduction. The green infrastructure perspectives apply key principles of landscape ecology, and specifically a multi-scale approach with emphasis on ecosystem connectivity. Whilst it is clear that the plurality aspect is a necessary reality to ecosystems appraisal, this provides significant challenges for local contexts due to the necessity of being comparable in terms of cost-benefits, different scales and approaches, and support of institutional agencies and policies at different levels of intervention. This work tackles this gap using the experience from five case studies that suggest different biophysical assessments to operationalize the green infrastructure based on the ecosystem service concept towards the disaster risk management.

Keywords: Green infrastructure, ecosystem service, disaster risk reduction, millennium goals, urban resilience

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1. Introduction

In the last decade, the concept of Green Infrastructure (GI) became increasingly important and prominent across the public spheres [1]. The reason is that human and natural drivers, such as urbanization, climate change, severe weather events, resource limitations, and the need of new regulatory requirements are pushing public and private sectors [2] to seek out innovative and more sustainable infrastructure solutions to address Sustainable Development Goals (SDG) and Disaster Risk Reduction (DRR) challenges in urban areas [3]. Local policy makers and practitioners from across the public, private, and civil society sectors have now recognized that we are facing increasingly urgent resource constraints [4], and that sustaining social and economic development within global limitations will require an optimization of the way we use resources and make plans [5].

As pointed out by UNISDR, UN Habitat, & European Comission [6], DRR is one of the most important challenges and priorities in urban areas, which means that we need to establish the targets to implement a broader governance process to consider both the top down and bottom up perspectives. In this context, GI is understood as a strategic approach for developing an interconnected network of green spaces, technology, and infrastructure that aim to conserve the forms and functions of natural ecosystem, and provide the associated benefits to living beings [7]. In terms of DRR initiatives, GI may not only be able to respond more quickly than the grey infrastructure, but its interventions may also be politically more acceptable by local agencies and populations involved due to the proximity of decisions, co-benefits, and the possibility of being part of the decision process [8]. In the last decades, it has become more evident that the co-benefits made the investments even more compelling, since the GI solutions demonstrate solid financial performance and is more sustainable, both economically and socially [9]. For instance, the investment in green solutions, such as landscape conservation and restoring for upstream floodplains or wetlands, is more cost-efficient and provides multiple co-benefits to the society, such as carbon sequestration, improvement of atmospheric conditions, flood prevention, and water source and reuse. Therefore, GI has provided an attractive option, as it can offer cost-efficient ways of managing the urban disaster risks [8].

In this approach we support action-oriented risk identification in order to develop urban development and disaster prevention plans through bottom up and top down perspectives, since DRR is achieved through distinct jurisdictions, agencies, civic organizations, public institutions, and private sectors. We therefore seek to generate stakeholder's motivation to identify and pursue possible synergies between different sectors, jurisdictions, and technical domains, so as to increase the local institutional performance in order to optimize resource management and ecosystem services. This motivation involves responsibility for integrating DRR activities into the planning, (re)design, construction, and operation of the built environment. We believe that searching for solutions through these prospects will become real if they are operationally feasible within the current operating services, and negotiable with the key stakeholders and users. Such prospects can be identified at different scales, given the different political articulations.

In this work we present a participatory process that was idealized through a workshop on Mobilization for Ordination and Feasibility of Resilient Urban Spaces (MOVER). The MOVER workshop approach describes a process for identifying and developing opportunities to further optimize green infrastructure and ecosystem services involving different agencies and sectors to meet basic human needs while increasing DRR measures in urban areas.

1. Background

The green infrastructure can assist people adapt to climate change due to inclusion of managing Ecosystem Services (ES) to reduce the impacts on ecosystems [10]. In decision contexts, the GI and supporting social economic services are necessary for the production of an interconnected net of ecosystem services [11]. In other words, the GI and supporting ecosystem services must be combined to meet practitioner needs [12].

The role of human actions, values, knowledge, and technology in generating services to support ecosystem services are essential. [13]. For this reason, addressing formal rules and specifically power relations in decision-making is a fundamental issue in GI implementation [14]. GI within an ecosystem is fundamental for the continuity of all necessary ecosystem services and provision of their processes such as primary production, photosynthesis, soil formation, nutrient cycling, and water cycling [11]. However, the variation in ecosystem productivity around the world is huge, because the productivity of ecosystems is highly dependent on local and regional rainfall levels and temperature regimes. For example, from a primary production standpoint, the tropical forest ecosystems are typically more productive than the forests located in boreal regions [15].

Accordingly, it is necessary to understand the GI framework and the support services chain in order to: (i) address a range of ES; (ii) assess both supply and demand of ES; (iii) assess a range of value types; (iv) reach different stakeholder groups; (v) cover weaknesses in other methods used; and (vi) meet specific decision context needs [16].

The role of human interventions in ecosystem services delivery is increasingly being acknowledged as a part of the effort to improve the management of social–ecological systems towards sustainability [17]. In the perspective of GI, we assume that ecosystem services are jointly produced by social–ecological processes and, at their base, they require ecosystems management [12]. It becomes clear more and more of the necessity to emphasize the role that local organizations can play in DRR through the incorporation of ecological prevention measures into the long-term development plans based on Sustainable Development Goals (SDG) [18]. The collaborative disaster risk governance framework can ensure better collaborations between governments, the private sector, civil society, academia, and communities at risks [19]. To make coherent policies and strategies the policymakers need a rubric for thinking systematically about the DRR interactions [20].

We also assumed that the GI concept is becoming recognized in policy planning processes since investing into GI makes sound economic sense, a way of managing the natural capital [9]. Undoubtedly, the spatial planning is an important tool for DRR through GI implementation, as it presents an opportunity to regulate the long-term use of space through which the exposure to natural hazards and human-induced threats can be minimized [20]. GI represents an attractive option, as it can offer cost-efficient ways of tackling DRR [9]. GI promotes dynamic solutions that often provide multiple co-benefits to society, such as pollution reduction, carbon sequestration, flood retraction, and drought prevention. [21].

In terms of DRR initiatives, the local mechanisms may not only be able to respond more quickly than the national ones, but their intervention may also be politically more acceptable by local agencies and by the population involved due to the proximity of decisions and the possibility of being part of the decision process [9]. In this context, the important programs should be addressed to build areas using legal and formal mechanisms which provide a significant reduction of disasters [22].

2. Methodology

The study area is located in the Campinas Metropolitan Area (CMA), 90 km from São Paulo Metropolitan Area that is the largest metropolitan area in Brazil with 21,090,791 inhabitants. The CMA comprises 20 municipalities with a population of 3,168,019 people distributed in 3,791.79 km^2, which translates to a population density of 835.49 inhabitants/km^2. This metropolitan area is experiencing rapid economic growth driven by service sector and technological advancement, which a gross domestic product (GDP) of around US$50 billion in 2017.

The operationalization of the concepts of DRR and GI through landscape governance was achieved through lectures of invited researchers, specialists, and stakeholders. In this case, we consider the experience of five municipalities and not only of the municipality of Campinas. We reported the practitioners' perspectives on the practical implementation of the DRR concept in 5 case studies.

The approach was developed as a "how-to" framework based on over five concrete urban and metropolitan examples of São Paulo state (i.e. São Paulo, Campinas, São Jose dos Campos, Santo Andre, and Sorocaba) of offering real entry points for urban integration. In this case, the five concrete events considered were: Flood, landslide, rain on the top of mountain (upright), dam disruption due to heavy rain, disruption of creeks due to excessive flow of the main basin river.

For the first prospection, we considered five urban typologies addressed to the municipal disaster risk conditions (i.e. accelerated urban expansion, irregular and illegal occupation, presence of slums or dwellers, lack of sewage and garbage collection, inadequate drainage system) and the institutional arrangements (i.e. municipalities, civil defense, universities, private and public sectors) in order to promote an integrated disaster risk perception. To make this operation feasible we used local maps, questionnaires, and promoted site visits for distinct working groups. Through the development of a comprehensive concept of visual basins we surveyed different types of green infrastructure in urban settings varying from larger public parks, urban woodlands, green fields, and rural landscapes.

The MOVER workshop was designed for the purposes of identifying and understanding current and future risks, stress, shocks, and exposure threats to both human and physical assets. The analysis did not involve an exhaustive risk assessment, but rather a multi-stakeholder engagement process to establish a common understanding. Taking into account the actions or corrective measures already undertaken, the analysis produced a dashboard-style risk assessment of the hazards and risks to human and physical assets in order to identify possible solutions and opportunities to the specified locations.

The MOVER workshop was organized in four main sections. We first provided background information on the methods and case studies. We then invited researchers and stakeholders to present their experiences showing which factors would be important to GI implementation to achieve DRR across each of their works and which features of the decisions would help to characterize their strengths and limitations. We then described how the decision framework can be designed and tested in an interactive group of experts and multidisciplinary teams building together on the decisions. Finally, we discussed the pros and cons of using the decision framework for aiding the selection of GI alternatives to achieve DRR proposals, compared this approach with other possible formats for providing similar guidance, and illustrated how different forms of guidance might work together to better cover different user demands.

3. Results

To a large extent the impact of disasters was attributed to intensive urban expansion and agricultural activities that may encompass the suppression of remaining vegetation such as legal conservation areas and springs, which has been leading the government to change its position.

More than half of the working groups reported a necessary change in action (e.g. management or policy change), and a further 50% anticipated that a change would result from collaborations. In this sense, the urban green spaces are essential for well-functioning of cities and for prevention of environmental risks and hazardous because they: (1) contribute to the avoidance of environmental disasters (e.g. flood and drought); (2) contribute to the balance of technical solutions related to infrastructure problems (e.g. water supply, drainage system, between other); (3) play an important role for nutrient cycling and absorption of greenhouse gases; (4) contribute to the conservation of biodiversity of the Atlantic Forest biome, responsible for the source of natural resources and water from springs in São Paulo state.

The limitations and barriers were mostly pointed to and have highlighted the crucial role of communication, participation, and collaboration across different stakeholders, to implement the GI concept and enhance the democratization of nature and landscape planning. In this sense, a regulatory framework base on the benefits of GI is necessary, which includes procedures, regulations, guidelines, codes of conduct, and other regulatory documents. Such a framework would produce the basic structure that gives focus and support to the DRR that municipalities are trying to solve.

4. Conclusions

A comprehensive guidance for the selection of appropriate infrastructure with inclusion of managing ecosystem services assessment to disaster risk reduction that address the requirements of different decision-making contexts is lacking. The survey of the reasons why the working groups emphasized particular solutions revealed that stakeholder-oriented alternatives (i.e. citizens and stakeholder participation, inclusion of local knowledge and ease of communication, and green infrastructure implementation) were key considerations. In addition, the available maps, data, technology, and expertise were also considered important factors.

There is a growing pool of stakeholders and practitioners working on how to include green infrastructure and support services in policy and disaster risk reduction management decisions aimed at different sectors, but an integrative framework is needed for guiding the process for an adaptive management plan since it can help structure and rationalize the selection of alternatives addressing a broader range of user needs. In other words, a guidance is essential to help the practitioners who are new to the green infrastructure assessment select and test relevant approaches that take account of user needs and constraints.

5. Acknowledgement

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Damage Assessment of Different Ancient Masonry Churches by the Smeared Crack Approach and the Non-Smooth Contact Dynamics Method

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Abstract. A numerical dynamic analysis was employed for studying seismic vulnerability of different masonry churches severely damaged by the Central Italy seismic sequence of 2016. The dynamic properties and the vulnerability have been evaluated using both a continuous approach, where the nonlinear behavior of masonry has been considered by proper constitutive assumptions, and a discontinuous approach, where the sliding motions are governed by the Signorini's impenetrability condition and by the Coulomb's law of dry friction. Advanced numerical analyses can offer significant information on the understanding of the actual structural behavior of historic structures, and the methodology and the conclusions of case studies suggest that these methods are applicable to a wide variety of historic masonry structures in Europe.

Keywords: Churches, damage assessment, Non-Smooth Contact Dynamics Method, Smeared Crack Method

1. Introduction

The conservation and restoration of ancient buildings of cultural heritage, and preservation of their main architectural features, are becoming a significant issue in Europe. This is especially true in Italy, which hosts the largest number of monumental churches, monasteries, and towers in the world, and where some earthquakes during the last few decades (Umbria-Marche 1997–1998, Abruzzo 2009, Emilia-Romagna 2012, Marche-Lazio-Umbria-Abruzzo 2016) severely damaged a number of unique pieces of this architectural heritage.

The vulnerability assessment of historical constructions against seismic actions is the necessary prerequisite for their continuous protection, and is of strategic importance considering the richness of the European and Italian architectural heritage. Most historical constructions are masonry structures that were not conceived to resist

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lateral forces, since the old design concepts mostly focused on the effects of gravity loads and did not provide adequate lateral resistance and ductility. Furthermore, many historical and architectural structures are currently used with different functions, such as residential areas, offices, museums and headquarters of critical civil activities. In particular, when the building has a strategic function during calamitous events, it has to guarantee safety to host the headquarters of rescue teams and function as a safe place for the short-term hosting of people who lost their houses. Hence, the buildings of cultural heritage require a high level of safety against both vertical and horizontal loads.

Masonry constructions are typically complex structures and there is a lack of knowledge concerning the behaviour of their structural systems, particularly about their seismic response. Typically, these structures are more massive than the ones of today and they usually carry their actions primarily in compression. Successful modelling of a historical masonry structure is a prerequisite for a reliable earthquake-resistant design or risk assessment. For modern structures with new industrial materials (reinforced concrete, steel, etc.), the development of reliable mathematical models is possible, since the materials and structural elements are more uniform and sufficiently well-known [1, 2]. Conversely, the seismic behaviour of old masonry structures is particularly difficult to be examined. It depends on many factors, such as material properties, geometry of the structure, stiffness of the floors (diaphragm effect), and connections between orthogonal walls and structural and non-structural elements [3, 4].

One key consideration is the material behaviour modelling. Masonry is a composite material obtained by joining natural or artificial bricks by means of mortar layers and its nonuniformity is due to the variability of both components, mortar and bricks, that can vary significantly from place to place due to different local construction technologies. Consequently, the stiffness and resistance of masonry have a great dispersion and is often useful to characterise this material of ancient constructions by means of average values suitable for use in codes or manuals.

Furthermore, in addition to the heterogeneous nature of masonry, also its nonlinear response, that is often triggered at low deformation levels, is a challenge for structural engineering, both from a scientific and from a professional point of view. Indeed, the formulation of models for reproducing the complex nonlinear mechanical behaviour of the masonry is an active research field. Experience shows that the masonry mechanical behaviour is dominated by the nonlinear phase, characterised by cracks opening and dissipative and brittle behaviour with a softening branch. For this purpose nonlinear anisotropic constitutive laws are required whose behaviour is markedly different in tension and compression. Much focus is currently given to the formulation of nonlinear constitutive relationships for masonry and a large number of models are now available [5].

The most natural approach for describing the mechanical behaviour of masonry structural elements is the adoption of continuous material models because in this framework a wide variety of continuous 2D and 3D nonlinear models have been proposed and developed. These models include complex nonlinear processes such as friction-plasticity, cohesion, crushing, damage, and so on [6, 7].

From a numerical point of view, elastic-plastic analyses may be used to simulate masonry nonlinear behaviour, but they fail to simulate crack formation and brittle behaviour when the material enters into the softening regime. Limit analysis methods have been frequently applied in order to investigate the collapse mechanism of masonry structures subjected to given load distributions [8]. Smeared crack approaches and/or damage models may be used to simulate the local loss of strength masonry material suffers when it enters the nonlinear behaviour. However, to the best of the authors' knowledge the numerical analysis itself is still very demanding, especially when dealing with large and complex structures. For the sake of completeness, we note that an alternative to modelling masonry as a homogenised continuum is the Discrete Element Method approach, which models the structure as an assembly of blocks with suitable interface laws [9]. This method focuses on the possible non-smooth nature of the dynamic response, which allows for sliding and impacting between different blocks, and situations that are common just before and during the collapse.

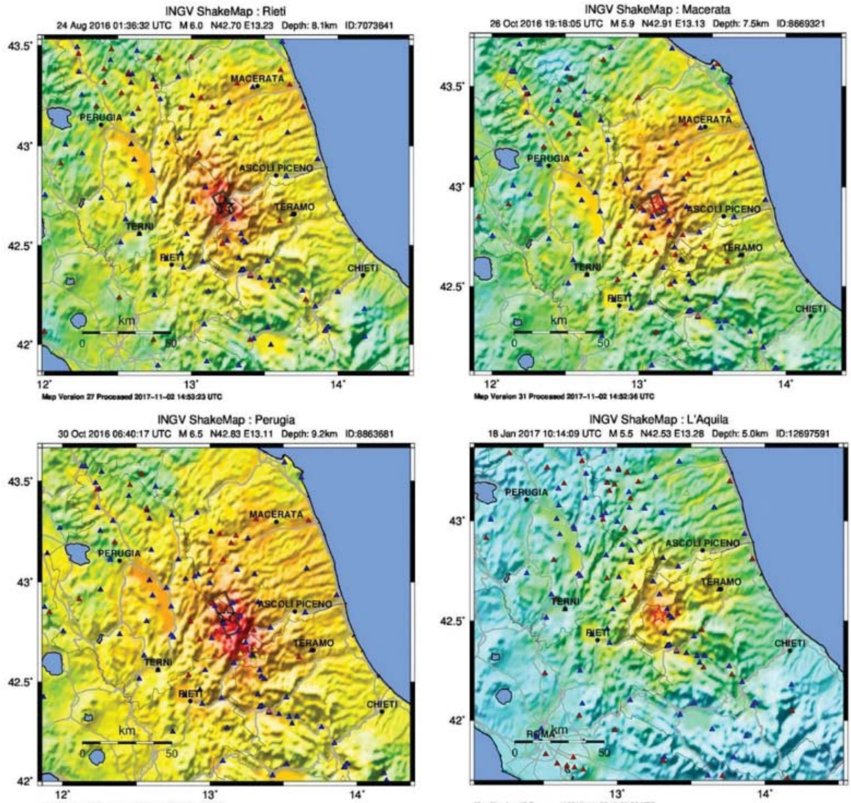
In the present work, the importance of considering the nonlinear and three-dimensional behaviour of masonry structures is shown, in order to highlight the structural deficiencies of different churches damaged by the last Central Italy earthquakes of 2016. For this purpose, the exact geometries of the structures have been reconstructed, with the information regarding the mechanical properties of masonry material derived from previous investigations and literature references. Based on this information, different numerical models are used to reconstruct the damages.

Firstly, different three-dimensional Finite Element (FE) models, endowed with an elastic plastic (softening) constitutive damage law, are adopted to determine the seismic vulnerability of the building by means of nonlinear static analyses using the smeared fracture energy approach. With this method it is possible to establish, with a suitable approximation, the areas where the most important cracks are expected and, in general, the locations of the potential damage caused by horizontal forces. Where possible, the dynamics of different churches is investigated using a distinct element code that implements the Non-Smooth Contact Dynamics method (NSCD) [10]. The main goal is to determine the weakness zones of the structures during seismic events and the possible collapse mechanisms. Numerical analyses are performed to assess the effects of the friction coefficient and geometry of blocks on the dynamics, and, in particular, on the collapse modes. Then, a study of the churches' stabilities against recorded seismic excitations is also addressed. Attention is paid to the occurrence of out-of-plane overturning mechanisms and further comparisons of the damage obtained with the present approach and after real earthquakes are reported.

2. The Central Italy Seismic Sequence of 2016-2017

The seismic events, occurring in Central Italy on 24th August 2016, 26th and 30th October 2016, and 18th January 2017, have caused casualties and major damage mostly to buildings and architectural heritage of the Italian regions of Marche, Lazio, Abruzzo, and Umbria. The mainshock occurred on 24th August at 3:36 am (local time) with epicenter close to Accumoli (Rieti province) and with a magnitude M_w= 6.2; it was followed, at 4.33 am, by an aftershock with epicenter close to Norcia (Perugia province) and with a magnitude M_w= 5.5. These events caused a total of 299 fatalities, 386 injuries, and about 4800 homeless [11, 12]. Most of the victims were in the areas of Amatrice, Accumoli, and Arquata del Tronto. In these municipalities, heavy damage and collapses of residential buildings were reported.

On 26th October, there were two strong aftershocks, the first at 07:10 pm with M_w= 5.6 and the second at 09:18 pm with M_w= 6.1. The earthquake of 30th October, which happened at 07:40 am with M_w= 6.5, is the largest event in terms of the released energy that occurred in Italy since the M_w= 6.9 in 1980 during the Irpinia earthquake.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.06	0.2	0.8	2.0	4.8	12	29	70	>171
PEAK VEL.(cm/s)	<0.02	0.08	0.3	0.9	2.4	6.4	17	45	>120
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Faenza and Michelini, 2010, 2011

Figure 1. Felt intensity (http://shakemap.rm.ingv.it/shake/index.html) of the four main shocks of the Central Italy sequence 2016-2017.

The seismic events of 26th and 30th October did not cause any victims, thanks to the evacuation of people from damaged and vulnerable houses after the previous seismic events. It is also necessary to consider that the October epicenters are located close to Norcia municipality, where many buildings had been strengthened after the 1997 earthquake. Nevertheless, the impact of the seismic events of 26th and 30th October 2016 and 18th January 2017 was distributed on a larger portion of territory extending northwards in the Marche Region in comparison to the earthquake of 24th August that had a very destructive impact on a restricted area included in the above-listed municipalities. Many small towns and villages, which have survived the first earthquake, were heavily damaged during the 30th October earthquake [6, 13, 14]. Finally, on the 18th January 2017 a new sequence of four strong shocks of M_w= 5 occurred, with the maximum equal to M_w= 5.5 and epicenters located between the municipalities of Montereale, Capitignano, and Cagnano Amiterno. All these earthquakes are indicated in Fig. 1 with the relative intensity map.

3. Case Studies

A sample of five churches in the crater area of the Central Italy seismic sequence has been studied (Fig. 2), with the main aim to confirm the weakness zones, the efficacy of past interventions, and to evaluate the acceleration of the activation of different mechanisms. All the selected churches have suffered heavy damages and collapses during the seismic sequence.

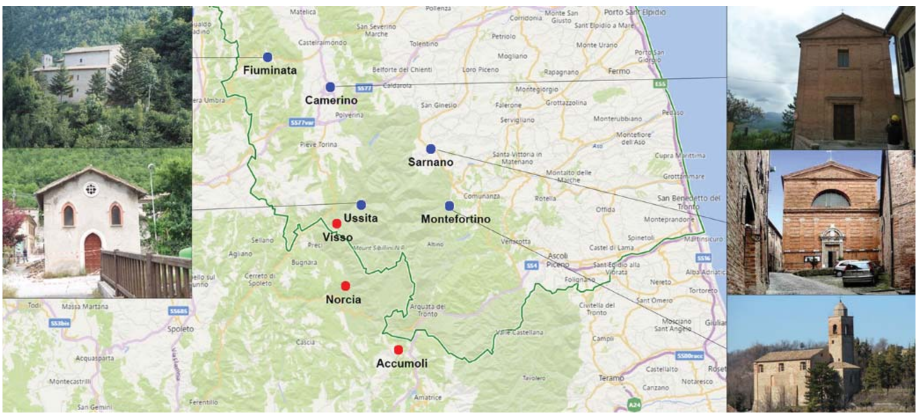


Figure 2. Locations of the five masonry churches severely damaged by the seismic sequence of Central Italy 2016-2017.

The first church is San Francesco in Montefortino (Fermo province) was built in the 15th century on the ruins of the church of Santa Maria of Girone. It is a Romanesque-Gothic's style with a unique nave. After the earthquake occurred in September 1997, the church suffered severe damage, in particular on the façade, in the vault of the apse, and in the upper part of the tower, and some retrofitting intervention were designed and then applied on this occasion. The second is the church of San Francesco in Sarnano (Macerata) which goes back to the 14th century, and it was restructured between 1822 and 1833. Actually, it has a unique nave. The third is Sant'Anna's church in Camerino (Macerata) built in the 13th century. It was erected in place of a church seriously damaged by the quake of 1799. A retrofitting intervention was done after the earthquake of 1997. The forth church is Sant'Antonio is located in Ussita (Macerata) and this little church goes back to the 17th century. Also, this church has suffered severe damage after the 1997 seismic event, and some retrofitting intervention were added after this earthquake. The last church is the Santuario of Valcora and is located in Fiuminata (Macerata). It was built early in the 15th century and enlarged early in the 18th century.

4. Numerical Results

To limit the length of the paper, only the results of Sant'Antonio's church in Ussita are here reported with both the continuous and discontinuous modelling approaches, in order to compare results of different numerical approaches with actual damages and determine the best modelling approach.

4.1 The Smeared Crack Approach

The nonlinear damage behavior of the masonry is considered within a continuum mechanics theory and is based on a smeared crack approach where the cracks are not described individually but are instead continuously spread within the body and affect (reduce) the average stiffness. The panels were modelled with solid tetrahedron elements with 4 nodes, and optimized regular mesh was used for discretization. The nonlinear behavior of the masonry panels of the historical complex is represented by a Total Strain Crack Model based on fixed stress–strain law concepts available in Midas FEA©. In this way, the cracks are fixed in the direction of the principal strain vectors and being unchanged during the loading of the structure.

The compression behavior of the masonry was modelled by a constitutive law comprising a parabolic hardening rule and a parabolic softening branch after the peak of resistance, whereas the tension behavior was characterized by a linear hardening branch followed by a nonlinear softening branch (see Fig. 8 of [7]).

The seismic behavior was analyzed by using a nonlinear static analysis method where the structure is subjected to constant gravity loads and monotonically increasing horizontal loads have been applied by using a pushover analysis. It is noteworthy to point out that the study employed conventional pushover, i.e. loads applied to the building did not change with the progressive degradation of the building that normally occurs during loading. This means that the conventional pushover does not account for the progressive changes in modal frequencies due to yielding and cracking on the structure during loading. Hence, the hypothesis of invariance of static loads could cause an overestimation in the analysis of the masonry building seismic capacity especially when a non-uniform damage of the buildings or a high level of cracking is expected. However, also in its conventional form, the pushover analysis provides an efficient alternative to expensive computational nonlinear dynamic analyses and can nevertheless offer useful and effective information on the damage state that the building can develop under seismic loads.

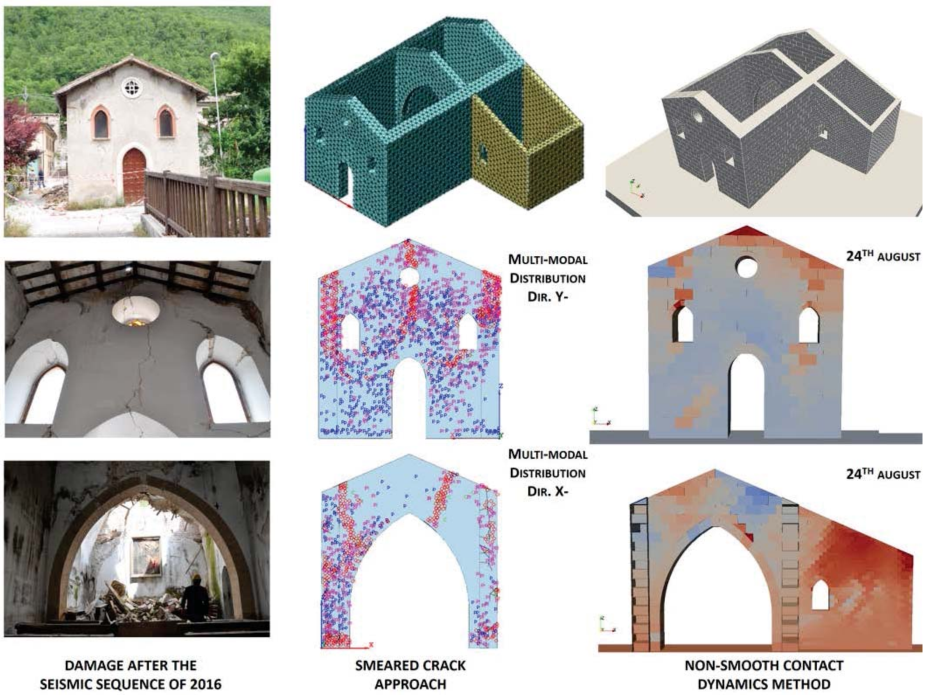


Figure 3. Comparison between real and numerical damages for the church Sant Antonio in Ussita.

The main results of smeared crack modelling approach are reported in Fig. 3, where a good comparison between the real and the numerical damages are summarized for the triumphal arch and the main façade.

4.2 The Non-Smooth Contact Dynamics Method

The NSCD method belongs to the family of discrete element methods, which is distinguishing from the classical Distinct Element Method in three ways: (i) it integrates the non-smooth contact laws directly, (ii) it uses an implicit integration scheme, and (iii) it does not account for any structural damping. It is important to stress the fact that the NSCD method is based on some modelling simplifications. The main assumption is that bodies are rigid. Since the contact between blocks is governed by the Signorini's impenetrability condition and the dry-friction Coulomb's law, the churches exhibit discontinuous dynamics. Regarding the contacts between bodies, the above-mentioned relations imply perfectly plastic impact, i.e., the Newton law with restitution coefficient equal to zero and no bounces after impact are accounted for. This presents two main advantages: (i) the contribution of impacts to the computational complexity is modest since they are modelled in a very basic and simple way; and (ii) since the impact is perfectly plastic it dissipates energy. From a mechanical viewpoint this is a way to account for material damages and microcracks that form in the stones at impact, and from a computational point of view dissipation contributes to the stability of the numerical integration. We also notice that friction contributes to dissipation, but the damping, which is a fundamental ingredient of continuum models, is not considered here.

The main numerical results are reported in Fig. 3 and compared with the real damage for the conditions of the main shock recorded in Amatrice (AMT station). This shows a good match between the real and the numerical damages as reported for the triumphal arch and the main façade.

5. Conclusions

The results obtained from modelling the seismic sequence of five different churches in Central Italy suggest high vulnerability of these structures, especially at the upper levels. Two completely different mathematical models have been employed for the interpretation of the real observed damage and reported in this paper for the case of Sant'Antonio's church: The smeared crack model (continuous approach) implemented in MIDAS FEA© and the non-smooth contact dynamics model (discontinuous approach) implemented in LMGC90©. Further evaluations and comparisons of different computational methods are, however, necessary for a more complete comprehension of the mechanical response of such complex structures as churches subjected to seismic loading, and identification of locations where most damage can be produced by the seismic actions.

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A New Tool Based on Artificial Intelligence and GIS for Preventive Conservation of Heritage Buildings

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Abstract. This paper describes a new predictive model for preventive conservation of buildings. It allows for multi-scenarios of several hazards, assessments of environmental risks, and the use level of buildings together with cultural values of monuments. This modeling approach is based on fuzzy logic and geographic information system available to organizations dedicated to the restoration and rehabilitation in Spain. This system has a transversal development that includes urban, architectural, cultural heritage value, and the analysis of environmental and socio-demographic situations around the monuments. This new tool allows for decision-making based on scientific criteria and minimizes risk losses of cultural assets.

Keywords: Hazard, vulnerability, preventive conservation, artificial intelligence, GIS, heritage building.

1. Introduction

A monument is more than just the construction itself [1]; it is a part of the local identity and a source of memory of historical events [2]. National governments and European institutions increasingly recognise the importance of the conservation of cultural assets. The service life prediction of the materials and components of the built heritage should achieve their maximum permanence in order to avoid possible failures of buildings and future extremely costly interventions [3]. Fuzzy logic, introduced by Zadeh in 1965 [4], has been successfully applied in the construction area and this kind of models is especially interesting when the problems modelled are subject to uncer-

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tainties. In this sense, fuzzy models present some advantages: (i) ability to model naturally systems that other models find vague and difficult to describe, (ii) ability to tolerate accurate and inaccurate data, (iii) ability for incorporating input information based on human observations, and (iv) ability to include the expertise of professionals [5].

The Geographical Information System (GIS) is a tool widely used in hazard evaluations [6], in assessments of flood risks when integrated with satellite remote sensing systems [7], and in combination with chemical techniques to study hazards from pollutants [8]. This paper presents a new tool based on Artificial Intelligence (AI) and includes GIS for environmental variables (GIS maps) that can be easily supplied by stakeholders and focused on the preventive conservation of heritage buildings. These methodologies are able to deal with the uncertainty associated with the performance loss of heritage buildings.

2. Methodology

The Art-Risk 3 model is a tool for the preventive conservation of cultural heritage that is based on a quantitative method able to deal with the uncertainty associated with the building's degradation process. Art-Risk 3 was developed by Art-Risk project funded by Spanish National Ministry and European Union. This modeling system is supported by 21 input parameters, nine involving vulnerability [9], one related to the building's maintenance, five static-structural risk parameters [10], four environmental risk parameters, and two naturals risk parameters (Table 1). These variables are involved in the functionality degradation of heritage buildings, their external risks and their own vulnerabilities, and provide a sequenced classification of priority actions for the conservation of the homogeneous architectural heritage.

Several parameters of the model pertain to the location of buildings, such as AR1 (geological location), AR16 (average rainfall), AR17 (rain intensity), AR18 (thermal stress), and AR19 (freeze danger). The ArcGIS ArcMap software from ESRI was employed to build GIS Map, where each hazard was determined utilizing a relative scale based on five values (Table 1). The remaining parameters are introduced manually by stakeholders (professional expert, users, practitioners, etc.). A total of 17 professionals with expertise from Spain, Portugal and Chile worked on the design of the model.

In general terms, the fuzzy expert systems are structured in four stages: "fuzzification", in which input values, subject to certain imprecision and subjectivity, are represented by fuzzy sets; knowledge base; "inference" stage, in which fuzzy rules are defined such as modus ponens propositional inference rules (IF "fuzzy proposal" AND "fuzzy proposal" THEN "fuzzy proposal"); and "defuzzification", which is used to generate specific output values. The core of a fuzzy system is the knowledge base comprised of two components: The database and the rule base. This step is the principal part of a fuzzy expert system that combines the facts derived from the fuzzification process with the rule base generated previously and carried out in the modelling process [10]. Finally, the defuzzification stage is used to obtain a (crisp) value representing the fuzzy information produced by the inference. Based on this output model it is possible to obtain a priority ranking of maintenance activities related to the functionality, risks, and vulnerabilities of a set of built heritage with homogeneous characteristics.

Table 1. Input variables of the Art-Risk 3 model.

ID	Variables	Categories	Quantitative valuation (very low/medium/very high)	Descriptive valuation of the input parameters
AR1	Geological location	Vulnerability	1.0/3.0/5.0	Very favourable/acceptable/very unfavourable ground conditions
AR2	Built context		1.0/3.0/5.0	Buildings without or between complex constructions around it.
AR3	Constructive system		1.0/3.0/5.0	Uniform or heterogeneous characteristics of constructive system.
AR9	Roof design		1.0/3.0/5.0	Fast/normal/complex and slow evacuation of water.
AR10	Conservation		1.0/3.0/5.0	Optimal/normal/neglected state of conservation
AR4	Population growth	Anthropic Vulnerability	1.0/3.0/5.0	Population growth greater than 15%/0%/less than 5%.
AR5	Heritage value		1.0/3.0/5.0	Great/average/low historical value
AR6	Furniture value		1.0/3.0/5.0	High/average/low furniture value
AR7	Occupancy		1.0/3.0/5.0	High/media/low activity in the building
AR8	Maintenance	Maintenance	1.0/3.0/5.0	Good/average/bad building's maintenance
AR11	Ventilation	Static-Structural risks	1.0/3.0/5.0	Natural cross-ventilation in all or only in some areas.
AR12	Facilities		1.0/3.0/5.0	All/some facilities are in use or they are not ready to be used.
AR13	Overloads		1.0/3.0/5.0	Live load below/equal/higher than the original level.
AR14	Risk of fire		1.0/3.0/5.0	Low/medium/high fire load in relation with combustible structure.
AR15	Structural modification		1.0/3.0/5.0	Apparently/symmetric and balanced/disorderly modification.
AR16	Average Rainfall	Environmental risks	1.0/3.0/5.0	< 600 mmm/600 mm < 1000 mm/ > 1000 mm
AR17	Raindrop impact (Torrenciality index)		1.0/3.0/5.0	< 7/8 < 9/> 10
AR18	Thermal stress (Thermal amplitude)		1.0/3.0/5.0	< 6/6<10/<10
AR19	Frozen damage (days below 0)		1.0/3.0/5.0	< 1 day/5 days < 20 days/> 60 days
AR20	Seismic risk (acceleration)	Natural risks	1.0/3.0/5.0	< 0.04 g/0.08 g < 0.12 g/>0.16 g
AR21	Flooding (return period)		1.0/3.0/5.0	Never/100 years/10 years

3. Requirements, Design, and System Architecture

The Art-Risk tool has three important design requirements. It must be usable, accessible, and multiplatform. The usability is important because it is intended to be managed by the end users and is therefore required to conform to ISO 9241-11 standard which defines usability as "the extent to which a product can be used by specific users to achieve specific goals with effectiveness, efficiency and satisfaction in a specific context of use" [11]. As such, a user group evaluates the usability of the tool by performing several tasks and measures whether these tasks can be completed or not (effectiveness) on time in an efficient manner. Satisfaction for each task is measured using the Single Ease Question (SEQ) questionnaire. There is also a final questionnaire to test the overall satisfaction level using the System Usability Scale (SUS) standard questionnaire.

Accessibility is also a mandatory requirement according to the EU Directive 2016/2102 of the European Parliament on the accessibility of the websites and mobile applications of public sector bodies [12]. In this case the TAW online service is used. TAW is a mature and online tool with technical reference Web Accessibility Guidelines (WCAG 2.0) of W3C. It allows checking the accessibility of a certain URL. It generates a summary report based on the analyzed page with information about the result of the review [13]. Art-Risk is based on the standard web technology as is described below. The multiplatform characteristic is very relevant in Art-Risk. The tool can be used not only in desktop computers, but also in mobile devices. This facilitates the fieldwork and it speeds up large building evaluations and comparisons. Therefore, the user interface (front-end) of the Art-Risk tool must be responsive. Bootstrap and HTML5 technology are used to implement the user interface part.

Art-Risk architecture can be divided into two parts: A user interface or front-end and an AI engine or back-end. The Xfuzzy 3.3 tool models the Art-Risk AI engine. Xfuzzy 3.3 has a final synthesis stage that is divided into tools generating several high-level languages descriptions for software or hardware implementations. Its aim is to generate a system representation that could be used externally [14]. Art-Risk uses C language description of Xfuzzy 3.3 to generate a CGI or program (back-end) that is invoked by the user interface (front-end).

On the home page of Art-Risk [15] there are available 2.0 and 3.0 versions of this tool. The 2.0 version is based on a previous AI model, whereas the 3.0 version is an ongoing prototype version that adds some automatic input variables based on GIS maps that can provide some characteristics related to building's thermal stress, rainfall, or geothechnics. Here the *automatic* means that the users need only insert the building coordinates and the system will provide values for those variables associated with the stored GIS maps.

4. Conclusions

The prototype method described in this paper aims at evaluating the functional degradation conditions of heritage constructions. This methodology considers the consequences of natural, environmental, static-structural, and intrinsic and anthropogenic vulnerability conditions on the functional service life of cultural heritage (given by risks, vulnerability, and functional service life indices - Art-Risk 3).

The Art-Risk 3 methodology should be very useful in the management and organization of preventive maintenance-oriented activities of buildings. This approach can provide some guidance regarding the risks, vulnerabilities, and performance of buildings that should be carefully analysed in order to minimize the degradation of cultural heritage and their risk of failure. The expert system of the model is able to simulate human reasoning to study relations between vulnerability and risk factors of buildings through a fuzzy sets theory. Moreover, the utility of this system can increase with the users' inputs and can be upgraded and improved.

The described GIS + fuzzy methodology can be applied to different cultural heritage buildings, and can be adjusted to diverse environments in Europe and elsewhere. The model should enable building owners, users, public administrations, and private companies to use this open-access software to manage better the conditions of buildings.

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Assessment of Vulnerability Index Applied to Churches of 18th Century in the Historic Center of Popayan (Colombia)

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Abstract. The objective of this paper is to provide a tool for decision-makers to prioritize strategies for cultural heritage preservation in Popayan (Colombia), that could be applied to similar cities in Colombia. The vulnerability analysis is based on matrix and the relationship of damage with static and structural factors, climatic conditions, air quality, urban planning and social agents for preventive conservation of cultural heritage in urban centers. To determine the first vulnerability approach of each monument, the vulnerability indexes (VI %) was calculated, based on a Leopold matrix that depend on intrinsic variables and the life of the monuments. The influence of different deterioration agents has been balanced with a Delphi forecast based on opinions of experts in architectural heritage. The degradation of building materials and structures is mainly due to deterioration caused by static-structural damage during the last earthquake in 1983, as well as lack of planning and little knowledge about conservation.

Keywords: Vulnerability, preventive conservation, heritage building

1. Introduction

Popayán is a city located in southwest of Colombia between the central and western mountains, and it was founded in 1537 on the Valley of Pubenza by Sebastian de Belalcazar after the Spanish conquest. Today, Popayán has the largest historical center of Colombia and in spite of the earthquake of 1983 it maintains its image of a colonial city. The urban layout of Popayán evolved in a grid as a base with streets, blocks, and some squares as the main components. The heritage buildings that survive nowadays in Popayan have a Hispanic influence with several reconstructions.

In the work reported in this paper, three churches have been studied: The church of San Francisco of baroque style (18th century) that has survived several earthquakes and has had a lot of interventions; the church of Santo Domingo, which also was partially destroyed during the earthquake of 1983 and is mainly suffering from weather-

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ing agents; and the church of San Agustín, which is a temple rebuilt after the earthquake of 1735 and contiguous to one of the main vehicular streets of the center.

2. Methodology

In the study, the methodology developed for vulnerability analysis by Ortiz [1] has been employed to assess the conservation degree of different monuments of the historic center of Popayan. The methodology has been modified to include the assessment of fire charge, roof design, and conditions of facilities (electricity, sewage, and fire control system). The three variables were classified between 1 and 5, from low to high level of vulnerability.

The expanded vulnerability index (VIe %) was calculated on the basis of a vulnerability matrix (VM) based on the adapted Leopold Matrix to suit the nature of specific heritage conservation problems of Popayán, with its own DELPHI surveys. The vulnerability matrix was prepared by inserting the hazards of this city in the rows and the building material characteristics, degree of structural conservation, and anthropogenic factors in the columns. The weathering forms were described according to CNR-ICR Normal 1/88 [2], Fitzner [3] and the ICOMOS-ISCS glossary [4].

3. Results

Table 1 shows the expanded vulnerability index (Vi%) of the three buildings studied by the adapted Leopold Matrix.

Table 1. Vulnerability index (Vi%) and expanded vulnerability index (Vie%) , fire charge, roof design, conditions of facilities (electricity, sewage, and fire control system), and building simplicity of San Agustin, Santo Domingo, and San Francisco. Data (September/2018).

Church	Vi(%)	Vie(%)	Fire charge	Conditions of facilities	Roof design	Building simplicity
San Agustin	16	30	2	3.5	2.5	2.2
Santo Domingo	25	36	2	3.3	2	2.5
San Francisco	29	40	2	3.2	3	3.5

San Agustin was restored in 201 and shows a low vulnerability (16%), whereas Santo Domingo and San Francisco with Vi% of 25 and 29%, respectively, show moderate vulnerabiliies, mainly due to rainfall and water percolation. The higher vulnerability of San Francisco is due to its building and roof designs. The expanded vulnerabilities increase due to the three new variables fire charge, roof design, and conditions of facilities, though the three churches maintain their moderate vulnerabilities and the order of restoration. The facilities conditions and the fire charge are identical in the three buildings.

The recently restored San Agustin does not require a direct action but it necessitates a preventive conservation plan. Santo Domingo and San Francisco require cost-benefit analyses of mitigation versus research, minor interventions, and their own preventive conservation plans. These plans could be similar for the three buildings and represent a measure of resilience, especially for the treatment of wood against xylophages.

The location of Popayan in a seismic area suggests reinforcements of the towers and roofs of the buildings, and a special plan for the conservation of the most valuables statues of holy week (Unesco intangible world heritage), even under disasters. Risk mitigation must be prioritized by cost-benefit analysis of research and further risk analysis.

4. Conclusions

The presented cultural heritage vulnerability analysis procedure provides protocols to develop policies for making decisions about which monuments must be preserved of a list of monuments. This methodology allows risk comparisons of buildings of similar characteristics and serves to produce strategies for cultural heritage preservation, the building, and the art-works inside. This enables Public Administration to make decisions for preventive conservation, resilient policies, and prioritize the restoration resources of Popayán. Further studies could be focused on the risk mitigation versus cost-benefit analysis.

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Robotics and Virtual Reality Gaming for Cultural Heritage Preservation

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Abstract. This paper reports on the open session held during the International Conference on Resilience and Sustainability of Cities in Hazardous Environments, where the aim was to discuss how the modern technology of robotics, virtual reality, and gaming could help in preserving cultural heritage sites. There is a plethora of achievements in this technology, but how and whether their fusion can add a new dimension to the preservation of cultural heritage sites and untimely contribute to their resilience and sustainability in our rapidly changing world is open to discussions and further research investigations.

Keywords: Cultural heritage, robotics, virtual reality, serious games, sustainability

1. Introduction

Culture plays a fundamental role in economies, in particular in urban economies, through monetary and non-monetary values. According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Universal Declaration on Cultural Diversity, culture is "*the set of distinctive spiritual, material, intellectual and emotional features of a society or a social group that encompasses art and literature, lifestyles, ways of living together, value systems, traditions and beliefs*" [1]. Culture is an integral part of our society.

Cultural Heritage is not just a historical site or a collection of objects, either historical or artistic or both. It is part of our ecosystem and a window into our past, and however **paradoxical it may appear** it is a window into our future. Our identities are formed by our cultural roots and the life of the communities is intertwined with our cultural past.

The UNESCO defines cultural heritage as "*the legacy of physical artifacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations*" [2].

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In some cases a cultural heritage site is a landmark and pride of communities living nearby, such as Pompeii or Ironbridge [3], and there are a lot of efforts made in various countries and communities to protect and preserve such cultural sites.

With the developments in modern technology we can, however, create new approaches, not only to protect cultural heritage sites and make them available for a wide range of public, but also to produce a framework, a kind of Cyber-Physical Social System that aims at connecting the audience to events and/or objects, or phenomena, separated either in time or in space or both, as well as provide 'rendezvous' among the members of the audience, via various media and mediums. In addition, this can lead to the development of new types of storytelling, allowing the visitors to create their own narratives as well as communicating with each other.

During the open session of the conference, three technologies were proposed for discussion: Robotics, Virtual Reality (VR), and Serious Games (SG).

2. Background

Robots are often associated in popular press with either impressive Hollywood humanoid characters or with machines that are capable to do repetitive tasks, such as industrial robots. In reality, however, the recent research in the domain of robotics has allowed for robots to become complex creations used in variety of contexts. Robots are also moving out of research laboratories and are used in such applications as service providers [4], robot assistants [5], and robot guides [6].

Nevertheless, one of the most important robotic applications is robot exploration of environments. There is a diversity of environments, such as archeological sites, large indoor environments, urban environments, monuments, etc. Robotics systems are versatile and complex and are used in search and rescue [7], surveillance [8], and monitoring. For instance, heritage sites are often large and may be exposed to a plethora of geological, landscape, and other hazards. Robot exploration of hazardous environments can help in the collection of data for improving digitized databases, assisting and protecting human resources, and providing remote access to restricted areas. Unmanned Autonomous Vehicles (UAV) can provide aerial surveys of archeological sites and automatic image processing can help identifying hidden regular shapes and/or possible safe paths for human workers.

Virtual reality (VR) technology has been applied to the protection of cultural heritage for about two decades [9-11]. This allows anyone with a web connection or a virtual reality headset to visit some of the world's most famous heritage sites, without leaving their homes. Creating virtual versions of heritage locations through VR may also help preserving site records or aiding in reconstructions if heritage locations are damaged in the future. The data collected by robots, sensors, and other means will help in creating a three-dimensional (3-D) representation of historic sites. Further modifications can be applied in order to visualize the site at it was initially and analyze the hazards (and/or disasters) that led to its current state. This can help to prevent similar events in other places. In addition, a 3-D model of a cultural-heritage site can contribute to better management and organization of the scene [12]. Combining VR and gaming technology can create a realistic representation of the site at various moments of time by adding characters (avatars) to the 3-D representation, thus creating a 3-D+time scene reconstruction. This will allow visitors to 'explore' and to 'see' events in the past. However, the main challenge is to determine how to link the real and virtual worlds so that the visitors relate to every world simultaneously in such a way that they have rewarding and enjoyable visits.

Open session feedback

The feedback from the conference audience confirmed the interest in the ideas regarding the use of robots, VR, and SG presented above, and provided further insights to their applications.

Robots as explorers, such as drones together with telemetry, could observe inaccessible places, access damage and reconstruct models of sites and objects with telemetry. Various sensors can be used, such as RGB and IR cameras, and 3-D lasers. In addition, robots can be used for transportation by air and by land.

Robots as guides can interact directly with people and provide information regarding a cultural site, its historical past, and its present state. In addition, robots can indicate safe routes and potential hazards. Robots can also provide a link between a particular location at a cultural site and artefacts from this site deployed in a museum. This can be accomplished by using communication networks between robots and the WiFi networks at a museum.

Virtual reality together with serious games can, in addition to simulation of a particular heritage site, be used to raise awareness of potential challenging situations, and can ultimately lead to the development of tools that can simulate various potential disaster situations and help with educating the public and in emergency planning.

In the following sections we explore the potential approaches of how to present our cultural heritage in a new way whilst preserving the areas and artefacts, and how to make available spaces, objects and narratives, and background history and influences that are associated with a historical site or an artefact to allow people experience history first hand. A site can be located remotely or does not even have to exist as it existed in the past. We would like to move away from the vertical system of the 'Authorised Heritage Discourse' [13] to the multi-view approach of Cyber-Physical-Social eco-Systems noted in the introduction

3. Pompeii, Vesuvio, and Campi Flegrei

The city of Naples is jammed between the two volcanos, Vesuvius (Fig. 1) which is very well known due to its disastrous eruption in AD 79 that destroyed and buried the cities of Pompeii and Herculaneum, and the less known super volcano Campi Flegrei or the Phlegraean Fields on whose deposits the city is built. Naples' western edge is literally living inside the Campi Flegrei's caldera.

Figure 1. The Somma-Vesuvius volcanic complex in the background, with the city of Naples in the foreground.

The ruins of Pompeii (Fig. 2) are partially open to the visitors and are a celebrated heritage site that inspired many painters and scientists to portray its past. Robots, VR and SG can contribute to the reconstruction of this past and create the city in a Virtual Space as it was before and during the eruption.

Figure 2. The Forum at Pompeii.

As noted above, robots can act as guides, monitor and scan the areas, and act as links to the reconstructed city in VR. In Fig. 2, two types of robots can be seen. A robot-guide on the ground (the robot at the lower left corner) can 'meet and greet' visitors, answer their questions, and direct them to the locations of interest. Robot-drones (above the image) can scan the area and submit resulting images to the robot-guide on the ground, so that the robot can display them to the visitors (for example, using the screen on its chest). Robot-drones can guide visitors to a requested area, because for a ground robot is difficult to travel on the roads of Pompeii due to their uneven structures. In the case of robot-drones, the safety requirements should be applied with utmost care [14]. In addition, the data collected by robot-drones can be used for generating and updating a 3-D model of the site.

Most of the artefacts found in Pompeii are part of the collections of the Naples National Archaeological Museum, and in VR these artefacts can be allocated to the places where they were found. The 'virtual' Pompeii can be filled with automated characters that would 'represent' citizens of ancient Pompeii. Visitors can be represented as avatars and robots and can be connected to their avatars as well and can act as virtual guides. More details can be found in [15]. Therefore, in addition to visualizing historical sites such as Pompeii, the area can be closely monitored and a framework can be developed that could simulate and potentially predict future eruptions which could be integrated into VR and SG.

We should note that the full 'immersion' into the VR space is not necessary. A person can just do manipulations on a computer similar to playing games and navigate avatars by pressing buttons on the keyboard. It would also be useful to have the possibility of using Head Mounted Displays and experience 'being there' at the dedicated locations on the premises.

4. Virtual Museums

Museums are institutions that primarily care for cultural heritage preservation, exhibition and conservation of historical artifacts, making culture accessible to everyone [16]. The purpose is to enable visitors to understand key events that took place in history by presenting accurate complex information in engaging and entertaining ways. However, simply displaying artifacts in glass cases and expect visitors to read complex descriptions of their origin is not sufficient. Thus, the need to improve and modernize display methods to be able to compete with the entertainment industry and overcome the outdated principles of traditional museology is stressed [17]. The museum experience is now shifting from the traditional museum 'featuring displays' and having 'museum visitors' to the era of the 'museum experience' and 'museum consumer' [18]. Consumer satisfaction is crucial, and to avoid the negative financial and cultural implications of declining visitor numbers, museums employ different types of technology to attract and retain visitors. Some of the latest technologies adopted include the use of smart phones and tablets, augmented reality, and recently VR, introducing thus the concept of Virtual Museums [19].

4.1 Virtual Reality for Virtual Museums

The topic of Virtual Museums has drawn a lot of interest over the past few years, with many scholars attempting to form definitions, raising a debate as to the status of information conveyed and the utilized technology [19-24]. Pujol and Lorente [25] have considered many of them and have proposed that a Virtual Museum refers to "*digital spatial environment, located in the WWW or in the exhibition, which reconstructs a real place and/or acts as a knowledge of a metaphor, and in which visitors can com-*

municate, explore and modify spaces and digital or digitalized objects". Virtual museums offer a mixture of traditional museum practices, a range of semiotics communication modes, trends, and different technologies [26]. Furthermore, virtual museums have been classified according to their content i.e. archaeology, the duration (permanent or temporary), type of interaction (interactive or not), level of immersion (immersive or not), distribution type (online and offline), scope (education, entertainment, etc.), communication style (descriptive or narrative), and sustainability [27].

In virtual museums, the use of VR has been gaining a lot of attention among other technologies, especially in the field of cultural heritage, conservation, restoration, digital storytelling and education [16]. VR can help museums to overcome a number of challenges and limitations [28], and allow the presentation and reconstruction of artefacts and historical environments that may have been damaged over time [29], archeological sites that no longer exist [30], perform virtual restoration of already damaged artefacts without affecting the actual exhibit [16], and used as assistive devices for restoration [31]. VR allows more vivid and realistic experience when compared to the traditional multimedia presentation tools used in museums [32]. Studies have shown that the use of technology to customize the way visitors explore and experience a museum could improve their overall satisfaction [33-35], and VR can help a visitor to adapt to the cultural proposal and the information about the artefacts [36].

After decades of challenging technical issues and expensive requirements, VR is now finally a customer-ready technology, and despite some initial adoption resistance [33], is now increasingly used in museums due to the technology's unique affordances of immersion and presence to improve visitors' experience and interactions with cultural heritage [16]. Immersion concerns the experience of a technology that exchanges sensory input from reality with digitally generated input, such as audio and graphics [37]. It is defined as "*a form of spatio-temporal belonging in the world that is characterized by deep involvement in the present moment*" [38], and expresses the full absorption of the user into a new and digital dimension, which stimulates the interest and pleasure that are cognitively and emotionally engaging the user [39]. The notion of presence is similar to, but distinct from the concept of immersion [40]. Presence is defined as "*the subjective experience of being in one place or environment, even when one is physically situated in another*" [41], and is the subsequent reaction to immersion which leads to the users brains reacting to the virtual world in the same way as in the real world [42]. The attributes of presence and immersion, in combination with the ability to develop and experience situations that may be difficult or even impossible to experience in the real world and/or deviate from reality, are affordances that support motivations for technology adoption [43].

The technical characteristics of VR require hardware equipment to generate the virtual environment and to display information. The optimal hardware configuration for a high quality experience that will provide the highest level of immersion in the virtual setting requires the use of expensive VR systems such as CAVE, Power Wall and Reality Deck [44]. These are supreme quality immersive environments using multisided projections, which provide the highest level of immersion [45,46]. However, the main issue is the high cost of purchasing the equipment, which is static and requires a lot of physical space to be deployed [47]. The solution of Head Mounted

Displays (HMD), such as Oculus Rift, HTC Vive and hand trackers to allow gestures in the virtual world (i.e. Leap Motion), are good options to provide high quality experiences to users. These devices are affordable and can provide very good graphical quality [47]. Nevertheless, the main issue is that to run these devices requires high performance computers to generate the experience. A more compact and cost effective option is the use of VR ready smart phones that are powered by the users' smartphones and with the use of VR apps, rather than the dedicated built-in computer and display units such as Google Cardboard and Samsung Gear VR [48].

To date, there is only a small number of museums which have managed to explode the potentials of VR, mainly due to affordability of developing and executing a virtual environment, as this is a time consuming process that requires the collaboration of many experts from multiple disciplines [32].

4.2 Virtual Museum Prototype

In order to investigate and better understand the affordances of VR, we have created a Virtual Museum prototype that promotes the history of robotics in VR. The RoboSHU (Fig. 3) is a multi-purpose, multi-user virtual environment in which users can interact with the environments, its objects, and each other through the use of their Avatar. The environment is designed using the Opensimulator platform and users can experience it through a desktop and a monitor or in VR using Oculus Rift. RoboSHU is hosting the Robotics Museum featuring informational boards and exhibits designed by students, and aiming to inform visitors about the history, general information about the research conducted by the Sheffield Robotics Group and the Robotics Department at Sheffield Hallam University, and the current state of robotics knowledge.

In the Desktop mode, the Virtual Museum can be accessed through a computer, using its monitor, keyboard, and mouse. The computer's monitor is delivering the visual aspect of the environment, and the navigation and interaction is utilized through the use of the mouse and keyboard (Fig. 4). In VR mode, the user can access the environment through Oculus Rift and use an Xbox 360 controller for navigation and interaction (Fig. 5).

Further to the Desktop and VR mode, we have ported the Robotics Museum to a Smart Phone VR prototype, which allows the environment to be experienced with the use of an Android smart phone device and a low cost HMD such as the Google Cardboard. The environment was ported using the Unity 3D Gaming engine, and is currently targeting Android devices. The user can navigate the environment through the use of the touch input mechanism of the Google Cardboard and interact with artefacts by focusing for a few seconds on virtual hotspots. Future work aims at further developing, improving, and evaluating the environment, as well as adding additional functionalities and greater interactivity.

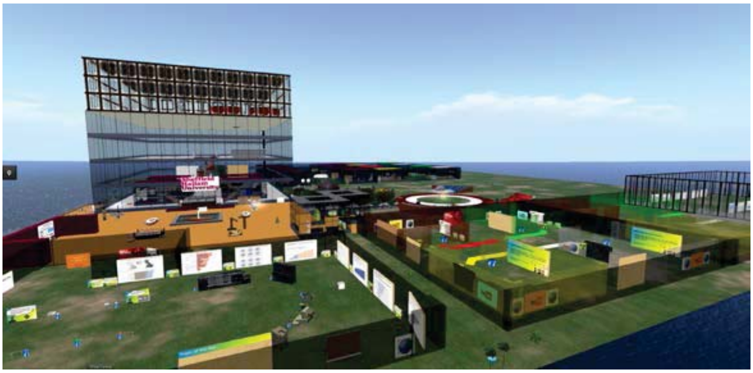

Figure 3. Virtual Sheffield Hallam University (SHU).

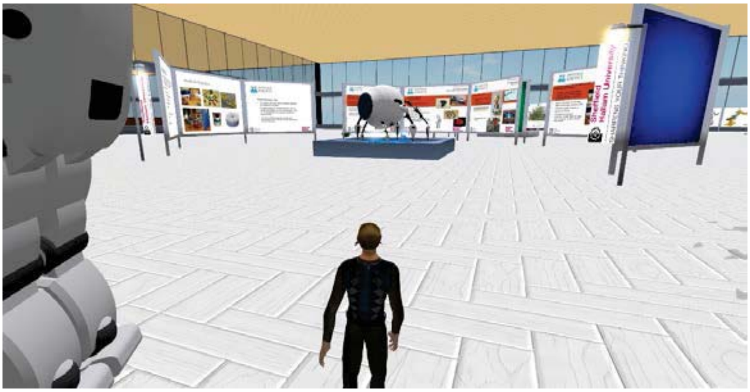

Figure 4. Desktop View of the Virtual Robotics Museum at Sheffield Hallam University.

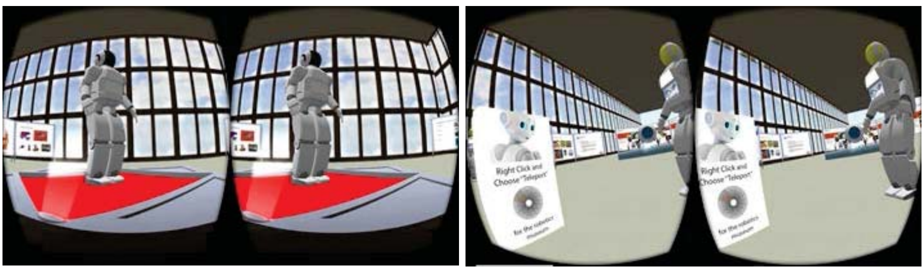

Figure 5. VR View of the Virtual Robotics Museum at Sheffield Hallam University.

5. Conclusions

In this paper we presented some initial principles of a new type of a multifaceted Cyber-Physical-Social System that will be able to intertwine diverse technologies such as Robotics, Virtual Reality, and Gaming. This system will encompass both physical and virtual environments, including real and artificial agents and elements, capable of interacting dynamically, reflecting, and influencing each other and with the interactions engendered by human behaviour. Its primary application is cultural and creative industries, but the proposed framework is applicable to many other domains. Among those, we can mention large shopping malls, education, personnel training, health care, and exploration of remote environments.

At Sheffield Hallam University we are currently working on creating a VR Museum of History of Robotics and connecting 'virtual robots' that 'live' in the museum to some of real robots that we have in our Robotics Laboratory.

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Urban Planning for Disaster Risk Reduction From Climate Change

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Abstract. By the end of this decade, more than half of the world's population will live in cities and the development of urban areas hold the key for many of the challenges we face in our interactions with the environment. In the last decade, many researchers from the Urbanization and Global Environmental Change (UGEC) have been seeking to provide a better understanding of the interactions between the urbanization process at the local, regional and national scales and the global climate change, and this work represents a review of the recent efforts of these researchers. The majority of world cities have been affected by a great diversity of natural adverse events, such as floods, landslides, droughts, storm surges, and coastal erosion. Generally, the urbanization process, particularly in rapidly urbanizing areas, is not well accompanied by spatial planning, sustainable industrialization, economic growth, and welfare considerations or investments in environmental services and infrastructure, leading to poverty (social exclusion and service gaps) and extensive informal settlements. This is one of the reasons why urban areas have become an increasing focus for the global society. The core work on urbanization places emphasis on the global environmental change, both as a driver and outcome of economic, political, cultural, social, and physical processes in urban areas. Urban areas are complex and dynamic systems that reproduce within their territories the interactions among socio-economic, geopolitical, and environmental processes at local, regional, and global scales, and many of the most important and significant consequences associated with the impact of climate are therefore taking place in urban areas. As urbanization represents a critical topic of special policy relevance nowadays, the development of well-crafted designs constitute a pivotal step to urban master plans, since they must primarily provide a clear guidance on land use. We should, therefore, make the scientific research more effective and translate scientific knowledge in more coherent and visible ways into urban contexts for adaptation opportunities and urban resilience.

Keywords: Resilience, ecosystem services, disasters, green infrastructure, urban planning

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1. Introduction

The climate system is influenced by land use/cover, oceans and water bodies, atmosphere, cryosphere and biosphere [1] and affects the physical and biological systems on all continents and in most oceans. The urban areas, and especially those in the developing countries, are particularly vulnerable to frequent climate variability and associated extreme events [2-5] and the high-impact weather events have lead researchers to question whether their frequency and intensity have changed and will continue to change over time [6]. Some projections reveal that it is very likely that the effects of atmospheric pollution (disease) [7] as well as extreme weather events, such as heavy rainfall, warm spells and extreme heat, drought, intense storm surges and sea level rise, will increase in frequency, intensity and duration as a result of climate change [2-4,8]. It is clear that the climate is also transforming the cities in which we live, with the geographical locations of observed changes showing consistency with spatial patterns of atmospheric and warming trends.

The urban areas worldwide, such as New York City [9], São Paulo [10], Rio de Janeiro [11], Shanghai [12], Beijing [7], and London [13], are all experiencing multiple climate changes and resulting impacts. Climate impacts interact with the context specific urban conditions (social, economic and environmental stresses) and exacerbate and compound risks to individual and household well-being [3-5,14]. These interactions not only have widespread negative impacts on people (health, wellbeing, livelihoods, and assets) but also on local and national economies and ecosystems [8]. Together, climate variability and urbanization pressures produce profound impacts across a broad spectrum of infrastructure (water and energy supply, sanitation and drainage, transport and telecommunications), services (health care and emergency services), socio-economic conditions (income inequality), the built environment and ecosystem services [3-5,8,15]. As urban areas continue to experience seasonal shifts, rising temperatures [13], fluctuations in rainfall patterns, rising sea levels and storm surges [16], the risks, including heat stress, water scarcity and worsening air pollution, also increase. Disaster situations can occur when hazards (floods, landslide and drought) combine with the conditions of social vulnerability (poverty and socioeconomic inequalities) and insufficient capacity or measures to reduce the negative consequences of risk [17]. In rapidly urbanizing countries, the combination of structural poverty and unequal concentration of income, the absence of infrastructure (decaying and sub-standard), high population densities and the centralization of economic assets and commercial and industrial activities heighten urban vulnerabilities [18].

This work summarizers several research efforts [19,20] and provides an overview of urban climate risks, in order to understand how the cities are being impacted by specific extreme events. In the sequel, we examine the actions that some cities have undertaken in order to face extreme human, environmental and economic losses that could be the opportunities for shared learning to effectively respond to future risks. We conclude by making a link between the extreme events and the potential for a transition towards a more sustainable future while emphasizing that even in the presence of multiple stresses, the policy relevant information from ongoing scientific research, experience-gathered knowledge, and observation provide opportunities for future adaptation and urban resilience.

2. Climate Variability and Extreme Events

Some of the largest climate impacts on cities are associated with extreme events, such as drought, heat waves, intense precipitation, coastal storms and cyclones, and are critical components of the climate impact assessments [8]. Over the last decade, a significant number of these events have caused large losses of human life; for example, Typhoon Bopha in The Philippines (1,901 deaths in 2012), flooding and landslides in Brazil (900 deaths in 2011), Storm Nargis in Myanmar (138,366 deaths in 2008) and Storm Stan in Guatemala (1,513 deaths in 2005), as well as the tremendous economic losses [21], e.g., Hurricane Sandy in 2012 (~50 billion USD), flooding in Thailand in 2011 (~41 billion USD), and Hurricane Katrina in 2005 (~147 billion USD) [22]. The landslide risk is likely to remain a highly challenging issue now and into the future as the urban poverty, climate variability, and environmental degradation expose vulnerable populations to an entirely new scale of devastation [17]. The disasters resulting from tropical cyclones, windstorms and related landslides affect the populations concentrated in urban sites the most, with 366,000 people affected every year by only the landslides [23].

Large populations of the poor remain at risk, because they often settle on unstable slopes and steep terrains that have previously been affected by and prone to future landslides. Asia is most affected by landslides; the Americas, on the other hand, have suffered more deaths; and Europe bears most economic losses with an average damage of almost 23 million USD per landslide event [17]. Climate projections indicate a rise in temperature for the majority of cities around the world, such as New York City, London and Toronto [5,24]. Global mean surface air temperatures over land and oceans have increased, and the measurements show a continuing increase of heat content in the oceans. It is expected that the droughts will be more frequent and intense as a warmer atmosphere is expected to hold more moisture. Sea level rise and stronger tropical storms may further increase flood risk, particularly when high tides combine with storm surges and/or high level river flows. Low-elevation coastal zones are particularly at risk of flooding and storm damage as a result of climate change [25,26]. Heat and cold waves, intense rainfall and cold and dry spells among other extreme events have distinct effects on nations with varied impacts across many sectors (water, agriculture, food security, forestry, health and tourism) [27].

The processes affecting climate can exhibit considerable natural variability, much of which can be represented by simple (unimodal or power law) distributions, but many components of the climate system also exhibit multiple states such as the glacial-interglacial cycles and certain modes of internal variability, such as El Nino-Southern Oscillation (ENSO) [28]. Delhi is one city where annual mean temperature is projected to increase over the next century, but certain aspects of its humid subtropical climate are markedly different from many other humid subtropical cities, such as São Paulo, where there are dry winters and rainy summers [8,29]. Tokyo and Brisbane experience dust storms as a result of monsoonal climate patterns and have relatively dry winters but often-prolonged spells of very hot weather [30].

Furthermore, warming is expected to increase with the distance from the Equator. Inland or continental regions are expected to warm more than the coastal regions because they experience climate-moderating influences from the oceans; this explains why more warming is expected in Toronto than London despite comparable latitudes [30]. Warming will also generally be greatest in winter of extra-tropical regions, such as the United States, but there is a greater variability in these climate change projections and in the potential for disasters [30]. Moreover, some cities are expected to see increases in precipitation while others are projected to experience declines. When precipitation does occur it will tend to be more intense and basically concentrated in extreme events [5,8]. In mid-latitudes such as Tokyo, New York City, and Toronto most of the precipitation will be in the form of rainfall. However, London is expected to experience decreases in precipitation, which could lead to drier summers [5]. Similarly, other cities located between mid-latitudes and the subtropics are expected to experience greater aridity, e.g., Melbourne in Australia [30]. Other cities in tropical latitudes such as Manaus in Brazil (Tropical rainforest climate - Af) will experience more precipitation while others less, such as São Paulo and Rio de Janeiro (Tropical wet and dry - Aw). This depends on the wet and rainy season and the influence of Pacific Decadal Oscillation (PDO) or sea surface temperature anomalies (SSTA) over the Pacific that interact with ENSO combined with stochastic atmospheric variability [31]. Extreme precipitation events can have important effects on urban areas, such as in the São Paulo Metropolitan Area (SPMA) of Brazil [29] where the flash floods associated with intense precipitation, even during the periods of brief rainfall, may be destructive.

3. Adaptation Planning as a Learning Process for Adaptation and Urban Resilience

The importance of considering urban planning as a tool for adaptation will likely require the revisiting of regular development policies, plans, and projects as the climate and socio-economic conditions change [32]. And at this moment of changing we need to consider the adaptation planning as a learning process rather than the culmination, with more discussions taking place at local levels for the purpose of developing alternatives connecting climate change with urban physical conditions and infrastructure [33]. Rhetorically, urban planning is considered a societal tool to improve the distribution of services and infrastructure, reducing conflicts between diverse interests and promoting the well-being of inhabitants. Actually, it is a more complex process because it is related to a dynamic system endowed of infinity of economic, political, and socio-cultural conflicts that the urban planning does not have the pretension to solve, given also that the conflicts are in a constant process of change. In fact, the connection of climate and adaptation development can be influenced by how the issues are framed [33]. For this reason, it is pivotal to understand the multi-scale relationship between cause and effect to better perceive the dimensions of adaptation actions and planning.

We propose that the adaptive capacity building can be delivered and focus on developing effective disaster reduction to climate-related hazards (such as floods, landslides, storm surges and droughts) and implementing policy reforms that address urban structure, which often represents the œanatomy of the cities. For instance, the concept of green infrastructure became increasingly important and prominent across the public spheres in the last decade (e.g. for urban policy and planning). It is understood as a strategic approach to develop an interconnected network of green spaces that conserves natural ecosystem form and functions, and that provides associated benefits to human populations. The growth of urban brownfield redevelopment and the green field protection initiatives is a positive indicator of the redirected priorities of the public sector to restore and regenerate significant places and spaces in the urban landscape. Besides, there is an ever growing evidence base on the benefits of green infrastructure. Therefore, the increasing interest in these areas is driven by several factors, such as widespread concern for the decline in the conditions of many parks and other urban green spaces due to their generally low priority in the political agenda at local level. Actually, the urban green spaces are essential for the well-functioning of cities and for the prevention of environmental risks and hazards because they: (1) play an important role for nutrient cycling and absorption of greenhouse gases; (2) contribute to the conservation of biodiversity; (3) contribute to the avoidance of environmental disasters; and (4) contribute to the balance of technical solutions related to infrastructure problems (water supply, drainage system). Green infrastructure plans apply key principles of landscape ecology to urban environments, and specifically a multi-scale approach with the emphasis on ecosystem connectivity.

4. Final Thoughts and Key Messages

More and more people will be at greater risk in the future as global populations increase and concentrate in urban settlements, and especially along the coast where exposures to cyclones, storms and floods is the greatest and the urban areas continue to concentrate problems of illegal settlements and urban slums. Consequently, the number of disaster victims from floodings and landslides will also increase since these are often located in areas with the highest risk. While the knowledge of how disasters unfold in urban areas remains incomplete, we have learned from the events such as Hurricanes Katrina and Sandy in New Orleans and New York City, respectively, and from the drought events and water scarcity in California, São Paulo, Beijing and Shanghai, how the infrastructure, services and society's environmental interventions are affected depending on climate variability and on specific environmental characteristics. It is, therefore, necessary to develop a different vision about urban form and environmental interactions based on ecological services and social-technological interactions. In this context, some key messages are equally important:

- Investment in public infrastructure and a more equitable distribution of public and private resources will have the biggest impact on reducing disasters;

- Governments have the primary responsibility of protecting their citizens against disasters while preserving the human rights of disaster-affected populations and victims;
- Public-private partnerships have increasingly emerged as the key features in adaptation to climate change and related governance, and further investigation in needed into what drives these partnerships and experimentation, the factors hindering actions, effectiveness on the ground, and impacts;
- There are contradictions that need to be overcome immediately; for example, notwithstanding the acknowledgement of human rights protection as being a critical element of humanitarian strategies in emergency response to disasters, the longer-term aspects of human rights-based approach to prevention through urban planning and disaster mitigation is still limited;
- The mainstreaming of emergency planning and response mechanisms into urban strategic planning and policies (i.e. population growth, housing and public transport conditions, environmental pollution, socio-spatial inequality and poverty, migration and racial discrimination);
- Integration of water sanitation and water supply systems (waste management, sewage, water sources and supply, reuse and protection) that are flexible to a changing urban landscape (such as the cut-off and/or partial cut-off effect of underground aquifers, the decrease in the groundwater level due to leakage of underground infrastructure and the reduction in recharge of groundwater from surrounding areas);
- Ongoing risk and vulnerability assessments of urban and intra-urban populations to climate change impacts along with preparedness (observational/monitoring research; early warning systems) measures to develop and prioritize short- to longer-term preventative actions.

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From Disasters to Comprehensive Resilience in Government Policies

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Abstract. Actions directed at risk reductions of cities, municipalities, regions, and countries require collaborations of professionals and governing authorities, and in this work some actions taken by the Province of Potenza in Italy are presented that address the resilience of this province. This province is subjected to the risks of earthquakes, landslides, floods, climate change effects, industrial operations, urban sprawl, and land use management policies. The presented vulnerability and damage assessment studies of earthquakes show that some areas of the province are at very high risk from strong earthquakes where tenths of thousands of people risk of being trapped by the collapsed buildings. The disaster management strategy of the province starts by involving the civil protection services of municipalities and then involving the provincial and national services as necessary. The province structured a territorial coordination plan that provides land use and government policy coordination, and for cities evaluated ten essentials of United Nations Make Cities Resilient initiative. The resilience initiative of the Province of Potenza also showed some gaps that exist at the municipal level and suggests that the technical, social, and governance elements are the key in achieving long-term resilience of the population in the province.

Keywords: Hazards, earthquakes, vulnerability, risk, civil protection, governance, Province of Potenza

1. Area of Interest

The region of Basilicata in Italy (Fig. 1) has a population of 580,000 people and consists of two provinces: Province of Potenza and Province of Matera. The Province of Potenza has the area of 6500 km^2, population of 378,000 people, population density of 60 people/km^2, 100 municipalities, and its capital city is Potenza with 67,000 inhabitants [1].

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Figure 1. (a) Province of Potenza (red), (b) Location of Region of Basilicata in Italy.

The main risks in the Province of Potenza derive from both the natural and anthropogenic hazards. The natural hazards are associated with earthquakes, landslides, floods, drought/desertification, wild fires, and cold and heat waves. The anthropogenic hazards are associated with climate change, land-use and management policies, hydraulic network system and dams, industrial settlements, urban sprawl, and soil sealing, consumption and degradation [2].

2. Disaster Risk Management and Reduction

The Italian Civil Protection service was established with the law n. 225 in 1992 and is concerned with hazards, risk assessment, risk prevention/mitigation, disaster risk reduction, disaster management, provincial civil protection, and post disaster actions of relief and recovery. Civil protection starts from local municipalities and then cascades to provincial, regional, and national levels as the severity levels increase [2].

The seismic hazard of the Province of Potenza is grouped into 4 classes or zones (Fig. 2): Zone 1 where major earthquakes are expected, zone 2 where the municipalities may be affected, and zones 3 and 4 where the seismic hazard is low. These classes were established for 28 municipalities through questioners (Guided Interview Protocol or GIP) and then assigned *vulnerability levels* 3,2,1,0 corresponding to the classes A,B,C,D. The *vulnerability indices* were then computed based on the vulnerability levels and their associated frequencies. The *exposure indices* were determined from vulnerability levels and frequencies of people living at each vulnerability level [3].

The results of these calculations are shown in Fig. 3 and demonstrate that the vulnerability indices range from less than 0.2 (white) to greater than 0.8 (dark green), with the buildings in each municipality grouped into 4 vulnerability classes of MSK:

Class A (red), Class B (orange), Class C (yellow); and Class D of EMS98 (green) (Fig, 3a). The seismic exposure shown in Fig. 3b is comprised of 5 levels, where <0.2 (white) corresponds to the low index of exposure and >0.8 (dark green) corresponds to the high index of exposure. The percentage of buildings associated with seismic exposure is represented in terms of Class A (red), Class B (orange), Class C (yellow), and Class D (green).

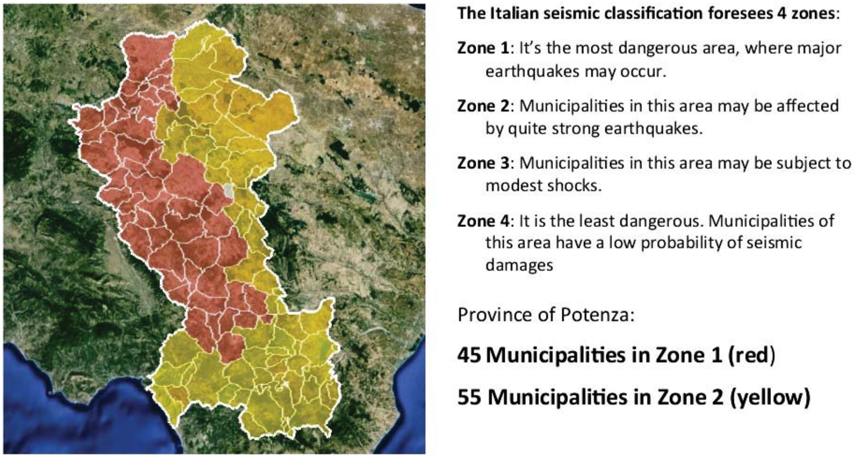
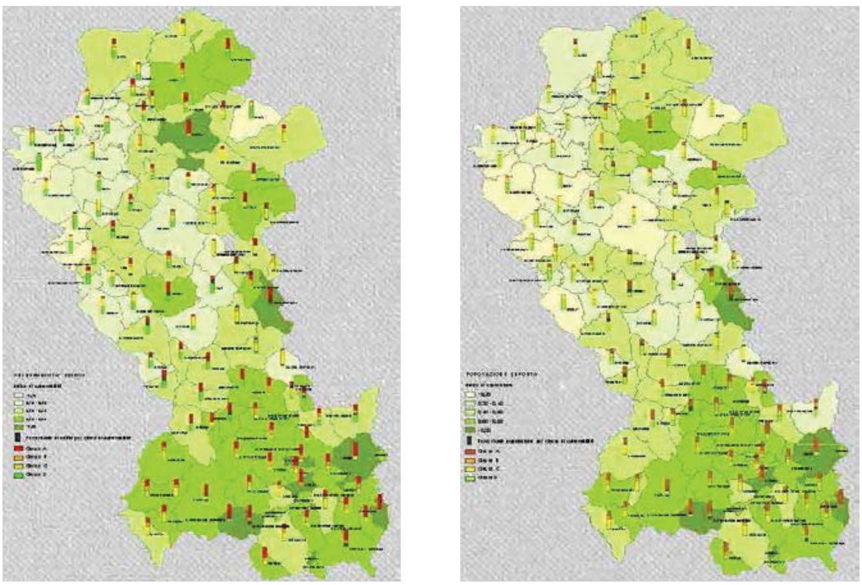


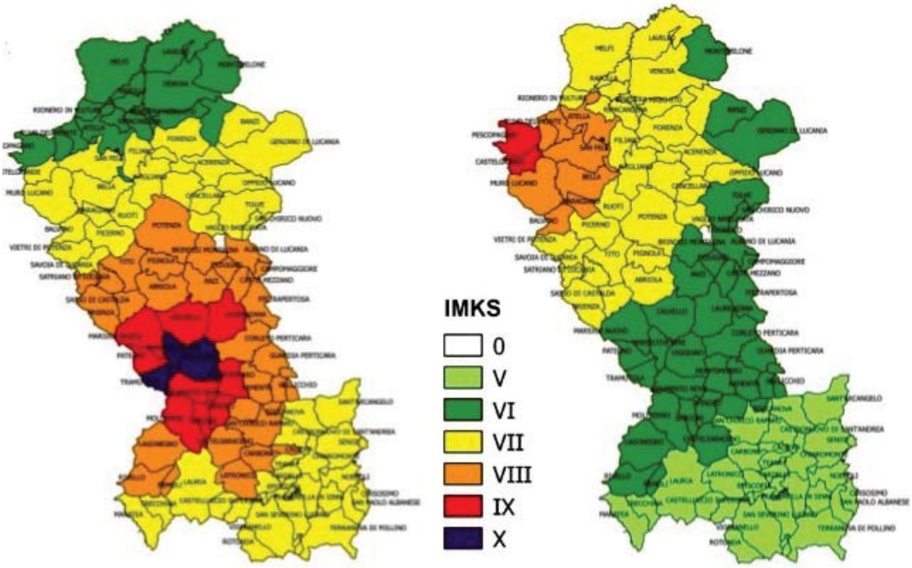
Figure 2. Seismic hazard classification in the Province of Potenza.



(a) (b)

Figure 3. (a) Vulnerability indices and percentages of buildings associated with different classes of seismic hazard in the Province of Potenza. (b) Exposure indices and percentages of buildings associated with different classes of seismic hazard in the Province of Potenza.

A seismic risk study was also conducted for the Province of Potenza by assessing the potential damage that may result of the earthquakes similar to those of 1857 Basilicata earthquake with moment magnitude of 7.0 and 1980 Irpinia earthquake of magnitude 6.9. The *damage indices* were computed by using the damage levels 0,1,2,3,4,5,6 corresponding to earthquake strengths (O,V,VI,VII,VIII,IX,X) and frequencies corresponding to these levels. The intensity level V corresponds to "strong" and intensity level X corresponds to "very destructive" earthquakes [4,5].



(a) (b)

Figure 4. Earthquake simulated scenarios for (a) 1857 Basilicata earthquake and (b) 1980 Irpinia earthquake.

The results of the calculations show that the consequences of Basilicata- and Irpinia-like earthquakes would be devastating not only in the middle of the province but also in localities quite far from the epicenter. Some 20,000 buildings would be damaged, 50,000 people would become homeless, and some 10,000 people would be trapped from building collapses.

3. Disaster Management

Figure 5 illustrates the General Operational Model for local and national Civil Protection. The disaster "A" lies within the domain of municipal authority, "B" within the provincial and regional authorities, and "C" within the domain of National Civil Protection authority. The planning strategy of disasters "B" and early "C" is shown in Fig. 6.

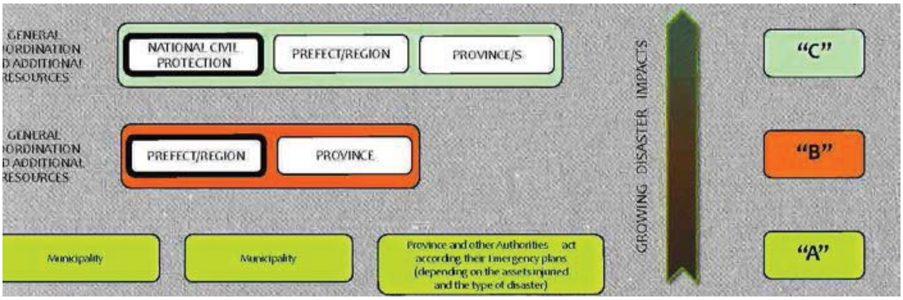


Figure 5. Local and national Civil Protection services.

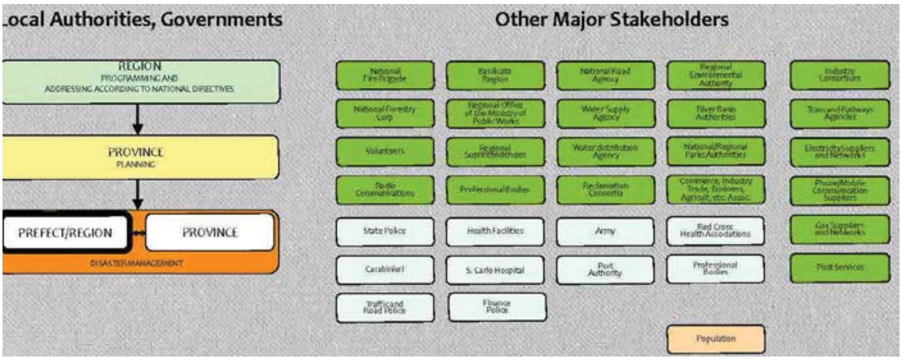


Figure 6. Planning for disasters of type "B" and early "C".

The organization and procedures for managing disasters "B" and early "C" of Province of Potenza are illustrated in Fig. 7 (2004 and updates).

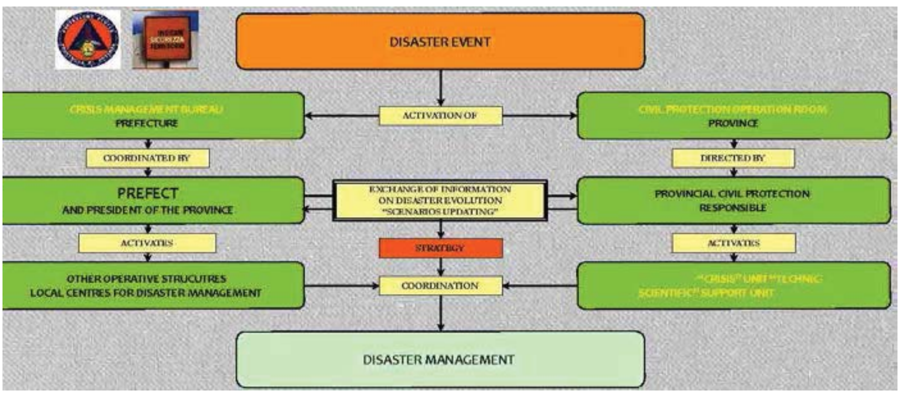


Figure 7. Disaster management of Province of Potenza.

4. Disaster Risk Reduction

The main activities of Disaster Risk Reduction (DRR) of Province of Potenza are associated with:

- Risk Assessment and monitoring (including early-warning systems);
- Active DRR (prevention, mitigation). In the last decade, several M€ were invested in:
    a) Provincial road network: about 2700 km;
    b) High schools building estate: About 80 buildings (the “Safe-Ecological Schools” program);
    c) Maintenance and requalification interventions on the hydraulic river network and on the regional forest heritage (in cooperation with the Basilicata Region);
- “Non-structural” DRR (prevention). Preparedness, trainings, information campaigns, drills, participation in interregional cooperation projects (mostly EU co-funded), etc.

For strengthening the Provincial Civil Protection and down-scaling the experience to municipalities, the province in 2004 established **1st Provincial Civil Protection System** by engaging/working *with all relevant local and national stakeholders* for the purpose of prediction, prevention, disaster management, and post-disaster recovery. This system was praised by the National Civil Protection Department and is *serving as a Model for other Italian Provinces*. The system currently serves for:

- Planning and management of many regional/national/interregional and EU *cooperation projects* (investigation of specific risks and topics);
- Preparedness, trainings, information campaigns, drills, etc.;
- Project management of risk-mitigation interventions (accounted for several M€);
- Participation in major national emergencies;
- Providing support (NOT substitution) to municipalities (on voluntary basis).

The vision and the strategy of the Provincial Territorial Coordination Plan (TCP) (Fig. 8) is to achieve resilience [6], i.e.

Territorial safety
+
Sustainable Development
+
Climate Change
=
#weResilient

Figure 8. Provincial Structural Master Plan of the Province of Potenza.

The purpose of TCP is to provide land use and government policy coordination (Fig. 9) through:

- Strategic and structural development action-plan based on extensive wide-area analysis and programs of *governance* interventions on different interacting sectors, including: Environment (natural, environmental and landscape systems); settlements and urban structure (urban, *periurban*, suburban, open-land areas); relational system; viability, mobility, transport and other infrastructures; energy, productive sectors (tertiary, agriculture, industry), social, cultural, etc. systems; and territorial data collection and organization (GIS);
- Transversal factors: Territorial safety (DRR+CCA+CCM) and sustainability (SDGs) leading to resilience.

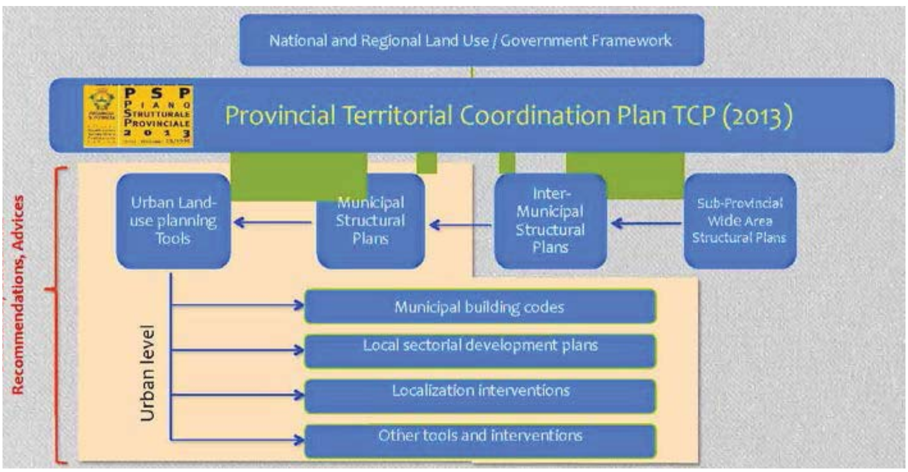


Figure 9. Provincial Territorial Coordination Plan (TCP) of Province of Potenza.

5. Make Cities Resilient

The United Nations Make Cities Resilient UNISDR Campaign (MCR) [7] aims at down-scaling policies into actions at city level by addressing poverty, hunger, health, education, equity, clean water and sanitation, energy, economy, innovation and infrastructure, inequality, sustainability, consumption, climate, green spaces, justice, and collaboration (Fig. 10).

Figure 10. Making Cities Resilient (MCR) objectives [7].

The actions taken by Province of Potenza for reducing disasters involved evaluating 10 *essentials* used in MCR [8]. Figure 11 illustrates some examples of this evaluation where 41 indicators were employed for different cities in the province. The 10 essentials are:

Essential 1: Put in place organization and coordination
Participation of citizen groups and civil society. Build local alliances (Mostly Civil Protection volunteers).

Essential 2: Assign budget
Assign a specific budget for disaster risk reduction. Provide incentives (mostly after disasters).

Essential 3: Up-to-date data on hazards and vulnerability
Maintain up-to-date data. Risk assessment in urban level plans and decisions.

Essential 4: Invest and maintain critical infrastructures
Investment in maintenance of critical infrastructure (critical for financial problems).

Essential 5: Schools and health facilities
Assessment only by law (critical for financial problems).

Essential 6: Risk compliant building regulations and land use planning principles
Moderate risk compliant land use planning (referred mostly to disaster management activities).

Essential 7: Ensure education programs and training
Few direct programs and training on disaster risk reduction (Mostly higher level initiatives).

Essential 8: Protect ecosystems and natural buffers
Few direct actions (mostly national, regional and provincial actions)

Essential 9: Install early warning systems, disaster management capacities, drills.
Few direct actions (mostly national, regional and provincial actions).

Essential 10: After any disaster, ensure the needs of the survivors for reconstruction
Very critical at the municipal level.

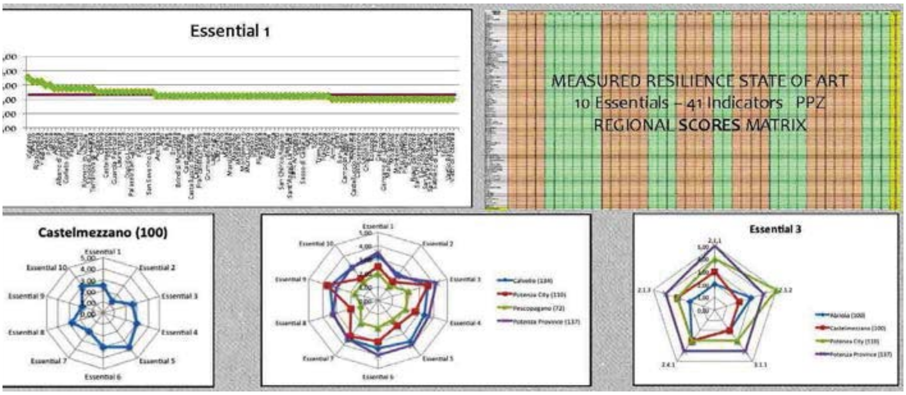


Figure 11. Indicators of some essentials of MCR for different cities in the Province of Potenza.

The results of this evaluation point out some gaps or barriers that exist at the municipal level, i.e.

1. Low public support – Political will;
2. Poor dialogue with and within stakeholders small-sized municipalities;
3. Urban structure unfit to cope with disasters and climate changes injuries;
4. High urban and communities sprawl;
5. Lack of information (including data);
6. Lack of resources;
7. Lack of skills and capacities;
8. Low community engagement in decision making;
9. Lack of public awareness.

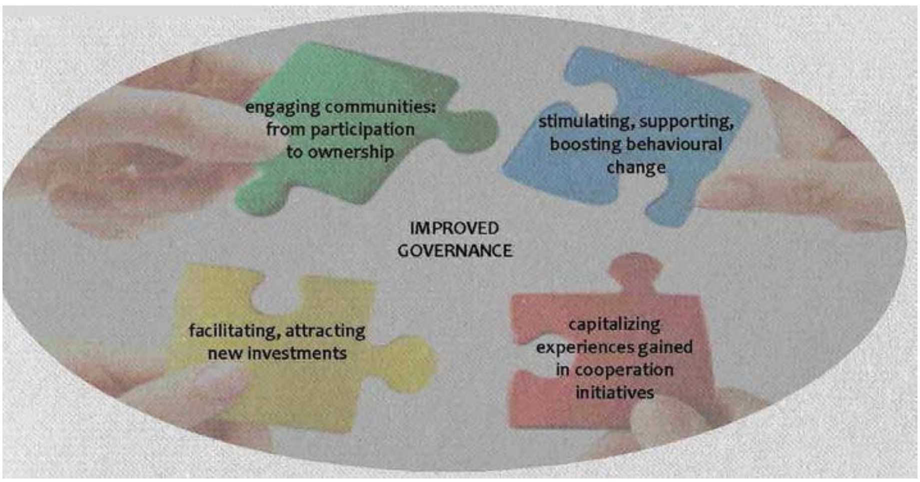
The following is a list of suggestions as Inputs for the Strategy:

1. Act on a “structural” channel: Land-Use and Government Policy Coordination;
2. Engage/Involve;
3. Provide support and cooperation;
4. Entrust and empower and facilitate dialogues with stakeholders;
5. Build partnerships and share experiences;
6. Collect and facilitate data circulation (example: GIS);

7. Attract private business;
8. Enhance capacities;
9. Progressively engage civil society in decision making;
10. Enhance public awareness.

Boosting political leadership and subsidiary *networking* for building local resilience and exchanging and advocating partnerships with cities and countries in transnational cooperation is essential for reaching the goals of Sendai Framework for Disaster Risk Reduction 2015-2030 [9] (Fig. 12). Figures 13 suggests the requirements for improving the governance through engaging communities, stimulating behavioral change, cooperating, and attracting investments. Figure 14 lists the elements of cooperation initiatives, and Fig. 15 the necessity of pursuing funding opportunities.

Figure 12. #weResilient network for resilience.



Figurte 13. Elements of improved governance.

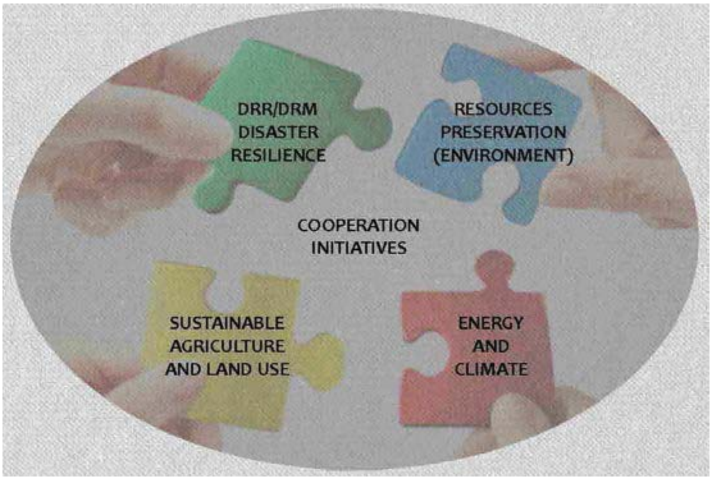


Figure 14. Elements of cooperation initiatives.

Figure 15. Funding opportunities.

6. Review Process

As a review of our work at the Province of Potenza, we can list the following key considerations:

1. Resilient and sustainable development is built on a shared vision and a well-structured strategy;
2. Implementation must be constantly monitored;

3. Different methodologies and tools must be used, such as qualitative/quantitative data collection (indicators); multiscale and multilevel elaboration and diffusion; and standardized methodologies, tools and data: ISO 37120, ISTAT, ESW (BES), LGSATs/Scorecard, Covenant of Mayors Climate and Energy, etc. (a mainstreaming process is ongoing);
4. Accountability is a critical element;
5. The strategy must be periodically reviewed and recalibrated on specific needs, FuR and accountability outcomes;
6. Networking must use of permanent *platform* with municipalities, relevant stakeholders, and major groups;
7. Exchanges, partnerships, coordination, and leadership must be maintained.

7. Final Considerations

The #weResilient hashtag and Inclusive Strategy and MCR Campaign attempt to establish:

- Strong Political and Institutional Commitment;
- Coordination of 100 municipalities and boosting resilience policy through the political channel.

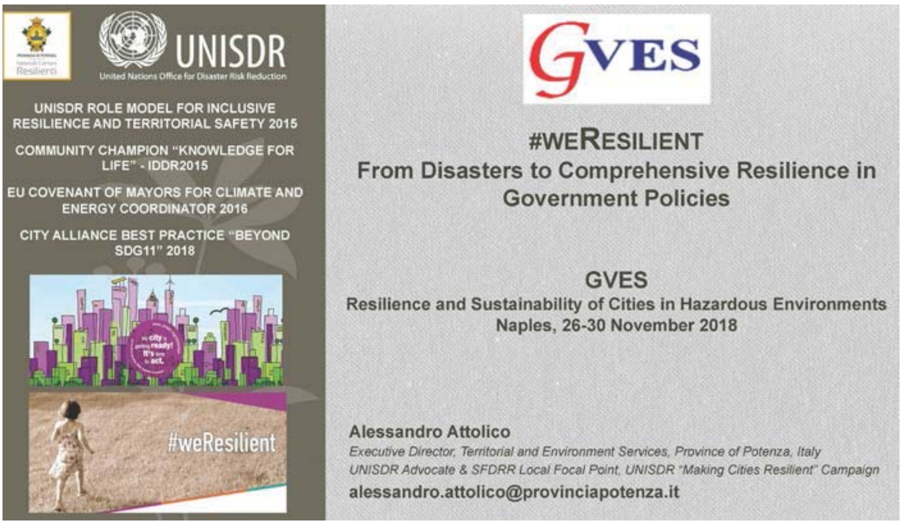
Political support:

- Inclusion of communities and social groups in decision making moving from the institutional side;
- Land-use and territorial governance with medium/long term strategies;
- Institutional bottom-up approach growing at wider and upper levels;
- Networking facilitates city-to-city knowledge exchanges and sharing of GPs;
- Advocacy: Strategically pushing for action every single day!

Achieving long-term resilience and Sustaiunable Development Goals:

- #WeResilient: Building a resilient and sustainable development for communities and future generations;
- Need for new/innovative tools (normative frameworks, standards, etc.) that allow downscaling wide national strategies to local plans and actions in an integrated, multiscale (national and regional city) and coordinated way:
- Empower Local Actors (local governments): Increase public support, political leadership, reinforce governance and institutions to manage development processes;
- Perform a clear and well-structured stakeholders' engagement: Multi-stakeholders approach;
- Empower local communities: Provide for active participation/engagement in relevant local decision making processes, assuring *inclusivity* (no-one excluded)

- **I**nvest in **individuals** for improving: attitudes, knowledge, awareness, capacities, skills, etc.
- Strengthen **networking and** build **partnerships**: between/among/across institutions, key-stakeholders and communities, also through regional/national/transnational cooperation programs
- Improve **governance**: establish a well defined strategy, measurable targets, implementation methodology and tools, transparency and accountability, monitoring and review processes à availability of **certified data**, at all levels, and their permanent collection and update is still a challenge
- Assure institutional ***subsidiarity*** but always preserving individual ownerships and leadership
- **Invest in safety (SFDRR is crucial on this!) and in economic, social, cultural and environmental resilience:** safe, resilient and sustainable human settlements are the foundations of SDGs:
- Provide for **poverty eradication**, starting from ensuring basic lifelines and resources (for example water, energy, basic services, etc.)
- Invest in ***Advocacy***: build a strong network of very skilled and motivated individuals who could provide support and facilitate the implementation processes acting as facilitator for policy-makers
- Action … Action … Action !



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Vesuvius and Campi Flegrei Evacuation Plans

Implications for Resilience and Sustainability of Neapolitans

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Abstract. The Evacuations Plans of Vesuvius and Campi Flegrei require the displacement of several million people in several days prior to the eruptions of Neapolitan volcanoes and resettle them all over Italy, but are unreliable from the technical, socio-economic, and cultural perspectives. These plans have been politicized through the regulatory capture of special interests and are institutionalizing fallacies that work in detriment to the achievement of resilience and sustainability for Neapolitans. Such massive deportation strategies are keeping the Neapolitans hostage to ignorance, slowing the development of resilience and sustainability science for the territory, and inviting disasters.

Keywords: Vesuvius, Campi Flegrei, Phlegraean Fields, evacuation plans, resilience, sustainability

1. Introduction

Vesuvius and Campi Flegrei (Phlegraean Fields, Campi Phlegraei) volcanoes in the Bay of Naples have been producing explosive eruptions for millennia and the neighboring populations managed to cohabit with these volcanoes since the dawn of civilization. During the past 30,000 years Vesuvius has produced a dozen of explosive eruptions with each eruption ejecting several cubic kilometers of material. In between of these eruptions the volcano produced an order of magnitude smaller explosive eruptions that terminated with effusive activities [1]. The Campi Flegrei volcanic complex has been active for at least 60,000 years and during this time produced two super eruptions, with each erupting 10-100 times more material than the largest eruptions of Vesuvius and on which the city of Naples is built [2]. The volcanic deposits around these volcanoes [3] are, however, poorly constrained, because of the urbanization that covers large parts of the areas where these deposits are located and absence of verifications of the studied deposits. The scenarios of future eruptions [4] also produce large uncertainties of the potential effects of eruption products on the built environments on the slopes of volcanoes, and the Vesuvius Observatory (Osservatorio

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Vesuviano) that monitors these volcanoes for seismicity, deformation of ground, and gas content is unable to associate the current ground uplift at Campi Flegrei and occasional rise of seismicity below Vesuvius with impending eruptions [5].

There are thus difficult choices for several million people cohabiting with Neapolitan volcanoes whose future eruptions are certain, but uncertain when they will occur. The Neapolitans can simply wait for the impending eruptions and then try to escape or can build resilient and sustainable habitats for cohabiting with volcanoes. The first choice pursues the *emergency culture* and has been politicized by the geologists through their Vesuvius [6] and Campi Flegrei [7] evacuation plans, with the objective of forcefully resettling several million people around the volcanoes in different Italian regions without first conducting a feasibility study whether such a strategy is acceptable to both the displaced people and to the people that should host the refugees for an undefined period of time. The second choice promotes the *security culture* and is called VESUVIUS 2000 [8]. This strategy calls for an interdisciplinary and transdisciplinary feasibility study to determine how resilience and sustainability can be achieved for Neapolitans, before implementing any seismic and volcanic risk mitigation plans that require territorial interventions.

The Vesuvius and Campi Flegrei Evacuation Plans discussed in this paper are unreliable from the technical, socio-economic, and cultural perspectives, and work against building resilience and sustainability for the Neapolitan area. The regulatory capture and institutionalization of fallacies of these plans are preventing the development of such solutions and are inviting severe consequences not only for the Neapolitans but also for the nation and for the European Union whose resilience and sustainability will suffer. In the following we will elaborate on these issues and conclude that we should abandon the policies of massive deportations and work instead to produce safe and prosperous habitats for the people who want to cohabit with these volcanoes.

2. Vesuvius and Campi Flegrei Evacuation Plans

Vesuvius and Campi Flegrei evacuation plans require resettlements of some two million Neapolitans in different Italian regions as shown in Fig. 1, but do not consider what to do with the one million people from the city of Naples nor specify how to deal with the abandoned territories or specify that the displaced populations can return to their former habitats after the eruptions. These plans also do not consider plinian and super eruptions of the volcanoes, do not address the reliability of evacuation means (vehicles, ships, trains) in the presence of earthquakes that shake the ground and cause the collapses of buildings and blockage of escape routes, only vaguely quantify the parameters (earthquakes, ground deformation, gas content) associated with alert and evacuation levels, do not consider the possible panic of population from the collapses of pre-determined plans, and do not address the interactions and consequences of complex system components where a small system failure can lead to the entire system collapse [6, 7, 9–11].

Figure 1. Vesuvius and Campi Flegrei evacuation plans require the resettlement of some three million Neapolitans in different Italian regions. Department of Civil Protection (Dipartimento della Protezione Civile) [6, 7, 9, 10].

When the Vesuvius evacuation plan was issued in 1995 it required the prediction of an eruption at least three weeks in advance in order to evacuate 600,000 people, but after it was criticized [12] that the scientists cannot reliably predict an eruption for this time window the geologists consulting the Civil Protection (Protezione Civile) changed this prediction window to three days in advance to be closer to two to three days associated with the predictions of eruptions of Mount St. Helens in 1980 and Pinatubo in 1991 [13, 14]. The two to three days prediction windows of eruptions of explosive volcanoes (Vesuvius and Campi Flegrei belong to this category) are based on the harmonic tremors of about 10 Hz, produced by the magma rising in conduits and the Vesuvius Observatory *has not been recording such signals* [5]. Instead, the recorded sporadic increases and decreases of seismicity of Vesuvius and Campi Flegrei are interpreted as arising from the local tectonics and exsolution of gases, if it is assumed that some magma already exists at several kilometers from the surface [15]. Furthermore, even the precise identification of the epicenters of earthquakes is often problematic, as recently demonstrated for the 2017 Ischia earthquake where the observatory made the wrong prediction of earthquake epicenter and caused damage to the tourist industry of the island and faced considerable criticisms of its operations [16].

A simple calculation shows that an evacuation of 600,000 people from the Central Station of Naples would require some 200 trains, or a train departing the station with 3000 people every 20 minutes during 72 hours. This is simply unreliable, not only because of the impossibility of carrying out such an engineering logistics nightmare in the absence of appropriate infrastructure, but also because of the high probability that the railroad tracks will go out of the alignment from the presence of frequent earthquakes and terminate train arrivals and departures. When this was also criticized [12] the Civil Protection opted for the evacuations with buses and private vehicles, and failed again to justify the transportation logistics, such as to demonstrate the reliability of the supply and distribution of fuel for road vehicles, coordination of state and private vehicles on the shaking territory maneuvering through the streets with collapsed buildings and bridges, clearing of abandoned vehicles for other vehicles to pass through, etc. The revisions of evacuation plans have been cosmetic [9, 10] and are not convincing who will give evacuation orders and on the basis of what levels of monitored parameters [11]. Moreover, if Vesuvius and Campi Flegrei volcanos were to erupt with one of their plinian or super eruptions the proposed evacuation strategies would be inadequate, because it would leave several million people on the Campanian Plain and bordering regions on the mercy of the volcanoes.

Assuming that the people can be evacuated from the immediate danger areas, will the evacuees safely arrive to the predetermined hosting areas and will the hosts accept the masses of people that lost everything, have been separated from their preferred environments, and have to rebuild their lives? Taking the recent lesson from Middle Eastern and African refugees in Europe it is an illusion to expect that the refugees will easily adapt to new environments, not only because the evacuees will demand equal opportunities in hosting areas and thus produce socio-economic consequences, but also because the assimilations of different cultures take generations and in the process each culture strives to preserve its identity. There is also the danger that the cities hosting the evacuees will experience a significant reduction of their resilience and sustainability. Because of these issues many evacuees risk never arriving to their destinations and being housed in makeshift houses for years along the evacuation routes through the expenditures of significant National and European Union resources.

And what will happen to the abandoned territory? Can it be protected and for how long, should we be concerned with the destruction of the Neapolitan culture and changes of the cultures of hosting regions, should we allow or forbid (how) the influx of immigrants into the abandoned territories from the non-evacuated areas with high demographic pressures or from poor economic areas elsewhere? These concerns have been voiced since 1995 and have fallen on deaf ears with the mass media being unable or unwilling to present the issues to the population [12].

Vesuvius and Campi Flegrei evacuation plans have been institutionalized [17–19, and many others], and why bother with their consequences when the time scales of volcanic eruptions are inconsistent with life spans of evacuation plans' architects and proponents that also manage the Vesuvius Observatory? In 1995 the Observatory was the principal promoter of Vesuvius evacuation plan and ever since its researchers, and those of its parent institution INGV (Istituto Nazionale di Geofisica e Vulcanologia), have shown no interest in collaborating with those of us who are developing the alternative resilience and sustainability framework for the Neapolitan area [8, 20] and prefer instead to live dangerously [16] by bearing the responsibility for the consequences of their choice.

3. Implications for Resilience and Sustainability

The consequences of Vesuvius and Phlegraean Fields Evacuation Plans are: (1) replacement of resilience and sustainability with insecurity, stagnation of socio-economic development; (2) destruction of Neapolitan culture that even the volcanoes have not been able to accomplish in millennia; (3) corruption of weak researchers and public officials; (4) forcing the European Union to accept non resilient and sustainable policy for the Neapolitan area and generously supporting the research activities of the proponents of this policy; (5) marginalization of those who work in the direction of promoting resilience and sustainability for the territory; (6) suffocating interdisciplinary and transdisciplinary collaborations for risk management of complex systems; etc. The regulatory capture, spread of fallacies, and appeal to ignorance are the principal means by which the evacuation plans are succeeding in building the emergency culture and suffocating the development of the security culture in the Neapolitan area.

3.1 Regulatory Capture

Regulatory capture is a form of government failure which occurs when a regulatory agency, created to act in the public interest, instead advances the concerns of special interest groups that dominate the sector it is charged with regulating. In our situation the regulatory agency is the Italian Civil Protection and the special interest group comes from the Italian earth science community with strong lobbies in Brussels that ensure substantial supports for European earth science researchers associated with the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). This is the "mondo scientifico" that is used to justify Vesuvius and Campi Flegrei evacuation plans and convince Civil Protection that "everything is under control" without specifying what exactly is *under control*.

When the architects of flawed evacuation plans impose on their clients the enforcements of these plans and silence dissenting views one can only expect disastrous outcomes. This happened in 2009 in l'Aquila with earthquakes [21] where 308 people died and in 2011 in Fukushima with nuclear reactor accidents [22] where the people evacuated in the direction of propagating radioactive cloud and the accident left 30,000 km^2 of Japanese territory polluted and 650 km^2 exclusion area around the reactors.

3.2 Fallacies

Aristotle [23] was the first to discuss fallacies. Fallacies are false premises, and some of the prominent ones are appeal to authority, appeal to ignorance, and ignoring the issues.

The fallacy of *appeal to authority* occurs when someone accepts a truth on blind faith just because someone admired said it. In our situation this someone are the architects of Vesuvius and Campi Flegrei evacuation plans who with the control of volcano monitoring instruments and similar international collaborators, apparently have all the authority to claim to be the "ultimate authority" on deciding what to do with the Neapolitans and deciding the scientific research on volcanoes.

The fallacy of *appeal to ignorance* occurs when someone asserts a claim that must be accepted because no one else can prove otherwise. In our situation again, the populations around the Neapolitan volcanoes have no experiences with eruptions and cannot properly judge their potential consequences or the consequences of massive evacuations. The proponents of such evacuations know this and thus thrive in this ignorance. Only an electorate educated on volcanic risk can force its elected representatives to work for its interests, but unfortunately we are far from reaching this goal [24].

The third fallacy of *ignoring the issues* is not only practiced in political and some scientific organizations when their members commit grave errors [25], but also by many mass media that prefer to follow the official lines to maintain their access to authorities rather than to expose their wrongdoings [12].

When fallacies become "truth" it takes an extraordinary event to change their spreading, because the people start demanding changes. Unfortunately, this becomes too late for many and leaves a dark mark on the society. And the society alone becomes responsible for the consequences when it allows its elected officials to operate in a risky manner.

3.3 Resilience and Sustainability Framework

Building resilient and sustainable Neapolitan area for large and small eruptions of Vesuvius and Campi Flegrei requires a reorganization of the Campanian Plain for short- and long-term time frames, and a framework for addressing this objective can be accomplished through the achievement of five major objectives called VESUVIUS–CAMPIFLEGREI PENTALOGUE [20].

This framework delineates exclusion, resilience, and sustainability areas surrounding each volcano, where no permanent habitats are allowed in the exclusion area and the people in the resilience belt, surrounding the exclusion area, can be temporarily evacuated into the sustainability area, surrounding the resilience belt, until the volcanic crisis subsides. After the volcanic crises most of the evacuated people should be able to return and rebuild their habitats.

According to this framework no massive deportations of people are required, there is no need to house evacuees in distant places and uproot them from their local environments, and no need to build and maintain massive evacuation infrastructure, because the people can simply walk to their temporary settlement on short notice. The *sense of place and belonging* is a central pillar of sustainability [26] and it has been structured in VESUVIUS 2000 and five of its central objectives VESUVIUS–CAMPIFLEGREI PENTALOGUE.

4. Conclusions

We discussed some critical issues associated with Vesuvius and Campi Flegrei evacuation plans and stressed that they are unreliable technically, socio-economically and culturally, and work in detriment to the accomplishment of resilience and sustainability in the Neapolitan area. Their existence is rooted in the regulatory capture of special interests and institutionalization of fallacies that will have long term negative consequences. For the time-scales of Vesuvius-type eruptions, the immediate areas surrounding the craters of Vesuvius and Campi Flegrei should be excluded from permanent habitation, the belts surrounding the exclusion areas should be made resilient, and the areas beyond the resilient belts should be made sustainable and capable of temporarily housing the populations from high danger areas during the volcanic crises. For the time-scales of Campi Flegrei super eruptions these belts should be extended further out into the Campanian Plain.

The ultimate danger of Vesuvius and Phlegraean Fields evacuation plans is that they exist for the benefit of special interests, give the elected officials excuses not to produce the Neapolitan area resilient and sustainable, corrupt weak researchers, give the stakeholders false hopes, and are depriving the Neapolitans from constructing better lives in the area reserved for social, economic, environmental, and institutional developments.

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Vesuvio e Campi Flegrei Piani di Evacuazione
Implicazioni per la resilienza e la sostenibilità per napoletani

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Riassunto. I piani di evacuazione del Vesuvio e dei Campi Flegrei richiedono lo sfollamento di diversi milioni di persone in pochi giorni prima delle eruzioni dei vulcani napoletani e il loro reinsediamento in tutta Italia, ma sono inaffidabili dal punto di vista tecnico, socio-economico e culturale. Questi piani sono stati politicizzati attraverso la cattura regolamentare di interessi speciali e stanno istituzionalizzando le fallacie che impediscono il raggiungimento della resilienza e della sostenibilità per i napoletani. Tali massicce strategie di deportazione tengono in ostaggio della ignoranza i napoletani, rallentano lo sviluppo della scienza della resilienza e della sostenibilità per il territorio e procurano disastri.

Parole chiave: Vesuvio, Campi Flegrei, piani di evacuazione, resilienza, sostenibilità

1. Introduzione

I vulcani del Vesuvio e dei Campi Flegrei nel Golfo di Napoli producono eruzioni esplosive da millenni e le popolazioni vicine sono riuscite a convivere con questi vulcani sin dagli albori della civiltà. Negli ultimi 30.000 anni il Vesuvio ha prodotto una dozzina di eruzioni esplosive con ogni eruzione espellendo alcuni chilometri cubi di materiale. In mezzo a queste eruzioni il vulcano produsse un ordine di grandezza di piccole eruzioni esplosive che terminavano con attività effusive [1]. Il complesso vulcanico dei Campi Flegrei è attivo da almeno 60.000 anni e durante questo periodo ha prodotto due super eruzioni, ognuna delle quali ha eruttato 10-100 volte più materiale delle più grandi eruzioni del Vesuvio su cui è costruita la città di Napoli [2]. I depositi vulcanici intorno a questi vulcani [3] sono, tuttavia, scarsamente vincolati, a causa dell'urbanizzazione che copre vaste parti delle aree in cui si trovano questi depositi e l'assenza di verifiche di depositi studiati. Gli scenari delle eruzioni future [4] producono anche grandi incertezze sui potenziali effetti dei prodotti di eruzione sugli ambienti costruiti sulle pendici dei vulcani e l'Osservatorio Vesuviano, che monitora questi vulcani

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per la sismicità, la deformazione del suolo e il contenuto di gas, non è in grado di associare l'attuale innalzamento del suolo dei Campi Flegrei e occasionali aumenti di sismicità sotto il Vesuvio con eruzioni imminenti [5].

Vi sono, quindi, scelte difficili per diversi milioni di persone che convivono con vulcani napoletani le cui future eruzioni sono certe, ma incerte su quando si verificheranno. I napoletani possono semplicemente aspettare le imminenti eruzioni e, quindi, cercare di fuggire o costruire habitat resilienti e sostenibili per la convivenza con i vulcani. La prima scelta persegue la *cultura di emergenza* ed è stata politicizzata dai geologi attraverso i loro piani di evacuazione del Vesuvio [6] e dei Campi Flegrei [7], con l'obiettivo di reinsediare forzatamente diversi milioni di persone attorno ai vulcani in diverse regioni italiane, senza prima condurre uno studio di fattibilità se una tale strategia sia accettabile sia per gli sfollati, sia per le persone che dovrebbero ospitare i rifugiati per un periodo di tempo indefinito. La seconda scelta promuove la *la cultura della sicurezza* ed è nominata VESUVIUS 2000 [8]. Questa strategia richiede uno studio di fattibilità interdisciplinare e transdisciplinare per stabilire come sia possibile raggiungere la resilienza e la sostenibilità per i napoletani, prima di implementare i piani di mitigazione del rischio sismico e vulcanico che richiedono interventi territoriali.

I piani di evacuazione del Vesuvio e dei Campi Flegrei discussi in questo documento sono inaffidabili dal punto di vista tecnico, socio-economico e culturale, e lavorano contro la realizzazione della resilienza e della sostenibilità per l'area napoletana. La cattura regolamentare e l'istituzionalizzazione delle fallacie di questi piani stanno impedendo lo sviluppo di tali soluzioni e stanno facilitando gravi conseguenze, non solo per i napoletani, ma anche per l'Unione Europea la cui resilienza e sostenibilità ne risentirano. Di seguito approfondiremo questi argomenti e concluderemo che si dovrebbe abbandonare le politiche di deportazioni massicce e lavorare invece per produrre habitat sicuri e prosperi per le persone che vogliono convivere con questi vulcani.

2. Vesuvio e Campi Flegrei Piani di Evacuazione

I piani di evacuazione del Vesuvio e dei Campi Flegrei richiedono il reinsediamento di circa due milioni di napoletani in diverse regioni italiane come mostrato nella Fig. 1, ma non considerano cosa fare con un milione di persone della città di Napoli, nè specificano come trattare con i territori abbandonati o se le popolazioni sfollate possono tornare ai loro vecchi habitat dopo le eruzioni. Questi piani, inoltre, non considerano le eruzioni pliniane e super eruzioni dei vulcani, non affrontano l'affidabilità dei mezzi di evacuazione (veicoli, navi, treni) in presenza di terremoti che scuotono il terreno e causano crolli degli edifici e bloccano delle vie di fuga, solo vagamente quantificano i parametri (terremoti, deformazione del suolo, contenuto di gas) associati ai livelli di allerta ed evacuazione, non considerano il possibile panico della popolazione dai crolli di piani predeterminati e non affrontano le interazioni e le conseguenze di componenti di sistemi complessi, dove un piccolo fallimento di sistema può causare l'intero collasso del sistema [6, 7, 9–11].

Figura 1. I piani di evacuazione del Vesuvio e dei Campi Flegrei richiedono il reinsediamento di circa tre milioni di napoletani in diverse regioni italiane. Dipartimento della Protezione Civile [6, 7, 9, 10].

Quando il piano di evacuazione del Vesuvio fu emesso nel 1995, richiedeva la predizione di un'eruzione con almeno tre settimane di anticipo per evacuare 600.000 persone, ma dopo che fu criticato [12], perchè gli scienziati non possono prevedere un'eruzione in modo affidabile per questo tempo, i geologi che consultano la Protezione Civile hanno cambiato questa finestra di predizione sostituendola con tre giorni di anticipo per essere più vicini a due o tre giorni associati alle previsioni di eruzioni di Monte St. Helens nel 1980 e Pinatubo nel 1991 [13, 14]. La finestra temporale per la predizione di due o tre giorni di eruzioni di vulcani esplosivi (il Vesuvio ei Campi Flegrei appartengono a questa categoria) si basano sui tremori armonici di circa 10 Hz, prodotti dal magma che sta salendo nei condotti e l'Osservatorio Vesuviano *non ha ancora registrato tali segnali* [5]. Invece, i registrati aumenti sporadici e le diminuzioni della sismicità del Vesuvio e dei Campi Flegrei sono interpretati come derivanti dalla tettonica locale e dall'exsoluzione dei gas, se si presume che il magma esiste già a diversi chilometri dalla superficie [15]. Inoltre, anche la precisa identificazione degli epicentri dei terremoti è spesso problematica, come recentemente dimostrato per il terremoto di Ischia nel 2017 in cui l'Osservatorio Vesuviano fece la previsione sbagliata dell'epicentro del terremoto e causò danni all'industria turistica dell'isola, affrontando critiche considerevoli sulle sue operazioni [16].

Un semplice calcolo mostra che un'evacuazione di 600.000 persone dalla Stazione Centrale di Napoli richiederebbe circa 200 treni, o un treno in partenza dalla stazione con 3000 persone ogni 20 minuti, durante 72 ore. Questo è semplicemente inaffidabile, non solo per l'impossibilità di realizzare un tale incubo logistico di ingegneria in assenza di infrastrutture adeguate, ma anche per l'elevata probabilità che i binari della ferrovia si allontanino dall'allineamento per la presenza di frequenti terremoti e termineranno gli arrivi e le partenze dei treni. Quando anche questo è stato criticato [12] la Protezione Civile ha optato per le evacuazioni con autobus e veicoli privati, e ha fallito ancora una volta per giustificare la logistica dei trasporti, tale da dimostrare l'affidabilità della fornitura e distribuzione di carburante per i veicoli stradali, coordinamento di veicoli statali e privati sul territorio che si agita muovendosi per le strade con edifici e ponti crollati, rimozione di veicoli abbandonati per il passaggio di altri veicoli, ecc. Le revisioni dei piani di evacuazione sono state cosmetiche [9, 10] e non sono convincenti su chi darà gli ordini per le evacuazioni e in base a quali livelli di parametri monitorati [11]. Inoltre, se i vulcani del Vesuvio e dei Campi Flegrei dovessero esplodere con una delle loro eruzioni pliniane o super eruzioni, le strategie di evacuazioni proposte sarebbero inadeguate, perchè lascerebbero diversi milioni di persone nella pianura campana e nelle regioni confinanti in balia dei vulcani.

Supponendo che la popolazione possa essere evacuata dalle aree di pericolo immediato, gli sfollati giungeranno sani e salvi alle aree di accoglienza predeterminate e gli host accetteranno le masse di persone che hanno perso tutto, sono state separate dal loro ambiente preferito e devono ricostruire le loro vite? Prendendo la recente lezione dai rifugiati mediorientali e africani in Europa, è un'illusione aspettarsi che i rifugiati si adatteranno facilmente a nuovi ambienti, non solo perchè gli sfollati chiederanno pari opportunità nelle aree di accoglienza e quindi produranno conseguenze socio-economiche, ma anche perchè le assimilazioni di culture diverse richiedono generazioni e nel processo ogni cultura si sforza di preservare la propria identità. C'è anche il pericolo che le città che ospitano gli sfollati sperimentino una significativa riduzione della loro capacità di resilienza e sostenibilità. A causa di questi problemi molti evacuati rischiano di non arrivare mai alle loro destinazioni e di essere ospitati in "containers" per anni lungo le rotte di evacuazione attraverso le spese di importanti risorse nazionali e dell'Unione Europea.

E cosa accadrà al territorio abbandonato? Può essere protetto e per quanto tempo? Dovremo preoccuparci della distruzione della cultura napoletana e dei cambiamenti delle culture delle regioni ospitanti? Dovremo consentire o vietare (come) l'afflusso di immigrati nei territori abbandonati dalle aree non evacuate con elevate pressioni demografiche o dalle aree economiche povere altrove? Queste preoccupazioni sono state espresse dal 1995 e sono cadute nel vuoto perchè i mass media non sono in grado o non sono disposti a presentare i problemi alla popolazione [12].

I piani di evacuazione del Vesuvio e dei Campi Flegrei sono stati istituzionalizzati [17–19, e molti altri], e perchè preoccuparsi delle loro conseguenze quando le scale temporali delle eruzioni vulcaniche sono incoerenti con gli architetti e i fautori dei piani di evacuazione che gestiscono anche l'Osservatorio Vesuviano? Nel 1995 l'Osservatorio è stato il principale promotore del piano di evacuazione del Vesuvio e da allora i suoi ricercatori, e quelli della sua istituzione madre INGV (Istituto Nazionale di Geofisica e Vulcanologia), hanno mostrato poco interesse a collaborare con quelli di noi che stanno sviluppando la resilienza e la sostenibilità per l'area napoletana [8, 20] e preferiscono invece vivere pericolosamente [16], assumendosi la responsabilità delle conseguenze della loro scelta.

3. Implicazioni per la Resilienza e la Sostenibilità

Le conseguenze dei piani di evacuazione del Vesuvio e dei Campi Flegrei sono: (1) sostituzione di resilienza e sostenibilità con insicurezza, stagnazione dello sviluppo socio-economico; (2) distruzione della cultura napoletana che nemmeno i vulcani sono riusciti a realizzare in millenni; (3) corruzione di ricercatori deboli e funzionari pubblici; (4) costringere l'Unione europea ad accettare politiche di non resilienza e sostenibilità per l'area napoletana e sostenere generosamente le attività di ricerca dei proponenti di questa politica; (5) emarginazione di coloro che lavorano nella direzione di promuovere la resilienza e la sostenibilità per il territorio; (6) soffocare collaborazioni interdisciplinari e transdisciplinari per la gestione del rischio di sistemi complessi; ecc. La cattura regolamentare, la diffusione delle fallacie e l'appello alla ignoranza sono i principali mezzi attraverso cui i piani di evacuazione stanno riuscendo a costruire la cultura della emergenza e soffocando la cultura della sicurezza nell'area napoletana.

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3.1 Cattura regolamentare

La cattura regolamentare è una forma di fallimento del governo che si verifica quando un'agenzia di regolamentazione, creata per agire nell'interesse pubblico, avanza invece le preoccupazioni dei gruppi di interesse speciali che dominano il settore che è incaricata di regolamentare. Nella nostra situazione l'agenzia regolatoria è la Protezione Civile italiana e il gruppo di interesse speciale proviene dalla comunità italiana della scienza della terra con forti lobby a Bruxelles che garantiscono sostanziali sostegni ai ricercatori europei di scienze della terra e associati all'Associazione Internazionale di Vulcanologia e Chimica dell'Interno della Terra (IAVCEI). Questo è il "mondo scientifico" utilizzato per giustificare i piani di evacuazione del Vesuvio e dei Campi Flegrei e convincere la Protezione Civile che *tutto è sotto controllo*, senza specificare cosa sia esattamente *sotto controllo*.

Quando gli architetti di piani di evacuazione difettosi impongono ai loro clienti il rinforzo di questi piani e silenziano delle opinioni dissenzienti, si possono aspettare solo i risultati disastrosi. Questo è accaduto nel 2009 all'Aquila con i terremoti [21] in cui 308 persone sono morte e nel 2011 a Fukushima con reattori nucleari [22], dove le persone sono state evacuate in direzione della propagazione di nuvole radioattive e l'incidente ha lasciato 30.000 km^2 di territorio giapponese inquinato e un'area di esclusione di 650 km^2 attorno ai reattori.

3.2 Fallacie

Aristotele [23] fu il primo a discutere delle fallacie. Le fallacie sono falsi presupposti e alcuni di quelli importanti si rivolgono all'autorità, fanno appello all'ignoranza e ignorano i problemi.

La fallacia *dell'apello alla autorità* si verifica quando qualcuno accetta una verità sulla fede cieca solo perchè qualcuno lo ammira. Nella nostra situazione questo qualcuno è l'artefice dei piani di evacuazione del Vesuvio e dei Campi Flegrei che, con il controllo degli strumenti di monitoraggio del vulcano e dei simili collaboratori internazionali, sembrano avere tutta l'autorità per affermare di essere l'autorità suprema nel decidere cosa fare con i napoletani e quale ricerca scientifica perseguire sui vulcani.

La fallacia *dell'appello all'ignoranza* si verifica quando qualcuno afferma un reclamo che deve essere accettato perchè nessun altro può dimostrare il contrario. Di nuovo nella nostra situazione, le popolazioni intorno ai vulcani napoletani non hanno esperienze con le eruzioni e non possono giudicare adeguatamente le loro potenziali conseguenze nè le conseguenze delle massicce evacuazioni. I fautori di tali evacuazioni lo sanno e prosperano così in questa ignoranza. Solo un elettorato educato al rischio vulcanico pu'o costringere i suoi rappresentanti eletti a lavorare per i suoi interessi, ma sfortunatamente siamo lontani dal raggiungere questo obiettivo [24].

La terza fallacia di *ignorare i problemi* non è praticata solo nelle organizzazioni politiche e in alcune organizzazioni scientifiche quando i loro membri commettono gravi errori [25], ma anche da molti mass media, che preferiscono seguire le linee ufficiali per mantenere il loro accesso alle autorità, piuttosto che esporre i loro errori [12].

Quando le fallacie diventano "verità" ci vuole un evento straordinario per cambiare la loro diffusione, perchè la gente inizia a chiedere cambiamenti. Sfortunatamente, questo diventa troppo tardi per molti e lascia un segno oscuro sulla società. La società da sola diventa responsabile delle conseguenze quando consente ai suoi funzionari eletti di operare in modo rischioso.

3.3 Quadro della resilienza e della sostenibilità

Costruire un'area napoletana resiliente e sostenibile per le grandi e piccole eruzioni del Vesuvio e dei Campi Flegrei richiede una riorganizzazione della pianura campana per periodi di tempo a breve e lungo termine e un quadro per affrontare questo obiettivo può essere raggiunto attraverso il raggiungimento di cinque obiettivi principali del VESUVIUS-CAMPIFLEGREIPENTALOGUE [20].

Questo quadro delinea aree di esclusione, resilienza e sostenibilità che circondano ogni vulcano, dove non sono ammessi habitat permanenti nell'area di esclusione e le persone nella fascia di resilienza (che circonda l'area di esclusione) possono essere temporaneamente evacuate nell'area della sostenibilità (che circonda la cintura di resilienza) fino alla cessazione della crisi vulcanica. Dopo le crisi vulcaniche la maggior parte delle persone evacuate dovrebbe essere in grado di ritornare e ricostruire i loro habitat.

Secondo questo quadro non sono necessarie massicce deportazioni di persone, non è necessario ospitare sfollati in luoghi lontani e sradicarli dai loro ambienti locali, e non c'è bisogno di costruire e mantenere una massiccia infrastruttura di evacuazione, perchè le persone possono semplicemente camminare verso il loro temporaneo insediamento con un breve preavviso. Il *senso del luogo e dell'appartenenza* è un pilastro centrale della sostenibilità [26] ed è stato strutturato in VESUVIUS 2000 e cinque dei suoi obiettivi centrali VESUVIUS–CAMPIFLEGREI PENTALOGUE.

4. Conclusioni

Abbiamo discusso alcune questioni critiche associate ai piani di evacuazione del Vesuvio e dei Campi Flegrei e sottolineato che sono inaffidabili dal punto di vista tecnico, socio-economico e culturale e che non favoriscono la realizzazione della resilienza e della sostenibilità nell'area napoletana. La loro esistenza è radicata nella cattura regolamentare degli interessi speciali e dell'istituzionalizzazione delle fallacie che avranno conseguenze negative a lungo termine. Per le scale temporali delle eruzioni del Vesuvio, le aree immediate che circondano i crateri del Vesuvio e dei Campi Flegrei dovrebbero essere escluse dall'abitazione permanente, le cinture che circondano le aree di esclusione dovrebbero essere resilienti e le aree oltre le cinture della resilienza dovrebbero essere rese sostenibili e capaci di ospitare temporaneamente le popolazioni dalle zone ad alto rischio durante le crisi vulcaniche. Per le scale temporali dei Campi Flegrei, queste cinture dovrebbero estendersi ulteriormente nella pianura campana.

Il pericolo più grande dei piani di evacuazione del Vesuvio e dei Campi Flegrei è che esistono per il beneficio di interessi speciali, danno alle autorità scuse per non produrre l'area napoletana resiliente e sostenibile, corrompono i deboli ricercatori, danno agli stakeholders false speranze e privano i napoletani della possibilità di costruire una vita migliore nell'area riservata agli sviluppi sociali, economici, ambientali e istituzionali.

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Spatial Planning, Community Resilience and Natural Hazards: A Methodological Proposal for Areas at Volcanic Risk of Naples Metropolitan City

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Abstract. For a long time the disciplines related to the regional sciences have raised the problem of identifying new strategies for emergency planning, with particular attention to the modalities of post-event intervention, both from a technical-engineering and a planning point of view. In this paper we discuss how to overturn this perspective by starting from an analysis of some concrete case studies and the need to plan the actions and to manage the emergency with particular reference to the volcanic risk in the Metropolitan City of Naples where potentially devastating effects could arise. The expected outcome is to structure a method able to identify, in the case of evacuation and delocalization of populations and activities, the most suitable and congruent hosting territories with the socio-economic and cultural characteristics and vocations of the hosted locations. This method is based on a model of trans-communal planning, which overcomes emergency planning but operates on the basis of subsidiarity, solidarity federalism and cooperation principles, and is strongly characterized by an adaptive, multidimensional, and multiscale approach.

Keywords: Resilient spatial planning, adaptive capacity, disaster governance

1. Spatial Planning and Civil Protection, Towards a Trans-Communal Planning Model

The socio-economic contexts of contemporary era are characterized by the intensity and "globality" of relationships, making economic base of territories in continuous evolution [1,2]. We are attending to an ever more pervasive intensification of communication and information flows, with the new possibilities offered by telematics technology and data digitization, for transmitting images, data, knowledge and ideas instantly and almost everywhere.

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At the same time, there is an equally clear and increasing acceleration and increase in the consistency of capital, goods, and people flows. The innovative technologies, such as Big Data Analytics, Internet of Things, 3D Printing, Augmented Reality, to name but a few, characterize what is now defined by many as the fourth industrial revolution that is radically changing the way in which objects are designed, manufactured, distributed, and the way services are provided around the world. In particular, the technological development in the manufacturing, communications and mobility sectors is changing the concept of contiguity, in the sense that the territorial proximity is no longer the only one possible. These social, economic, and cultural processes tend to reorganize physical space, which appears to be less and less characterized by territorial adjacency, instead of functional and systemic contiguities. The “space-time compression” predicted by David Harvey [3,4] has arisen, allowing for an increasingly fragmented society in an increasingly globalized territorial context, in which the goods and information can be conveyed in real time. This changes the setting of the planning activity, since it broadens the framework of relationships, and often in positive terms, in the sense that synergistic relationships can benefit from a different geographical location to make the processes complementary and holistic [5].

This imposes a thematic analysis of the territories that constitutes the starting point for deciding the relationships on which to develop planning processes, no longer characterized by territorial and physical contiguity, but by a trans-communal dimension constituted by a continuous and interconnected flow of goods, people, and information.

One of the most interesting aspects in which this model of trans-municipal planning may find its natural application is in the planning of those territories that fall into possible areas of seismic and/or volcanic crises and are programmed for dislocating the inhabitants through coordinated solutions with twin territories. These solutions require the joint development of economic, cultural, and social activities, and are required to be put in place in “peacetime”, regardless of the occurrence of a crisis. In order for follow this vision, it is necessary to elaborate scenarios of “active prevention”, by planning solutions that develop economic and cultural activities as well as social networks within the twinned localities, and through the programming and planning of synergistic actions.

2. Materials and Methods

2.1 Volcanic Risk and Planning in Vesuvius “red zones”

The territory of Campania, and in particular in the province of Naples, is one in which the risk concentration from natural hazards is higher than in other areas of the country. The hydrogeological hazard, the instability of the soil caused by a chaotic and senseless land use, the seismic, and the volcanic hazard represent direct dangers for the Neapolitan population [6]. Among these, it is precisely the volcanic risk that is most underestimated.

In the province of Naples there are two active volcanoes that are the most dangerous in the world, both for their destructive potential and for the number of people exposed to the danger, and therefore at risk: the Vesuvius and the caldera of the Phlegraean Fields. There are a total of about 700,000 inhabitants in the Red Zone of Vesuvius and 550,000 people in the Red Zone of the Phlegraean Fields. The National Civil Protection has assumed the risk management of Vesuvius by drafting two successive evacuation plans, with the aim of saving the people around the volcano by relocating them to different areas in Italy [7].

An "awakening" of Vesuvius can cause an unprecedented human and environmental catastrophe due to the high population density very close to the crater of the volcano. Even a small eruption could produce many deaths and affect at least 3,000,000 people living within 30 km from volcano, where the infrastructure is completely inadequate to handle an emergency for such a high-risk territory. About 1,000,000 people live within 7 km from the crater of Vesuvius, with a population density that reaches peaks of 15,000 inhabitants per square kilometer (Portici, San Giorgio).

First of all, we want to highlight the deep difference between this kind of risk management and that of post-earthquake reconstruction needs which necessarily happen after disasters occur [8]. While in the case of territories and populations at risk of earthquakes the planning must be focused on the partial mitigation of this risk (thanks to the modern building technologies available today) and to reducing the discomfort suffered by the displaced persons, in the case of the proposed Vesuvius risk management (for which a plinian eruption is also possible but not considered in risk management) it is foreseen that in a crisis the inhabitants will be relocated to other locations for the undefined time periods, with the well-known problems of "disorientation" that will derive from this resettlement [9]. Programming must therefore take place before an emergency, and identifying the host territories with scientific criteria and planning the delocalization of populations and activities is a necessity [10].

The mitigation of volcanic risk based on emergency evacuation plans assumes that the populations can be safely evacuated before the eruptions and therefore that the eruptions can be predicted on time and that the politicians will know how to effectively act on the basis of these predictions [11].

2.2 Limits of Current Planning

The National Emergency Plan of the Vesuvius Area, elaborated on the basis of the assumed sub-plinian eruptive event determined by the geologists, identifies two areas with different hazard levels, defined as the Red Zone and the Yellow Zone [7]. The Red Zone is the area immediately surrounding the volcano, and therefore more dangerous since it is potentially subject to the propagations of pyroclastic flows which are mixtures of gas and solid materials at high temperatures that, flowing along the slopes of the volcano at high speed, can quickly destroy everything on their paths. As recent computer simulations suggest [12], the pyroclastic flows will not develop at 360° around the volcano, but will channel in different directions. The pyroclastic flows are produced from the collapses of volcanic columns and in the situation of Vesuvius may not develop at the beginning of the eruption but after a significant plinian activity where the material rises high into the atmosphere and falls as ash at low temperature [13]. The Vesuvius evacuation plan requires a complete evacuation of the red zone before the start of the eruption.

As stated previously, in order to create a stable and mutually beneficial cohabitations of the hosted and the hosts, the Municipalities belonging to the Red Zone need integrated planning and development policies able to mitigate the risk, and also to foster the economic production and cultural and tourism activities, in accordance with the historical vocations of each territory. The importance of such an approach is even more evident if we consider that, together, the two Red Zones of the Metropolitan City of Naples pertaining to Vesuvius and Phlegraean Fields include about 1,200,000 inhabitants on a territorial extension of approximately 485 km^2, which when compared to the area of the Metropolitan City of Naples correspond to 40% of the total population (3,107,336) and 41% of the territorial extension (1,171 km^2), respectively. Even if it could be possible to reduce the population densities in the areas of high risk around the volcanoes, it is not conceivable to produce the desertification of these areas, since it has not occurred in the past.

With this structure and in order for risk mitigation to fall into a planned hypothesis, it is necessary to promote thematic twinning between the volcanic risk locations and those of the hosts. In fact, if the latter can be chosen for economic, cultural, entrepreneurial affinities, etc., it may be possible to plan the activities in a complementary and synergistic way. Once the potential of the areas at risk are analyzed, the next step should be the choice of host territories capable of binding in an integrative way.

With particular reference to the Emergency Plan for the Vesuvius area elaborated by the National Civil Protection, the limits of the assumptions of this plan are evident. The intense urbanization and inadequate planning of the Vesuvius area have contributed to increasing the risk of people living and working in the area. The elements that determine this risk are the following: The population density is one of the highest in the world; the motorway and railways between the North and the South are located along the coast; the lines of communication and local transport systems are inadequate for mobility of the population and largely insufficient for an area at risk; the local population is unprepared for any volcanic event and has no memory of past eruptions; the concentration of priceless archaeological and architectural resources in the area; and, finally, the role of local administrators who have often delegated and continue to delegate to the central government the problem of governing the territory and planning emergencies.

The emergency evacuation plan for the Vesuvius area assumes that an eruption can be predicted at least two weeks before and that a week before the eruption about 700,000 people can be evacuated from the area and settled in different places throughout Italy. As such, the plan is unreliable under an engineering, socio-political and economic profile. The engineering reliability of the Plan is not justified because it does not take into account the functioning of the communication and transport systems, before and during a volcanic crisis, such as traffic flow, electricity networks, communication and telephone networks, fuel stations, how to get out of the city (who leaves first?); and for the effects of earthquakes that could produce collapses of buildings obstructing the escape routes, which should be provided by the Municipal Emergency Plans that have not yet been produced by the municipalities of the Vesuvius area. The socio-political reliability of the Plan is not justified because the local and national political effects, the "destruction" of the Vesuvius culture, the necessary consultation and information of the populations, and the ways to avoid a possible speculation caused by evacuation in faraway places, have not been taken into consideration. Given the cultural and political differences of the country, such an evacuation will be difficult to manage from a social and political point of view. Finally, the economic reliability of the Plan has not been calculated, such as the cost of a false alarm, the cost of evacuation and any desirable return, the cost to avoid speculation and protect the area during and after the evacuation, the cost to maintain the command and control centers in the area, the costs associated with the hosting regions that should host the evacuees for undefined time periods [14].

3. Results and Discussion

3.1 Land Use Planning and Civil Protection: A Framework for Vesuvius Red Zone

Starting from an analyses carried out at Torre del Greco which is located in the Province of Naples and being one of the most important municipality falling within the areas of the greatest risk of volcanic eruption in Vesuvius Red Zone, we have tried to address the following relevant problems with a lot of issues very intimately related to each other. The first of these is the location choice of the host territories. This requires first of all a verification of the actual territorial transformability and the availability of areas and/or properties to be re-used for accommodating about 1.2 million displaced people (for the Irpinia earthquake of 1980 this amounted to 300,000 people) and a potential impact of instantaneous "migration" that is often underestimated [15,16].

Although not provided in the plans drafted by the National Civil Protection, it is conceivable that the delocalization of populations and activities will be developed in two phases, with the first phase involving temporary settlements before reaching definitive decisions in the second phase. In any case, infrastructural systems, urban fabrics, and public spaces play an essential role in the complexity of a strategy for temporary housing and therefore should be considered as not merely complementary elements in the planning of actions [17].

The second phase in case of catastrophic events linked to particularly destructive eruptive scenarios would lose the characteristics of temporariness and assume the characteristics of permanence, and therefore requires the elaboration of a long-term strategy to be activated "in peacetime", that is before the effects of the crises occur. This relocation strategy can be implemented only through the elaboration of specific thematic analyses, which allow the identification of those host territories similar to those at risk, from the socio-economic, cultural and identity points of view, to facilitate the possibility of thematic twinning with the aim of not giving rise to mere settlement phenomena, but to new urban centers producing sense, sociability, and development. Only in this way can the delocalization avoid trappings of a deportation, and indeed it will be possible to build a development strategy and not an emergency planning. A volcanic risk mitigation strategy for the Vesuvius area called VESUVIUS 2000 requires similar socio-economic and culture-preserving and building requirements, but through the cohabitation of people with the volcano and reorganization of the built environment of the Vesuvius area [18].

3.2 A Method for Sustainable Relocation of People

This approach must be translated into a method, whose main objective is to identify the optimal characteristics of localization of people and activities for the choice of twin territories. It is therefore necessary to proceed with the definition of a Decision Support System (DSS) with procedural methodologies that are repeatable and applicable in the planning processes of all the cities falling within the "red zones" of the Province of Naples. The DSS is a useful and effective tool for implementing and achieving planning objectives, in line with the need to identify the characteristics of host territories [19,20].

To this end, it is necessary to proceed with a preliminary mapping that includes appropriate indicators of the demographic, social, and economic conditions of the hosted territories (Sending Sites (SSs)), with which the homologues indicator of the host territories must be congruent (Receiving Sites (RSs)). The mapping of the territorial conditions allows to highlight the actual productive specializations, and possibly stress, through the plan actions, the territorial vocations barely latent.

The selection of the so-called "landing criteria", that is the criteria for the selection of RSs, is the hard core of the method, which is structured in a stepwise evaluation divided into successive phases, according to four families of criteria [21].

The first one is a "physical-territorial criterion" through which to evaluate the susceptibility to the "transformability" of the RSs. This is a "prescriptive" evaluation criterion, to which a weight and a threshold value can be attributed, whose non-achievement leads to the exclusion of the RSs under examination from the subsequent evaluations. It is defined by a *Territorial Physical Index* given by the combination of a sub-indexes vector, weighed and normalized. Each sub-index will be obtained from the weighed and normalized sum of a set of indicators. The sub-indexes to be built are at least three, and in particular:

1. A sub-index of territorial anthropization, given by the following set of indicators: Population density; relationship between urbanized surface and land area; per capita area allocated services for public functions; ratio between length of railway and road axes and territorial area. This sub-index measures and evaluates the effective availability of RSs to welcome populations and activities by SSs;
2. A sub-index of territorial vulnerability, given by the following set of indicators: Number of plants at risk per km^2; percentage of areas exposed to high and very high hydrogeological risk; seismic hazard level. This sub-index analyzes and evaluates the propensity of RSs to the vulnerability to anthropic and natural risk;

3. A sub-index of territorial protection, given by the following string of indicators: percentage ratio between restricted and/or protected areas and total area; percentage ratio between areas of agronomic value and total area; surface of uncultivated areas on the total.

From the weighted sum of the three sub-indexes, we can then obtain a *Territorial Physical Index*, which will necessarily have a value between 0 and 1.

The assessment of the effective territorial transformability is the first step of the procedure. Exclusively, the RSs that have overtaken a pre-established threshold (for example equal to 0.66, but whose value should be established by the decision makers) will be evaluated according to the following criteria.

The following evaluation criterion is given by the *Containment of Settlement Costs*. In this case, the way of the evaluation is negative: The greater the cost per hectare or square km, the less will be the susceptibility to the location by the RSs of the activities and populations coming from SSs. This is a prescriptive criterion too, to which a threshold value and weight must be applied (prerogative of decision makers): This time, exceeding this threshold automatically entails exclusion from the subsequent phases of the evaluation.

The stepwise evaluation continues with the analysis of the “socio-economic criterion” and the “identity-cultural criterion”. The first is associated with a *Socio-Economic Index* and the second with a *Cultural Identity Index*. Both are descriptive criteria, where the evaluation should be conducted for both the RSs and the SSs. For each criterion, congruence must be calculated between the indexes that describe the RSs and the SSs, respectively, according to an approach similar to that implemented by the territorial marketing, in which a match or a correspondence is sought, between demand and supply of services and territorial functions that may be tangible and intangible. The substantial difference is the reversal of perspective, being in this case certain and measurable (even in the future) the demand and the supply -congruent with this demand- to be identified.

The *Socio-Economic Congruence* can be searched through the analysis and evaluation of a set of appropriate and representative sub-indexes of the socio-economic conditions of both the SSs and the RSs. The sub-indexes that make up the *Socio-Economic Index* should refer at least to: Population and households, housing conditions, education level, labor market, mobility, material and social vulnerability. Each sub-index is in turn formed by indicators that describe the phenomenon in detail. Single indicators, or groups of them, must therefore be compared between RSs and SSs, also through one-to-many or many-to-many comparisons, where necessary and appropriate. Therefore, the congruence between each of the SSs indicators with respect to those chosen for the RSs must be analyzed, assigning to the match a positive or negative symbol (‘+’ and ‘-’), established a priori by a branch expert. It is appropriate to graduate the intensity of this sign by using a symbolic-nominal scale (‘very positive’ = ‘+ +’, ‘very negative’ = ‘- -’), and assign a verse that indicates the desirable maximization or minimization of each value. Subsequently and thanks to an analysis of the frequency of positive and very positive coherences, it will be possible to identify the most appropriate localization choices [22, 23].

The same procedure can be addressed for *Cultural-Identity Congruence*.

A further and significant topic of reflection connected to the previous ones, is the sizing of the areas destined to population and delocalized activities and above all the related costs. Regarding the sizing of additional settlement weights, it is necessary that in instruments of territorial government at the municipal and provincial scale should be possible to achieve greater settlements, with specific characteristics to ensure a civil hospitality, provided they are intended for civil protection uses in the precise cases of necessity.

This could be done not only for hotels but also for housing, which could have an independent portion and equipped with equipment for complete autonomy. This would have the overall benefit that both the costs of construction and those of maintenance and management, which should not be neglected by waiting for an unpredictability of the event, would be borne by private entities. The private sector, on the other hand, would have the advantage of using wider assets than that normally established and these volumes would not remain "on hold", but would be destined for "temporary uses". From the point of view of the foreseeable settling weights, this approach is very opportune, because, if the realization of the twinning will have to take place "in peace time", the settlement weights of the host town can not only be the regular ones, but it must also include the increases deriving from further activities originated from the development of twinning.

The economic and financial sustainability aspect is therefore fundamental [24], and for this end, alongside the use of European Funds, the involvement of private resources is desirable, through financial engineering tools increasingly refined and innovative such as "social impact bonds", "development impact bonds", and "saving cost bonds", characterized by pay-for-success clauses. These clauses, in simple terms, are based on contracts under which the operators providing public services are not remunerated on the basis of output, but on the basis of the outcome, that is the results actually obtained [25]. This is also coherent with the provisions of the *Sendai Framework for Disaster Risk Reduction*, adopted at the Third United Nations Conference on Disaster Risk Reduction in March 2015, that, in defining seven objectives and four priorities for action to prevent new risks and reduce existing ones, recognizes the need to coordinate risk reduction and management strategies across all levels of government, and to strengthen the capacities and resources of local authorities and local communities, including the involvement of private partners for the financing of initiatives.

4. From Risk Management Towards Resilient Communities Through Land Use Planning

The notion of urban resilience is becoming increasingly prevalent in urban policy documents considering the uncertainty, such as climate change and flooding [26, 27].

Resilience has often been described as the ability to 'bounce back' after a disaster. This implies a short term phenomena, whereby resilience mostly relates to the immediate response and recovery phases of a disaster. More recent literature suggests that resilience is not just about 'bouncing back' but is more of an 'adaptive capacity' held by individuals and/or communities. Within a disaster context, Paton and Johnston [28] define resilience as the ability to adapt to the demands, challenges, and changes encountered during and after a disaster. Having an adaptive capacity means that the individuals, communities, and institutions are able to readily adapt to adverse circumstances when dealing with the impact of a disaster. The adaptation that occurs during the recovery from a disaster may mean that they do not 'bounce back' to their former state as such, but evolve to deal with the changing circumstances. To adapt and evolve people need to draw upon personal, collective, and institutional competencies and resources.

Building resilience and long term sustainability can be challenging when a recovery is protracted. A typical scenario for a protracted recovery could be something like this: A natural hazard event occurs (e.g. flood, earthquake), that requires some form of recovery. Insurance claims provide the financial means for a landowner to rebuild/do repairs to their house; the state repairs the infrastructure; life slowly returns to 'normal'. Unlike any other environmental or natural hazard, the disruption caused by volcanic eruptions can lead to permanent relocation of inhabitants, which can lead to irreversible social change [29]. At the same time, volcanic disasters may paradoxically act as catalysts accelerating the rate at which adjustments in social and political institutions occur. The community resilience is, therefore, dependent on pre-existing social, economic, and political conditions as well as post-disaster responses, relief efforts, mitigation strategies, and longer-term rehabilitation programs [30]. In this sense, resilience is the capacity of a community to respond to a change adaptively. Unlike the other forms of resilience where the community returns to its pre-existing state, the transformative resilience sees a more suitable and sustainable approach to the current environment. This form of resilience is concerned with the concepts of renewal, regeneration, and reorganization.

The scenarios stemming from the described assessment model is a move in the direction of a so-called "anti-fragile" planning [31, 32] that goes beyond the concept of resilience. Antifragility leads to an improvement of the system itself by deliberately adopting the unpredictable risk as possible development lever, and admitting the possibility of improvement and regeneration due to a disruption of the system and even a catastrophe.

The method proposed in this work is aimed at a sustainable management of risk conditions, not only in the "red zones" of Campania but also throughout the country where the adoption of policies, tools, and plans are strongly characterized by an adaptive, multidimensional, and multi-scale approach.

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VESUVIUS–CAMPIFLEGREI PENTALOGUE

Resilience and Sustainability Framework for Neapolitan Area

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Abstract. VESUVIUS–CAMPIFLEGREI PENTALOGUE is a resilience and sustainability framework for the Neapolitan area with two active volcanoes Vesuvius and Campi Flegrei (Phlegraean Fields). These volcanoes produce small and large eruptions that can affect several million people living in Naples and surrounding towns. The framework requires abandoning the evacuation plans that aim at deporting several million people all over Italy before the impending eruptions and the achievement of five key objectives of resilience and sustainability that makes possible the cohabitation of the population with volcanoes in security and prosperity. The pentalogue calls for the establishment of three danger zones around the volcanos: exclusion nuclei containing the craters, resilience belts surrounding the exclusion nuclei, and sustainability areas beyond the resilience belts. The built environments in the resilience and sustainability areas are required to conform to special construction codes to mitigate the effects of the eruptions and establishment of extensive volcanic risk information and educational campaigns. The achievement of these objectives depends on interdisciplinary and transdisciplinary collaborations and involvement of suitable investors for producing territorial interventions.

Keywords: Vesuvio, Vesuvius, Campi Flegrei, Phlegraean Fields, hazard, risk, resilience, sustainability

1. Introduction

The Neapolitans managed to cohabit with Vesuvio (Vesuvius) and Campi Flegrei (Campi Phlegraei, Phlegraean Fields) volcanoes for several millennia by rebuilding their habitats after the eruptions and built unique culture that contributed significantly to Western Civilization. Both of these volcanoes can produce explosive eruptions with the fall of ash from the eruption columns and propagation of deadly pyroclastic flows from the collapses of these columns. During the past 30,000 years of activity Vesuvius produced a dozen of large plinian eruptions

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with each ejecting several cubic kilometers of material, and in between of these eruptions produced an order of magnitude smaller explosive eruptions that terminated with effusive activities [1]. Campi Flegrei is 10-100 times more powerful volcano than Vesuvius and during the past 60,000 years produced two super eruptions on whose deposits the city of Naples is built [2]. This volcano can also produce Vesuvius-type eruptions and the geologists estimated that on average it erupts every 5-6 centuries [3].

The urbanization around the Neapolitan volcanoes is, however, preventing reliable assessments of erupted material and the development of credible eruption scenarios requires the development of complex multicomponent and multiphase physical-chemical-mathematical models and their computer implementations [4, 5]. The current ground uplift at Campi Flegrei and occasional rise of seismicity bellow Vesuvius [6] are of concern to the population and the Civil Protection (Protezione Civile) and Osservatorio Vesuviano (Vesuvius Observatory) keep assuring the people that "eveything is under control". But what exactly is *under control* is never specified.

Vesuvius and Campi Flegrei Evacuation Plans [7, 8] were politicized by the geologists with the objective of forcefully resettling several million people around the volcanoes in different Italian regions prior to the impending eruptions. This strategy requires reliable eruption forecasting that may be available only 2-3 days preceding the eruption [9, 10], adequate infrastructure and public order to produce reliable exodus from the territory that frequently shakes before the eruptions, willingness on the part of the evacuees to abandon their homes and properties, and willingness of hosting communities to absorb the refugees that will produce socio-economic and cultural consequences. The architects of these massive deportation plans failed, however, to conduct an exhaustive *feasibility study* of such a complex socio-technical undertaking and the institutionalization of these plans is preventing the development of resilience and sustainability for Neapolitans [11]. The criticisms of Vesuvius and Campi Flegrei evacuation plans have been available since 1995 [12], but neither the national nor the European Union authorities have found it necessary to support the development of *prevention strategies* that aim to produce the cohabitation of Neapolitans with their volcanos in security and prosperity.

VESUVIUS 2000 [13] is a proposed feasibility study that aims to achieve this cohabitation, or resilience and sustainability for Neapolitans, and requires interdisciplinary and transdisciplinary collaborations. Its central objective is directed at producing the *security culture* instead of the *emergency culture* promoted by the current evacuation plans. The development of this framework was proposed in 1995 through a proposal to the European Union [14] and it rejection was contested through the European Parliament without success[1] [15]. Once developed

[1] During the preparation of VESUVIUS 2000 proposal the European earth science community was invited to participate on the project but the Italian geologists opted instead to support Vesuvius and Campi Flegrei Evacuation Plans under the leadership of then Undersecretary of Civil Protection Franco Barberi and Director of Vesuvius Observatory Lucia Civetta.

for the Vesuvius area such a feasibility study could also have been developed for Campi Flegrei with some important modifications that require the considerations of super eruptions of this volcano. When dealing with complex social and technical issues the feasibility studies are necessary before implementing policies, not only to account for the interests of different actors but also for attracting the investors for successfully implementing territorial interventions.

TVESUVIUS 2000 was elaborated to stress its five key objectives and was named VESUVIUS PENTALOGUE [16], and this work summarizes its extension to the volcano of Campi Flegrei. The resulting framework for both volcanoes is called VESUVIUS–CAMPIFLEGREI PENTALOGUE and includes plinian-type eruptions for both volcanoes and super eruptions of Campi Flegrei. The development of this feasibility study requires several years to complete and even more time for achieving territorial interventions, while the normal life of Neapolitans is maintained with minimal disruptions and the volcanos remain dormant.

2. VESUVIUS–CAMPIFLEGREI PENTALOGUE

VESUVIUS–CAMPIFLEGREI PENTALOGUE requires the achievement of the following five key objectives:

1. The current National Emergency Evacuation Plans for the populations of Summa-Vesuvius and Campi Flegrei areas, which would create massive dispersions all over Italy of the current 1-2 million inhabitants living within the immediate danger zones of the volcanos, are both problematic and unacceptable. Further collaborative efforts (studies, discussions, workshops) among institutional representatives, scientists, as well as the communities at risk, are required, in order to:
   A. Select *temporary settlements* for some of these inhabitants within the areas much closer to their native homeland, until the volcanic crises subside;
   B. Minimize the effects of the eruptions on the built environment.
2. A continuing close cohabitation of the populations with the volcanos should be the crucial cultural point to be pursued, whenever possible, together with an overall risk reduction; this can be accomplished through a much more accurate identification of:
   A. Volcanic hazards (earthquakes, tephra falls, pyroclastic flows, bombs and missiles, mudflows, tsunamis);
   B. Vulnerabilities (civil construction practices, infrastructure systems, cultural patrimonies);
   C. Exposed values (with particular regard to people, strategic buildings, schools, heritage).

   To achieve this identification, a redefinition of the *danger zones* around Summa-Vesuvius and Campi Flegrei is required, as follows:
   a. An *exclusion nucleus* (*nucleo di esclusione*) should be established for each volcano that prohibits all future human settlements and discourage the existing ones;

b. A *resilience belt* (*cintura di resilienza*), housing most of the current population, should be established for each volcano, where:
   i. All structures (new and existing) conform to special construction codes based on *maximum plausible seismic and volcanic actions scenarios*;
   ii. Comprehensive scenario evacuation plans for the population within this belt should be implemented as backup strategies;
c. A *sustainability area* (*area di sostenibilitá*) should be established for each volcano beyond the resilience belt, allowing for both *sustainable practices* and *temporary resettlements* of the resilience belt citizens; if this area is sustainable, it is consequently resilient to future eruptions;
d. For the Campi Flegrei area, the exclusion nucleus, resilience belt, and sustainability areas should be established for both plinian and super eruptions of this volcano.

The three zones for each volcano should be urgently identified as follows:

a. Activating further multidisciplinary studies, researches, projects, with the cooperation among International and Italian scientists, institutional representatives, and communities at risk;
b. Enhancing the rule of law to fight illegality, guarantee the strict control of public funds, foster the transparency of local administrators, ensure the effectiveness of emergency and risk mitigation strategies.

3. The built environment construction codes for the populations of danger zones should be established utilizing:
   A. Plinian for Vesuvius and plinian and super eruptions for Campi Flegrei volcano scenarios;
   B. Scenario-based seismic hazard assessment and zonation;
   C. Dynamic structural analysis;
   D. Global volcanic simulations of thermo-fluid dynamic eruption processes capable of modeling the durations of *entire* eruptions.
4. The volcanic risk information and education should involve:
   A. An effective volcanic risk information campaign and active public preparedness strategy should be implemented for exclusion nuclei, resilience belts, and sustainability areas surrounding Summa-Vesuvius and Campi Flegrei.
   B. A Volcanic Risk Education Safety Program should be implemented in all schools located within each of the above areas surrounding the volcanos.
5. The political authorities, scientific community, and organizations participating on pentalogue framework should produce:
   A. A *memorandum of understanding* that univocally establishes an effective collaboration;
   B. Periodic progress reports that keep the populations informed on the progress leading to the realization of pentalogue objectives.

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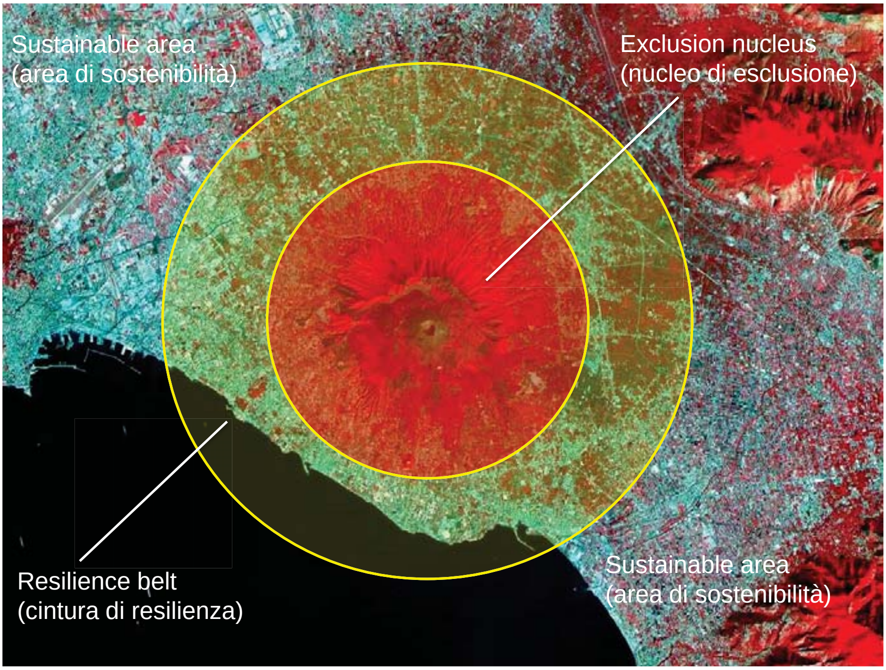

Figure 1. Schematic illustration of exclusion nucleus, resilience belt, and sustainability area for plinian eruptions of Summa-Vesuvius volcano [12].

3. Discussion

Figure 1 illustrates the exclusion nucleus, resilience belt, and sustainability areas for plinian eruptions of Summa-Vesuvius volcano, Fig. 2 is an illustration of similar areas for plinian eruptions of Campi Flegrei volcano, and Fig. 3 illustrates these areas for the super eruptions of Campi Flegrei volcano. The boundaries of different areas shown in the illustrations are provisional and their true nature can only be determined by achieving the above five pentalogue objectives. For Vesuvius there is only one exclusion nucleus, one resilience belt, and one sustainability area that account for the plinian eruptions of this volcano, whereas for Campi Flegrei there are two exclusion nuclei, two resilience belts, and two sustainability areas that account for the expected short-term plinian eruptions (order of 1000 years) and long-term super eruptions (order 10,000 years) of this volcano.

The achievement of five pentalogue objectives requires collaborations of engineers, earth scientists, educators, economists, populations surrounding the volcanoes, and governmental and nongovernmental organizations of the territory. This collaboration is, however, difficult to achieve because each group tries to maintain the group identity and mistrusts disciplines that are unknown to the group [17]. The acceptance of a new paradigm is for many incommensurable and

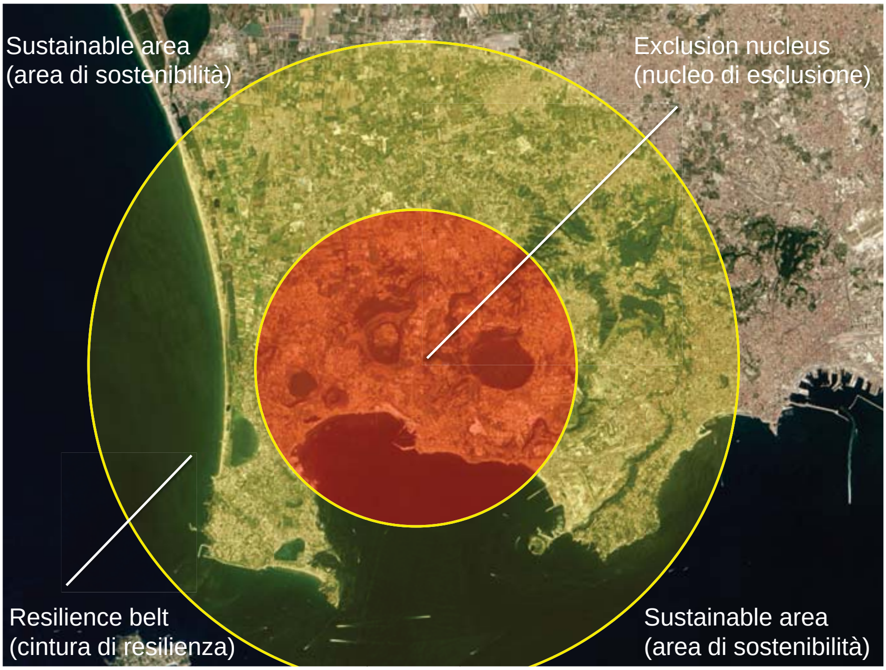

Figure 2. Schematic illustration of exclusion nucleus, resilience belt, and sustainability areas for plinian eruptions of Campi Flegrei volcano [12].

requires challenging the entrenched habits of mind until the sharing of paradigm becomes contagious and unproblematic [13]. Incommensurability is therefore a blindness or a "barrier" to seeing what the other side is saying.

Massive displacements of people from their habitats is problematic, not only for those being displaced but also for the authorities that must prepare and manage the exhodus in an orderly manner and the hosting communities that must accept the refugees. This strategy is thus in conflict with the *preservation of the sense of belonging* as required by one of the central pillars of sustainability [18], because the people who participate in culture building want to conserve their culture or group identity. VESUVIUS–CAMPIFLEGREI PENTALOGUE is consistent with this principle of sustainability whereas the evacuation plans of Vesuvius and Campi Flegrei are not.

The pentalogue requires a reorganization of the Neapolitan area to ensure that the future eruptions can only produce minimal socio-economic, cultural, and political consequences, and not only locally but also nationally and within other countries of the European Union if some Neapolitan refugees journeys across the Italian border. The explosive nature of Neapolitan volcanoes cannot be underestimated and by developing emergency evacuation plans for the eruptions of these volcanoes that are below the powers of plinian and super eruptions

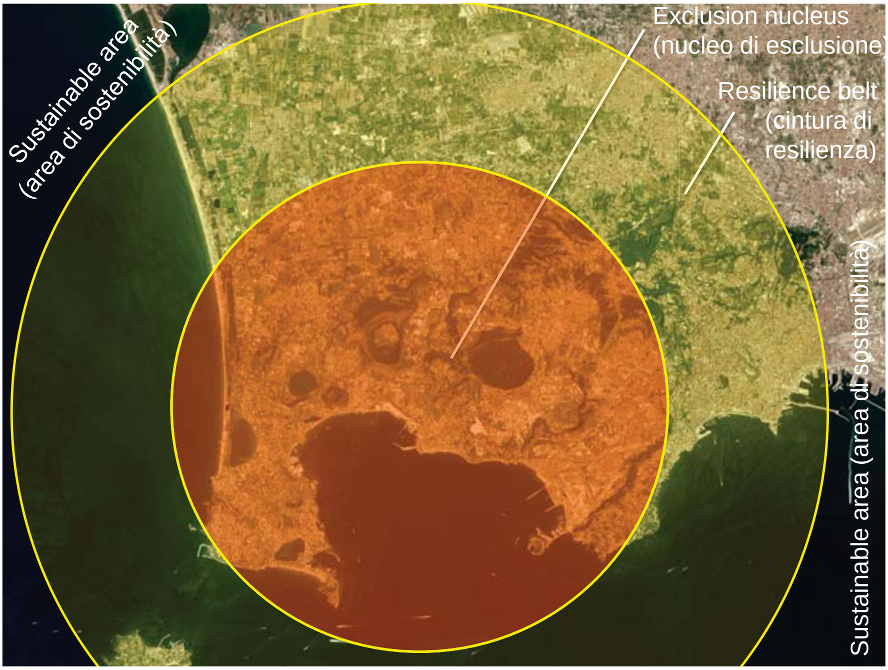

Figure 3. Schematic illustration of exclusion nucleus, resilience belt, and sustainability areas for super eruptions of Campi Flegrei volcano [12].

is another myopic vision of the architects and promoters of such plans. The VESUVIUS–CAMPIFLEGREI PENTALOGUE risk mitigation framework for the Neapolitans does not underestimate this vision and fully confronts the social and technical requirements that are necessary to seriously confront the eruptions of Vesuvius and Campi Flegrei.

The powers of these volcanoes, require, however, that within certain distances from the craters all human activities connected with the normal conduct of life should be prohibited. These are the *exclusion nuclei* of the pentalogue and must be carefully determined through the simulations of eruption scenarios, since any activity conducted in these nuclei risk of being destroyed. Surrounding the exclusion nuclei are the *resilience belts* where the built environments must conform to special construction codes. All constructions in the resilience belts should be able to withstand the eruptions with minimal damage to the built environment and the displaced people from these areas should be able to return and rebuild. While it should be possible for some people of resilience belts to remain in these belts during the eruptions, this should be evaluated very carefully through the extensive simulations of scenarios to ensure that no safety measures have been abused. The resilience belts should have the ability to *react* or respond appropriately in time, the ability to *monitor* their own states and the environments that interact with them, the ability of certain *intelligence* that allows them to learn and take actions when necessary. Resilience is, therefore, a capacity to recover from the difficulties, whereas the *sustainability areas* must have an ability to be maintained at a certain level or levels prior, during, and after the perturbing effects of their environments.

The resilience and sustainability areas of the pentalogue have an extraordinary technical component (objective 3 of the pentalogue) that requires professional engineering and urban planning competences. A precise knowledge of volcanic deposits around the volcanoes is essential in order to understand their past behavior and for verifying the volcanic and seismic scenario models in limited circumstances. As noted earlier, the volumes and compositions of these deposits are uncertain and need to be better understood and verified through independent geological investigations [11]. The volcanic scenario models require integrations of different volcanic processes: Magma accumulation and differentiation in magma chambers, magma ascent in volcanic conduits and interactions with underground aquifers, dispersions of volcanic products above the vents of volcanoes and along their slopes with built environment during the plinian and column collapsing phases of eruptions [4]. A Global Volcanic Simulator is being developed to accomplish this task with the objective of simulating the entire eruptive process, from start to finish [17, 19–21].

A typical result from computer simulation of a plinian eruption of Vesuvius showing the temperature distribution of erupted material on and above the surface of the volcano is shown in Fig. 4. The collapse of volcanic column produces ground-hugging pyroclastic flows that tend to move along the valleys and change the direction of propagation from horizontal to vertical by producing secondary columns. This behavior of pyroclastic flows suggests that only a certain region close to the crater (exclusion nucleus) will be subjected to the maximum impact from the eruption and that further out from the crater (in the resilience belt) this impact will be significantly reduced.

The knowledge of potential spatio-temporal displacements, velocities, and accelerations caused by earthquakes and deformations from magma accumulation in the volcanoes of the Neapolitan area is currently insufficient for designing resilient and sustainable built environments. Currently, the potential earthquake hazard can best be determined by employing the neo-deterministic seismic hazard assessment methodology of Panza [22] and co-workers, because it allows for building seismic hazard scenarios based on the materials and structures of the Earth's crust.

Having established possible volcanic and seismic loads on different types of residential, commercial, and industrial structures and infrastructures at different times during the eruptions and at different locations around each volcano it is now possible to employ the dynamic structural analysis methods to determine the vulnerability, or safety and serviceability, of current and future structures in the exclusion nuclei, resilience belts, and sustainability areas [23]. This procedure allows for the establishment of specific *construction codes* or standards for use in the built environments of the Neapolitan area.

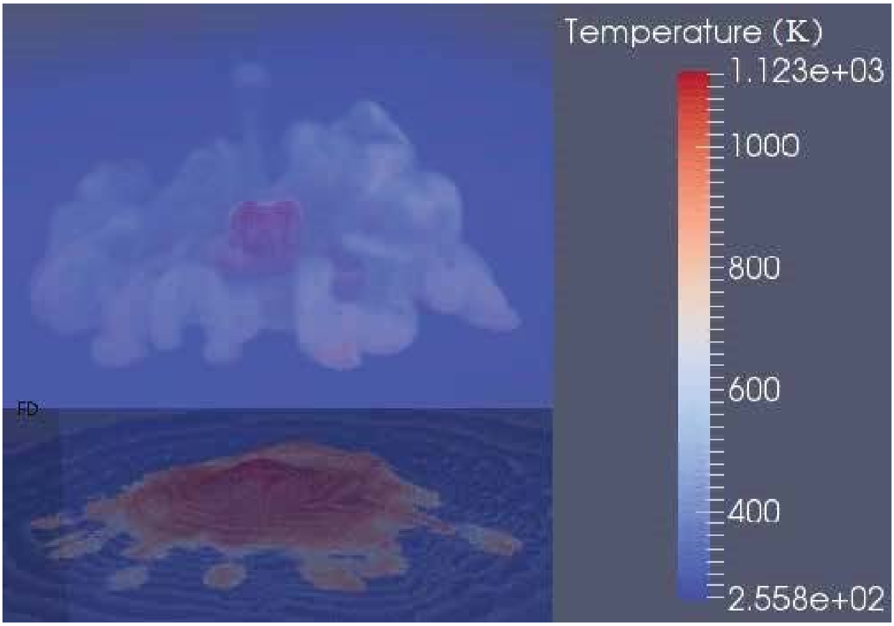

Figure 4. Three dimensional simulation of a plinian volcanic column of Vesuvius that produces pyroclastic flows. Shown in the illustration is the temperature distribution above the surface of the volcano (top image on the left) and on the surface of the volcano (bottom image). This result was produced with Global Volcanic Simulator that simulates volcanic column based on magma accumulation in magma chamber, magma ascent along the conduit, and current topography of the volcano [20].

The last two objectives of the pentalogue are no less significant, since without an informed public, responsible authorities, open-minded professionals, and organizations that value building the prevention culture more than promoting the current emergency culture there will be no clear paths toward resilience and sustainability for Neapolitans. Education must start in the schools and propagate through the students and their parents, and through the general public with effective risk information campaigns where the mass media provide the correct and critical information. But today we are far from achieving this objective, since neither the school students nor the public or the mass media are properly educated on the values of building resilient and sustainable societies [24].

4. Conclusions

VESUVIUS–CAMPIFLEGREI PENTALOGUE is an advanced interdisciplinary and transdisciplinary resilience and sustainability framework for the Neapolitan area and is an elaboration of the VESUVIUS 2000 framework proposed in 1995. The five key objectives of pentalogue aim at producing temporary and local shelters for populations of danger areas during the volcanic crises, developing advanced engineering and urban planning solutions for producing resilient and sustainable environments around the volcanoes, developing effective risk information and educational campaign for the public, and establishing effective collaborations between professionals, organizations, institutions, and stakeholders for securing territorial interventions. The progress toward the achievement of pentalogue objectives is however hindered by the unreliable and institutionalized Vesuvius and Campi Flegrei evacuation plans and incommensurable habits of mind of many professionals and public officials.

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VESUVIUS–CAMPIFLEGREI PENTALOGUE

Quadro di resilienza e sostenibilità per l'area napoletana

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Riassunto. VESUVIUS–CAMPIFLEGREI PENTALOGUE è un quadro di resilienza e di sostenibilità per l'area partenopea con due vulcani attivi: Vesuvio e Campi Flegrei. Questi vulcani producono piccole e grandi eruzioni che possono colpire diversi milioni di persone che vivono a Napoli e nelle città circostanti. Il quadro richiede di abbandonare i piani di evacuazione, che mirano alla deportazione di diversi milioni di persone in tutta Italia, prima delle imminenti eruzioni e il raggiungimento di cinque obiettivi chiave di resilienza e sostenibilità, che rendono possibile la convivenza della popolazione con i vulcani in sicurezza e prosperità. Il pentalogo richiede di stabilire tre zone di pericolo intorno ai vulcani: nuclei di esclusione contenenti i crateri, le cinture di resilienza che circondano i nuclei di esclusione e le aree di sostenibilità oltre le cinture di resilienza. Gli ambienti costruiti nelle aree di resilienza e sostenibilità sono tenuti a conformarsi alle norme di costruzione speciali per mitigare gli effetti delle eruzioni e alla creazione di ampie campagne di informazione e educazione al rischio vulcanico. Il raggiungimento di questi obiettivi dipende da collaborazioni interdisciplinari e transdisciplinari e dal coinvolgimento di investitori adeguati per la produzione di interventi territoriali.

Parole chiave: Vesuvio, Vesuvius, Campi Flegrei, Phlegraean Fields, pericolo, rischio, resilienza, sostenibilità

1. Introduzione

I Napoletani riuscirono a convivere con i vulcani del Vesuvio e dei Campi Flegrei per diversi millenni, ricostruendo i loro habitat in seguito alle eruzioni e costruendo una cultura unica che contribuì significativamente alla civiltà occidentale. Entrambi questi vulcani possono produrre eruzioni esplosive con la caduta di cenere dalle colonne eruttive e la propagazione di molto pericolosi flussi piroclastici dai crolli di queste colonne. Durante gli ultimi 30.000 anni di attività il Vesuvio ha prodotto una dozzina di grandi eruzioni pliniane e in ogni eruzione

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ha eruttato alcuni chilometri cubi di materiale, e tra queste eruzioni ha prodotto un ordine di grandezza di piccole eruzioni esplosive che terminavano con attività effusive [1]. Campi Flegrei è un vulcano 10-100 volte più potente del Vesuvio e negli ultimi 60.000 anni ha prodotto due super eruzioni sui cui depositi è stata costruita la città di Napoli [2]. Questo vulcano può anche produrre eruzioni del tipo del Vesuvio e i geologi hanno stimato che in media erutta ogni 5-6 secoli [3].

L'urbanizzazione intorno ai vulcani napoletani sta tuttavia impedendo valutazioni affidabili del materiale eruttato e lo sviluppo di scenari di eruzione credibili richiede l'elaborazione di complessi modelli multicomponenti e multifase fisico-chimico-matematico e le loro implementazioni informatiche [4, 5] . L'attuale innalzamento del suolo dei Campi Flegrei e l'aumento occasionale della sismicità del Vesuvio [6] preoccupano la popolazione, e la Protezione Civile e l'Osservatorio Vesuviano continuano a garantire alle persone che *tutto è sotto controllo*. Ma ciò che è esattamente *sotto controllo* non viene mai specificato

I piani di evacuazione del Vesuvio e dei Campi Flegrei [7, 8] sono stati pubblicizzati dai geologi con l'obiettivo di reinsediare forzatamente diversi milioni di persone attorno ai vulcani in diverse regioni italiane prima delle imminenti eruzioni. Questa strategia richiede previsioni di eruzioni affidabili che possono essere disponibili solo 2-3 giorni prima dell'eruzione [9, 10], infrastrutture adeguate e ordine pubblico per produrre un esodo affidabile dal territorio che frequentemente scuote prima delle eruzioni, la volontà da parte degli sfollati ad abbandonare le loro case e proprietà, e la volontà delle comunità per assorbire i rifugiati che produrranno conseguenze socio-economiche e culturali nei territori ospitanti. Gli architetti di questi massicci piani di deportazione fallirono, tuttavia, a condurre uno studio *esauriente di fattibilità* su un'impresa socio-tecnica così complessa e l'istituzionalizzazione di questi piani sta impedendo lo sviluppo di resilienza e della sostenibilità per i napoletani [11] . Le critiche ai piani di evacuazione del Vesuvio e dei Campi Flegrei sono disponibili dal 1995 [12], ma nè le autorità nazionali nè quelle dell'Unione europea hanno ritenuto necessario sostenere lo sviluppo di *strategie di prevenzione* che mirano a produrre la convivenza dei napoletani con i loro vulcani in sicurezza e prosperità.

VESUVIUS 2000 [13] è un proposto studio di fattibilit à che mira a raggiungere questa coabitazione, o resilienza e sostenibilità per i napoletani e richiede collaborazioni interdisciplinari e transdisciplinari. Il suo obiettivo centrale è diretto a produrre la *cultura della sicureza* invece della *cultura della emergenza* promossa dagli attuali piani di evacuazione. Lo sviluppo di questo quadro è stato proposto nel 1995 con una proposta all'Unione Europea [14] e il suo rifiuto è stato contestato attraverso il Parlamento Europeo senza successo[1] [15]. Una volta sviluppato per l'area vesuviana, potrebbe essere sviluppato anche uno studio di fattibilità per i Campi Flegrei con alcune importanti modifiche

[1] Durante la preparazione della proposta VESUVIUS 2000 la comunità europea della scienza della terra è stata invitata a partecipare al progetto ma i geologi italiani hanno invece optato per sostenere i piani di evacuazione del Vesuvio e dei Campi Flegrei sotto la guida dell'allora Sottosegretario alla Protezione Civile Franco Barberi e del Direttore dell'Osservatorio Vesuviano Lucia Civetta.

che richiedono considerazioni sulle super eruzioni di questo vulcano. Quando si affrontano questioni sociali e tecniche complesse, gli studi di fattibilità sono necessari prima di attuare le politiche, non solo per tenere conto degli interessi dei diversi attori, ma anche per attirare gli investitori per attuare con successo gli interventi territoriali.

VESUVIUS 2000 è stato elaborato per sottolineare i suoi cinque obiettivi principali ed è stato nominato VESUVIUS PENTALOGUE [16], e questo lavoro riassume la sua estensione al vulcano dei Campi Flegrei. Il quadro risultante per entrambi i vulcani si chiama VESUVIUS–CAMPIFLEGREI PENTALOGUE e include eruzioni di tipo pliniano del Vesuvio e dei Campi Flegrei e super eruzioni dei Campi Flegrei. Lo sviluppo di questo studio di fattibilità richiede diversi anni per arrivare a completamento e qualche decina di anni per effetuare gli interventi territoriali, mentre la vita normale dei napoletani viene mantenuta con interruzioni minime e i vulcani rimangono dormienti.

2. VESUVIUS–CAMPIFLEGREI PENTALOGUE

VESUVIUS–CAMPIFLEGREI PENTALOGUE richiede il raggiungimento dei seguenti cinque obiettivi principali:

1. Gli attuali piani nazionali d'emergenza per l'evacuzione delle popolazioni delle aree del Somma-Vesuvio e dei Campi Flegrei, che produrrebbe una massiccia dispersione per tutta l'Italia di 1-2 millioni di abitanti che vivono nelle aree maggiormente pericolose dei vulcani, si presentano problematici e risultano inaccettabili. Sono necessarie, pertanto, ulteriori e più impegnative azioni (studi, confronti, discussioni) tra i rappresentanti delle istituzioni e la comunità scientifica, unitamente alla comunità esposta al rischio, al fine di:
   A. Collocare parte di questa popolazione in *insediamenti temporanei*, localizzati in aree vicine al loro territorio di origine, fino alla conclusione della crisi vulcanica;
   B. Minimizzare gli effetti delle eruzioni sull'ambiente costruito.
2. Un continuo e stretto rapporto di convivenza della popolazione con il vulcano dovrebbe essere l'elemento culturale cruciale da perseguire, in quanto possibile, unitamente ad un'ampia riduzione del rischio; questo obiettivo può essere raggiunto attraverso una conoscenza molto più accurata di:
   A. Pericolosità vulcanica (terremoti, prodotti, di caduta dalla nube vulcanica, flussi piroclastici, bombe e proiettili vulcanici, colate di fango e tsunami);
   B. Vulnerabilità (costruzioni di abitazioni, sistemi infrastrutturali, patrimonio culturale);
   C. Valore esposto (con particolare riguardo alla popolazione, agli edifici strategici, scuole, centri storici).

   Per ottenere questo risultato si richiede che le *zone pericolose* intorno al Somma-Vesuvio e Campi Flegrei siano ridefinite nel modo seguente:
   a. Si dovrebbe stabilire un *nucleo di esclusione* nel quale siano proibiti tutti gli insediamenti futuri e si scoraggi la permanenza di quelli esistenti;

   b. Si dovrebbe stabilire una *cintura di resilienza*, nella quale possa essere insediata la gran parte della popolazione, dove:
      i. Tutte le costruzioni (nuove ed esistenti) devono essere conformi a specifiche norme di costruzioni basate su *scenari dei massimi verosimili terremoti ed azioni vulcaniche*;
      ii. Per la popolazione insediata in tale cintura dovrebbero essere realizzati "scenari dei piani di evacuazione" secondo le strategie della ridondanza (backup strategies);
   c. Al di là dellla cintura di resilienza si dovrebbe stabilire un'*area di sostenibilità* per consentire pratiche sostenibili e *insediamenti temporanei* per gli abitanti della cintura di resilienza; se quest'area risultasse sostenibile, sarebbe, conseguentemente, resiliente a future eruzioni.
   d. Per l'area dei Campi Flegrei si dovrebbero definire il nucleo di esclusione, la cintura di resilienza e le aree di sostenibilità per entrambe le eruzioni pliniane e super eruzioni di questo vulcano.

   Le tre cinture per ogni vulcano dovrebbero essere identificate urgentemente nel modo seguente:
   a. Attivare ulteriori studi, ricerche, e progetti multidisciplinari mediante la cooperazione tra scienziati italiani e internazionali, rappresentanze istituzionali e la comunità esposta al rischio;
   b. Rafforzare il ruolo delle norme per sconfiggere l'illegalità, garantire il controllo della spesa pubblica, promuovere la crescita della trasparenza delle amministrazioni locali, assicurare la validit'a delle strategie dell'emergenza e della mitigazione del rischio.
3. Le norme per le costruzioni dell'ambiente costruito nell'area pericolosa dovrebbero basarsi su:
   A. Scenari delle eruzioni pliniane per Vesuvio e pliniane e super eruzioni per Campi Flegrei;
   B. Scenari della pericolosità dei terremoti utilizzando la zonazione sismica;
   C. Analisi dinamiche per le strutture;
   D. Simulazioni vulcaniche globali attraverso la modellizzazione termo-fluidodinamica dei processi vulcanici in grado di modellare le durate di *intere* eruzioni.
4. La informazione e la educazione al rischio vulcanico dovrebbero comportare:
   A. La realizzazione di un'efficace campagna di informazione e una strategia di preparazione attiva della popolazione nelle zone dei nuclei di esclusione, delle cinture di resilienza e in quelle di sostenibilità intorno al Somma-Vesuvio e Campi Flegrei;
   B. In tutte le scuole delle zone sopra indicate si dovrebbe realizzare un Programma di Educazione alla Sicurezza per il Rischio Vulcanico.
5. Le Autorità politiche e la comunità scientifica dovrebbero sottoscrivere:
   A. Un *memorandum di intesa* che stabilisca univocamente un'effettiva collaborazione;
   B. Rapporti periodici alla popolazione sullo stato di avanzamento dei lavori per la realizzazione degli obiettivi sopra indicati.

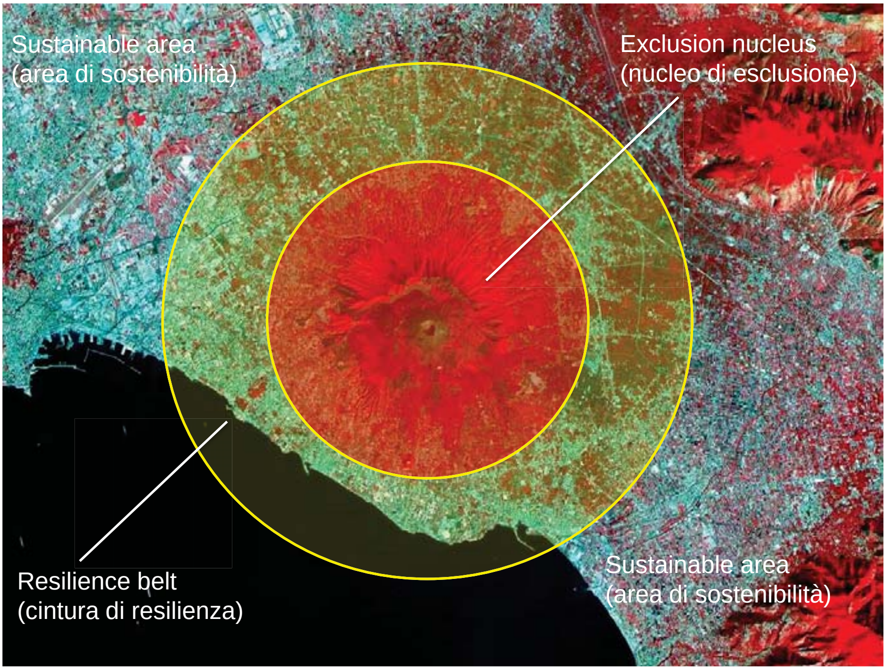

Figura 1. Illustrazione schematica del nucleo di esclusione, della cintura di resilienza e dell'area di sostenibilità per le eruzioni pliniane del vulcano Somma-Vesuvio [12].

3. Discussione

La Fig. 1 illustra le aree del nucleo di esclusione, la cintura di resilienza e la cintura di sostenibilità per le eruzioni pliniane del vulcano Somma-Vesuvio, la Fig. 2 è un'illustrazione di aree simili per le eruzioni pliniane del vulcano Campi Flegrei, e la Fig. 3 illustra queste aree per le super eruzioni del vulcano Campi Flegrei. I confini delle diverse aree nelle illustrazioni sono provvisorie e la loro vera natura può essere determinata solo raggiungendo i cinque obiettivi di cui sopra. Per il Vesuvio c'è un solo nucleo di esclusione, una cintura di resilienza e un'area di sostenibilità che rappresentano le eruzioni pliniane di questo vulcano, mentre per i Campi Flegrei ci sono due nuclei di esclusione, due cinture di resilienza e due aree di sostenibilità che rappresentano le eruzioni pliniane a breve termine (ordine di 1000 anni) e super-eruzioni a lungo termine (ordine di 10.000 anni) di questo vulcano.

Il raggiungimento dei cinque obiettivi del pentalogo richiede la collaborazione di ingegneri, scienziati della terra, educatori, economisti, popolazioni che circondano i vulcani e organizzazioni governative e non governative del territorio. Questa collaborazione è, tuttavia, difficile da raggiungere perchè ogni gruppo cerca di mantenere l'identit del gruppo e diffida delle discipline sconosciute al gruppo [17]. L'accettazione di un nuovo paradigma è per molti incommensurabile

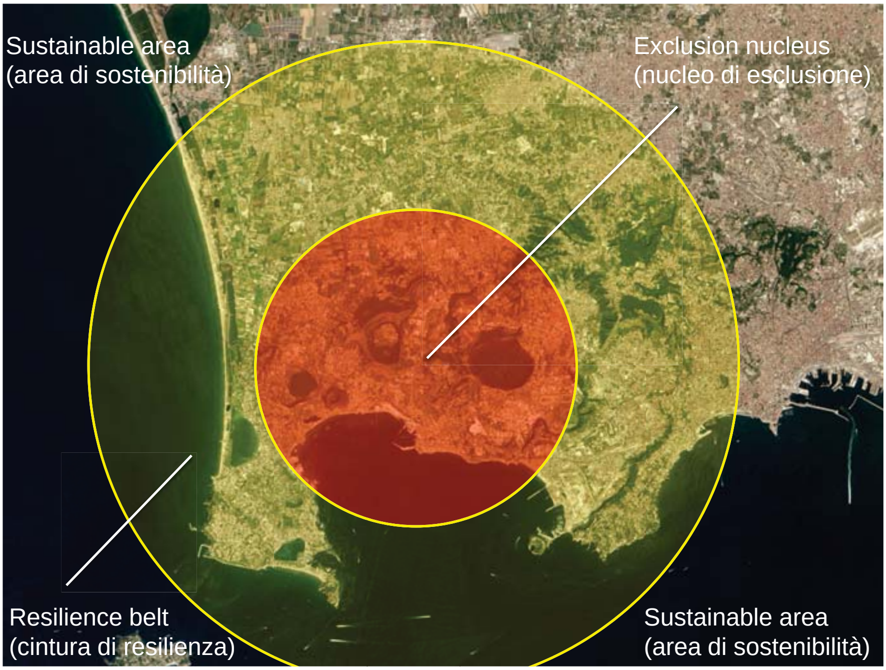

Figura 2. Illustrazione schematica del nucleo di esclusione, della cintura di resilienza e dell'area di sostenibilità per le eruzioni pliniane del vulcano Campi Flegrei [12].

e richiede di sfidare le abitudini trincerate della mente fino a che la condivisione del paradigma diventa contagiosa e non problematica [13]. L'incommensurabilità è, quindi, una cecità o una barriera al vedere ciò che sta dicendo l'altra parte.

I massicci spostamenti delle popolazioni dal loro habitat sono problematici, non solo per coloro che sono sfollati, ma anche per le autorità che devono preparare e gestire l'esodo in modo ordinato e le comunità ospitanti che devono accettare i rifugiati. Questa strategia è, quindi, in conflitto con la conservazione del senso di appartenenza, come richiesto da uno dei pilastri centrali della sostenibilità [18], perchè le persone che partecipano alla costruzione della cultura vogliono conservare la propria cultura o identità di gruppo. VESUVIUS–CAMPIFLEGREI PENTALOGUE è coerente con questo principio di sostenibilità, mentre i piani di evacuazione del Vesuvio e dei Campi Flegrei non lo sono.

Il pentalogo richiede una riorganizzazione dell'area napoletana per assicurare che le future eruzioni possano produrre solo conseguenze socio-economiche, culturali e politiche minime, e non solo a livello locale, ma anche nazionale e all'interno di altri paesi dell'Unione Europea se alcuni rifugiati napoletani attraversano il confine italiano. La natura esplosiva dei vulcani napoletani non può essere sottovalutata e sviluppando piani di evacuazione di emergenza per

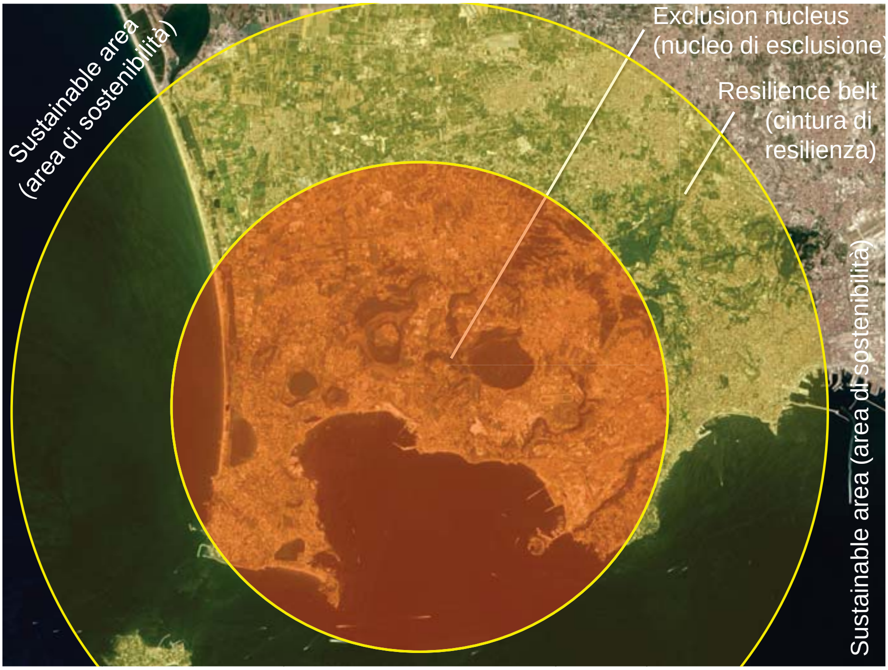

Figura 3. Illustrazione schematica del nucleo di esclusione, della cintura di resilienza e dell'area di sostenibilità per le super eruzioni del vulcano Campi Flegrei [12].

le eruzioni di questi vulcani che sono al di sotto dei poteri di pliniane e super-eruzioni è un'altra visione miope degli architetti e promotori di tali piani. Il quadro per la mitigazione del rischio napoletano VESUVIUS–CAMPIFLEGREI PENTALOGUE non sottovaluta questa visione e confronta pienamente i requisiti sociali e tecnici necessari per affrontare seriamente le eruzioni del Vesuvio e dei Campi Flegrei.

Le force di questi vulcani richiedono, tuttavia, che entro certe distanze dai crateri tutte le attività umane connesse alla normale condotta di vita debbano essere proibite. Questi sono i *nuclei di esclusione* del pentalogo e devono essere attentamente determinati attraverso le simulazioni degli scenari di eruzione, poichè qualsiasi attività condotta in questi nuclei rischia di essere distrutta. Intorno ai nuclei di esclusione ci sono le *cinture di resilienza* in cui gli ambienti costruiti devono essere conformi alle norme di costruzione speciali. Tutte le costruzioni nelle cinture di resilienza dovrebbero essere in grado di resistere alle eruzioni con danni minimi all'ambiente edificato e gli sfollati da queste aree dovrebbero essere in grado di ritornare e ricostruire. Mentre dovrebbe essere possibile che alcune persone della cintura di resilienza rimangano in queste aree durante le eruzioni, questo dovrebbe essere valutato con molta attenzione attraverso le estese simulazioni di scenari per garantire che non siano state abusate misure di sicurezza.

Le cinture di resilienza dovrebbero avere la capacità di *rispondere* in modo appropriato nel tempo, la capacità di *monitorare* i propri stati e gli ambienti che interagiscono con loro, la capacitè di alcuna *intelligenza* che consente loro per imparare e intraprendere azioni quando necessario. La resilienza è, quindi, una capacità di recupero dalle difficoltà, mentre le *aree di sostenibilità* devono avere una capacità di essere mantenute ad un certo livello o livelli prima, durante e dopo gli effetti perturbanti dei loro ambienti.

Le aree di resilienza e sostenibilità del pentalogo hanno una componente tecnica straordinaria (obiettivo 3 del pentalogo) che richiede competenze ingegneristiche e urbanistiche professionali. Una conoscenza precisa dei depositi vulcanici attorno ai vulcani è essenziale per comprendere il loro comportamento passato e per verificare i modelli di scenari vulcanici e sismici in circostanze limitate. Come notato in precedenza, i volumi e le composizioni di questi depositi sono incerti e devono essere meglio compresi e verificati attraverso indagini geologiche indipendenti [11]. La modelizzazione degli scenari vulcanici richiede integrazioni di diversi processi vulcanici: accumulo e differenziazione del magma in camere magmatiche, ascesa di magma in condotti vulcanichi e interazioni con falde acquifere sotterranee, dispersioni di prodotti vulcanici sopra le bocche di vulcani e lungo le loro pendici con ambiente costruito durante le fasi collassanti dei eruzioni [4]. Il Simulatore Vulcanico Globale à stato sviluppato per svolgere questo compito con l'obiettivo di simulare l'intero processo eruttivo, dall'inizio alla fine [17, 19–21].

Un risultato tipico della simulazione al computer di un'eruzione pliniana del Vesuvio che mostra la distribuzione della temperatura del materiale eruttato sopra e sulla superficie del vulcano è riportato in Fig. 4. Il collasso della colonna vulcanica produce flussi piroclastici che scorrono lungo il terreno e tendono a muoversi lungo le valli e cambiano la direzione di propagazione da orizzontale a verticale producendo colonne secondarie. Questo comportamento dei flussi piroclastici suggerisce che solo una certa regione vicina al cratere (nucleo di esclusione) sarà soggetta al massimo impatto dall'eruzione e che più lontano dal cratere (nella fascia di resilienza) questo impatto sarà significativamente ridotto.

La conoscenza di potenziali spostamenti spazio-temporali, velocità e accelerazioni causate da terremoti e deformazioni dall'accumulo di magma nei vulcani dell'area napoletana è attualmente insufficiente per progettare ambienti costruiti resilienti e sostenibili. Attualmente, il potenziale rischio di terremoto può essere meglio determinato, impiegando la metodologia neo-deterministica di valutazione del rischio sismico di Panza [22] e collaboratori, poichè consente di costruire scenari di rischio sismico basati sui materiali e le strutture della crosta terrestre.

Avendo stabilito possibili carichi vulcanici e sismici su diversi tipi di strutture e infrastrutture residenziali, commerciali e industriali in momenti diversi durante le eruzioni e in diverse località attorno a ciascun vulcano, è ora possibile utilizzare i metodi di analisi strutturale dinamica per determinare la vulnerabilità, o la sicurezza e la praticità, delle strutture attuali e future nei nuclei di esclusione, nelle cinture di resilienza e nelle aree di sostenibilità [23]. Questa procedura

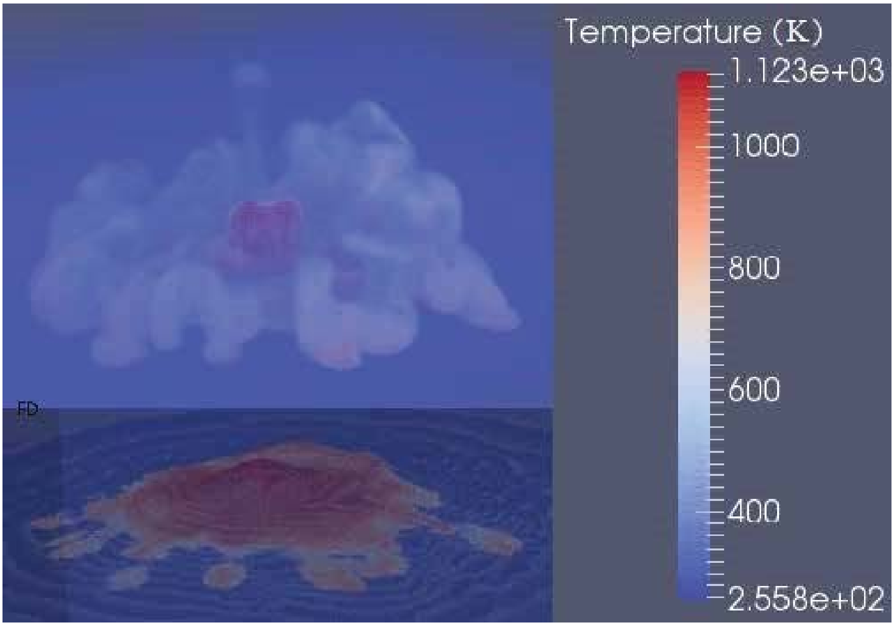

Figura 4. Simulazione tridimensionale di una colonna vulcanica pliniana del Vesuvio che produce flussi piroclastici. Nella figura viene riportata la distribuzione della temperatura sopra la superficie del vulcano (immagine in alto a sinistra) e sulla superficie del vulcano (immagine in basso). Questo risultato à stato prodotto con Simulatore Vulcanico Globale che simula la colonna vulcanica basata sull'accumulo di magma nella camera magmatica, l'ascesa del magma lungo il condotto e la topografia attuale del vulcano [20].

consente di stabilire specifiche *norme di costruzione* per l'utilizzo negli ambienti costruiti dell'area partenopea.

Gli ultimi due obiettivi del pentalogo non sono meno significativi, poichè senza un pubblico informato, autorità responsabili, professionisti di mentalità aperta e organizzazioni che valorizzino la cultura della prevenzione più che promuovere l'attuale cultura di emergenza, non ci saranno chiari percorsi verso la resilienza e la sostenibilità per i napoletani. L'istruzione deve iniziare nelle scuole e propagarsi attraverso gli studenti e i loro genitori e attraverso il pubblico in generale con campagne di informazione sui rischi in cui i mass media forniscono le informazioni corrette e critiche. Ma oggi siamo lontani dal raggiungere questo obiettivo, dal momento che nè gli studenti delle scuole, nè il pubblico o i mass media sono adeguatamente istruiti sui valori della costruzione di società resilienti e sostenibili [24].

4. Conclusioni

VESUVIUS–CAMPIFLEGREI PENTALOGUE è un avanzato interdisciplinare e transdisciplinare quadro di resilienza e sostenibilità per l'area napoletana e un'elaborazione del quadro VESUVIUS 2000 proposto nel 1995. I cinque obiettivi chiave del pentalogogo mirano a produrre rifugi temporanei e locali per le popolazioni di aree pericolose durante le crisi vulcaniche, lo sviluppo di soluzioni avanzate di ingegneria e pianificazione urbana per la produzione di ambienti resilienti e sostenibili intorno ai vulcani, lo sviluppo di efficaci informazioni sui rischi e campagne educative per il pubblico e la creazione di efficaci collaborazioni tra professionisti, organizzazioni, istituzioni e parti interessate per garantire interventi territoriali. Il progresso verso la realizzazione degi obiettivi di carattere professionale è tuttavia ostacolato da inaffidabili e istituzionalizzati piani di evacuazione del Vesuvio e dei Campi Flegrei e da abitudini mentali incommensurabili di molti professionisti e funzionari pubblici.

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THEME

Excursion to Neapolitan Habitats and Volcanoes

Escursione agli habitats e vulcani napoletani

Campi Flegrei and Pompeii 29 November 2018. Top Image: Grazia Paolella, Annamaria Imperatrice, Rocio Ortiz, Maria Pilar Ortiz, Mathieu Augustin, Fabiana Mennella, Cristina Lara Correa, Andrea Young, Flavio Dobra, Concettina Nunziata, Claudio Scarpati, Lyuba Albouf, Franco Vaccari, Maurizio Indirli, Fabio Romanelli, Antonio Formisano, with the volcanic islet Nisida of Campi Flegrei in the background. Bottom image: Same group at the Forum in Pompeii, with the volcano Vesuvius in the background.

Campi Flegrei 29 November 2018. Bus tour through the Neapolitan habitats, Claudio Scarpati at Lake Averno describing Campi Flegrei eruptions, interviews at Belvedere, and taking advantage of scenary at Coroglio.

GVES, Napoli – New York, ISBN 978-88-903183-1-3

Archeological Park of Pompeii 29 November 2018. Entrance at Porta Marina, Forum with Vesuvius in background, C. Scarpati explaining excavated and non-escavated areas of the city, Via Abbondanza, Necropolis with intact deposits of the 79 A.D. eruption of Vesuvius, victims from the 79 A.D. eruption.

Banquet at Circolo Ufficiali 29 November 2018 Naples. Banquet participants and tosting. Handling of conference participation certificate to Commander of Circolo Ufficiali Andrea di Raimondo. Neapolitan entertainment with the opera singer soprano Anna Rita Scognamiglio and pianist Rosario Pignatelli.

Neapolitan Habitats and Volcanoes

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Abstract. The aim of the excursion to Neapolitan habitats and volcanoes is to examine deposits of Campi Flegrei and Vesuvius eruptions and provide a general outlook of the danger of these volcanoes to the densely populated areas of Naples and surrounding towns. In particular, the field trips will examine the exposures of the Neapolitan Yellow Tuff on which Naples is built and the deposits of the A.D. 79 Vesuvius eruption that buried Pompeii. This brief guide summarizes recent research on the topics illustrated during the field trips.

Keywords: Naples, Pompeii, Vesuvius, Campi Flegrei

1. Introduction

The Neapolitan area was first populated in the pre-historic time, and it is only with the colonization of Greeks in the eight century B.C. that it began thriving commercially and in the twentieth century that it developed into one of the most populated and abused areas in the world. Under Greeks and then Romans this area enjoyed a relative autonomy, and when in 79 A.D. Vesuvius erupted with one of its powerful plinian eruptions and buried the nearby cities of Pompeii, Herculaneum, and others still protected by the modern urbanization, it took several centuries before the area began thriving again. With the fall of the Roman Empire in the fifth century the Neapolitan area passed under the domination of feudal landlords where there were no incentives to produce, and where the Byzantine, Norman, Angevin, Aragonese, and Spanish feudal barons maintained the territory at subsidence levels. With the spread of renaissance beginning in the thirteenth century the Greeko-Roman contributions began to be appreciated again and the volcanic character of the area taken in serious considerations [1].

The rediscovery of the buried cities of Pompeii and Herculaneum in the seventeen century and the eruption of Vesuvius in 1631 brought the Neapolitan area to the attention of Europe and the area thrived under the new-established Bourbon monarchy until the Neapolitan Jacobians declared the city of Naples a republic in 1799. The seventeenth and eighteenth century ideals of Enlightenment and the Age of Revolutions in Western Europe brought to an end the monarchic traditions and Naples passed from being the largest city of Europe to a subservient city serving the new-found Italian State that was established in 1865 [2].

When during the second half of the twentieth century Naples could not absorb anymore the demographic pressure, many Neapolitans settled on the slopes of Vesuvius and surrounding towns built on the deposits of Campi Flegrei eruptions, and today there are more than one million people living within 10 km of the craters of these volcanoes and one million people in Naples who for most part believe that the city will not be affected by future eruptions. The ignorance of the consequences of Campi Flegrei and Vesuvius eruptions is widespread in the Neapolitan area, because the current population has no experience with eruptions and the information and education campaigns are not directed at building a security culture that would make the area more resilient to these eruptions [1].

2. Campi Flegrei Volcano

2.1 Campi Flegrei Geological Setting

The Campi Flegrei volcanic field is a vast area that includes a large part of the city of Naples and the Island of Procida (Fig. 1). This area is characterized by the presence of diffuse monogenetic volcanic cones and two nested calderas associated with the Campanian Ignimbrite (39 ka BP) [3-5] and the Neapolitan Yellow Tuff (15 ka BP) [6,7] eruptions, respectively. These areas consist of pyroclastic deposits and subordinate lavas separated by paleosols. Numerous small volcanic centres have also been identified, including a lava dome and five scattered monogenetic vents located in the city of Naples [5], three lava domes along the morphological border of Campi Flegrei [3,8,9] and five local vents on Procida Island [10-12]. The products of this early activity are covered by tephra from different sources: (a) coarse fallout and flow deposits from Ischia Island (one of which has an age of 55 ka [13]) mantle the ancient volcanoes of Procida and Monte di Procida [9]; (b) stratified fall deposits from the eastern part of Campi Flegrei (Torre di Franco Tuffs dated at >42ka [14]) lie on the Neapolitan volcanoes [5]. An ubiquitous succession formed by coarse welded beds (Piperno) and lithic breccia (Breccia Museo) associated with the Campanian Ignimbrite eruption [3] covers the ancient sequence. These proximal deposits dated at 39 ka [15,16] or 37 ka [17] mark the oldest caldera rim that occupies the Campi Flegrei region and part of the city of Naples [3-5]. A few small volcanoes (Solchiaro and Trentaremi) located inside and outside the caldera and some local tephra layers (e.g. Withish Tuffs) crop out below the Neapolitan Yellow Tuff (15 ka) [7]. This huge pyroclastic deposit (50 km^3 dense rock equivalent) [6] crops out extensively in the Neapolitan area and produced a second caldera collapse inside the pre-existing Campanian Ignimbrite caldera. Tens of small volcanic edifices (most made up by lithified yellow tuff) emplaced almost exclusively within the Neapolitan Yellow Tuff caldera both during the prehistorical and historical times (Monte Nuovo volcano, 1538 AD) (Table 1).

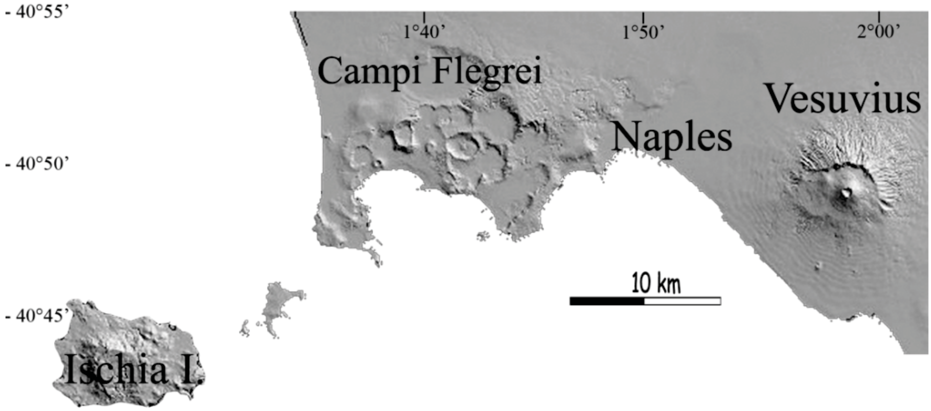

Figure 1. Map of the Campi Flegrei area.

Table 1. Stratigraphic scheme of Campi Flegrei

Previous Campi Flegrei Stratigraphy		**Synthemic Unit**	
		Synthem	Supersynthem
III period	**III Epoch** 20 explosive eruptions and 3 lava flows	**Monte di Procida** 9 explosive eruptions 6 volcanic edifices	**Flegrean**
	II Epoch 6 explosive eruptions		
	I Epoch 37 explosive eruptions		
Neapolitan Yellow Tuff		**Neapolitan Yellow Tuff**	
II period	More than 9 explosive eruptions. 7 volcanic edifices	**Solchiaro** 12 explosive eruptions 2 volcanic edifices	**Campanian**
Campanian Ignimbrite		**Campanian Ignimbrite**	
I period	More than 11 explosive eruptions and 5 lava flows. 2 volcanic edifices	**Serra** 19 explosive eruptions 1 volcanic edifice	
		Paleoflegrei 6 volcanic edifices	

The Campi Flegrei is in a persistent state of activity, as testified by the last eruption of Monte Nuovo in 1538 [18,19], the 1970-72 and 1982-84 unrest episodes and bradyseismic crises [20], and intense fumarolic activity [21].

On the basis of the presently available age data, a new chronostratigraphic model of the Campi Flegrei recent volcanism can thus be drawn [22]. The proposed scheme is characterized by three epochs of approximately continuous activity (Table 1): (1) Epoch I from 15 to 10.9 ka; (2) Epoch II from 9.6 (Fondi di Baia eruption) to 8.6 ka (Bacoli eruption); (3) Epoch III from 6.5 (Porto Miseno) to 3.9 ka (Nisida). Such epochs are separated by time spans of non-documented volcanic activity which are here no more referred to as "quiescent intervals" given that future dating of presently undated eruptions (which still make the great part of the ~60 post-NYT events) can result in a much more complex scenario, possibly totally lacking a clear distinction between periods of activity and periods of volcanic quiescence.

2.2 Volcanism of Naples and the Campanian Ignimbrite Caldera Collapse

The autochthonous volcanism in the central part of the city of Naples lies on sedimentary rocks. This ancient activity is recorded in few boreholes which cut 200 m of loose pyroclastic deposits with minor lava horizons. The main lava body was a lava dome identified during the excavation of various tunnels beneath S. Martino [23]. The subsequent activity was exclusively explosive producing the monogenetic vents of Parco Margherita, Parco Grifeo, Funicolare di Chiaia, S. Sepolcro and Capodimonte. Where exposed, the contacts between the remnants of the cones show a west to east trend of this pre-caldera activity. These volcanic edifices were successively covered by three lapilli pumice fall deposits associated with ash and pumice beds possibly related to the Torre di Franco Tuffs of Campi Flegrei. Rolandi and co-workers [24] do not recognize the paleosols between the different lapilli pumice fall deposits and attribute all this thick sequence to a single plinian event, vented in this area, that predate the Campanian Ignimbrite eruption of almost 1 ka. Our interpretation, based on the presence of paleosols and the good sorting of the lapilli pumice fall deposits, is that these deposits are the products of different eruptions and that their source is possibly within the Campi Flegrei. We suggest that only the uppermost and coarser fall deposit is related to the onset of the Campanian Ignimbrite eruption. The grading features and the thickness of this deposit are not easily comparable with that defined for distal locations (>30km from the presumed source, see details in [25,26]) but this is possibly due to the combined effect of deep erosion and the emplacement in a proximal environment. During the Campanian Ignimbrite eruption a thick sequence of welded tuff, spatter deposit and lithic breccia was emplaced in this area. The large average size of the clasts, their lithic nature and the welding feature suggest the proximal character of these deposits.

A caldera collapse cut through the Campanian Ignimbrite and Ancient Tuffs forming the steep scarps that border the south and east sides of Vomero-S. Martino hill and south side of Capodimonte hill. This collapse possibly produced a scarp also west of the Vomero-S. Martino hill, linking this structural high with the well known Piperno-Breccia Museo outcrop of Camaldoli, that is supposed to be completely buried by recent volcanic products (Neapolitan yellow Tuff). It is noteworthy that few tens of meters from the previously described proximal deposits of the Campanian Ignimbrite we have found a grey welded tuff, 5 metres thick, with reverse graded, black scoriae, embedded in an ashy matrix. We speculate that this deposit could represent the lateral transition between the proximal coarse and welded products and the typical facies of the Campanian Ignimbrite.

The volcanic activity post-Campanian Ignimbrite is represented by the Chiatamone volcano which, with the Trentaremi tuff ring located on the west side of the bay of Naples [27], testify of an explosive activity inside the city of Naples after the Campanian Ignimbrite caldera collapse. The thicker pyroclastic sequence present, at the same stratigraphic height, in the intra-caldera boreholes should be related to remobilized deposits during the prolonged (24ka) erosion of these scarps. Around 15 ka ago, the Neapolitan Yellow Tuff was erupted, producing about 50 km^3 DRE [6] of material and forming a second major caldera collapse in the Campi Flegrei. The eruption produced up to 150 m thick deposit in proximal areas, which draped the erosive remnants of the Campanian Ignimbrite rim, in the Campi Flegrei and Naples. The seaward side of the structural heights was deeply eroded again to the local exhumation of the Campanian Ignimbrite caldera wall. The primary (i.e. volcanic) post-Neapolitan Yellow Tuff activity produced several thin ash and pumice lapilli layers that do not contribute significantly to the structural and morphological features of the study area with the exception of Mt. Echia volcano [27]. On the contrary, volcanoclastic hydrologic remobilization and resedimentation processes were capable of transporting a voluminous sediment load to the level part of the city.

3. Somma-Vesuvius

3.1 Somma-Vesuvius Volcanism

The volcano of Somma-Vesuvius, located near Naples (southern Italy), buried Pompeii and Herculaneum during the 79 A.D. eruption. This volcano consists of an old stratovolcano, Monte Somma, that collapsed several times because of huge explosive eruptions, and a recent cone, Vesuvius, produced from the inside of the summit depression (caldera) after the 79 eruption (Figs. 2,3).

The Vesuvius crater is about 450 m in diameter and the highest elevation of its rim is 1283 m asl. Several large explosive eruptions (plinian) occurred a few thousand years apart (Fig. 4), with more frequent weakly explosive and effusive episodes that produced stratified ash and lapilli beds (pyroclastic deposits) and lava flows. The plinian events have an age of 21,670 yr B.P. (Pomici di Base eruption), 18,456 yr BP (Pomici Verdoline eruption), 9,348 yr B.P. (Mercato eruption), 3,670 yr BP (Avellino eruption) and 79 (Pompei eruption). During these eruptions the eruptive columns rose several kilometers above the vents forming umbrella-shaped tops that dispersed by the prevailing winds. Solid material (pumice lapilli) fell back from the ascending columns and the clouds draped the topography. Due to the prevailing direction of the wind in the Neapolitan area, the dispersions of fall deposits of the Somma-Vesuvius are usually towards the east, and the frequent collapses of sustained columns produce pyroclastic density currents that may be radially distributed around the volcano.

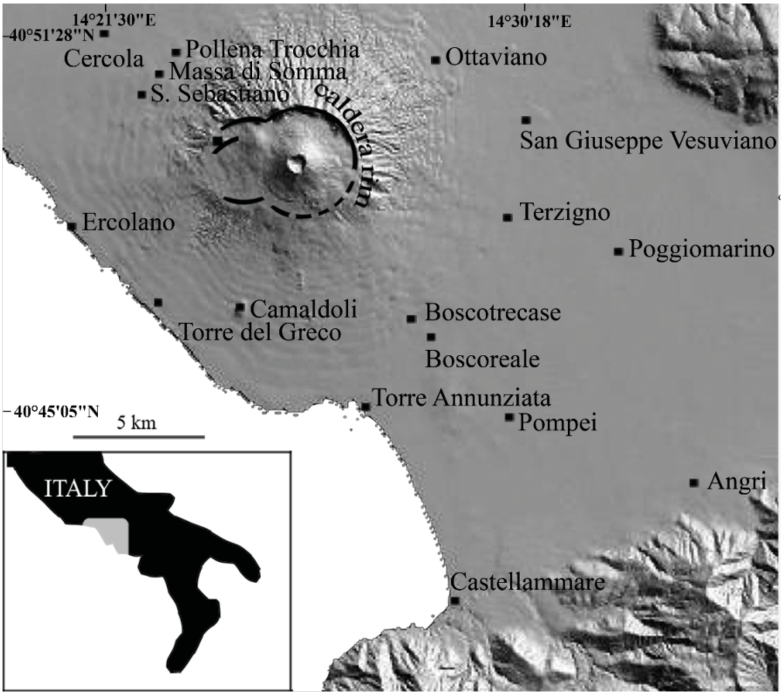

Figure 2. Campanian Plain with Somma-Vesuvius.

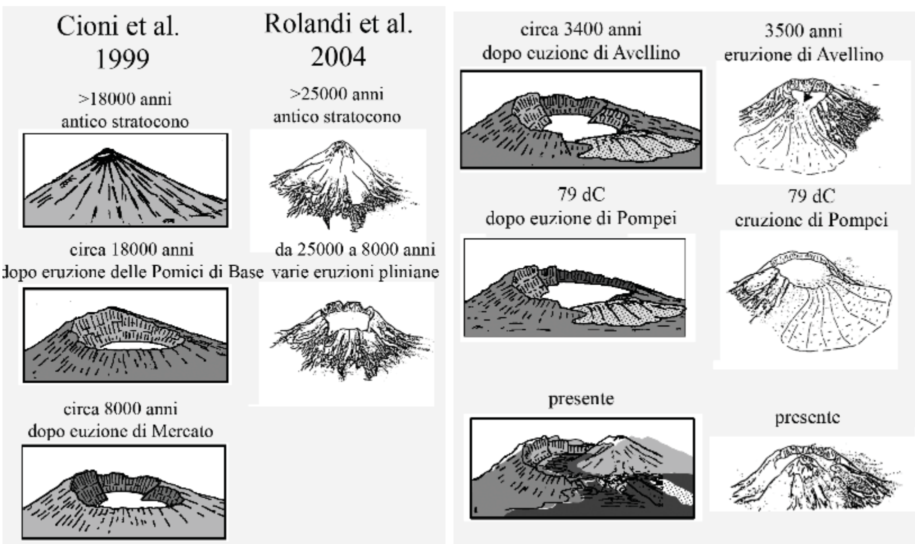

Figure 3. Schematic models of Somma-Vesuvius caldera genesis.

The destructive impact of the major Vesuvian eruptions on the surrounding volcanic territory is documented both by the numerous archaeological sites that suffered extensive damage and by historical accounts of the more recent eruptive events. In fact, many villages, towns and rural farms in a large area around the volcano were destroyed and buried under a blanket of tephra and mass flows in prehistoric and historic times. Some examples are the burying of Bronze Age villages by the products of the Avellino plinian eruption and the most famous destruction of Pompeii and Herculaneum during the 79 eruption as described by Pliny the Younger [28]. Pliny the Elder and thousands of other people were killed in the few days of this eruption. The next major subplinian eruptions occurred in 472 and 1631. During the 472 eruption the plain at the foot of the northern slope of the volcano was inundated and large Roman buildings and villae rusticae (country estates) were buried under several metres of volcanic debris. Historical records report over 4000 people killed and some 40,000 displaced in consequence of the 1631 eruption [29]. A few other smaller explosive episodes were reported in 512, during the Medieval period, and during the most recent activity cycle (1631–1944).

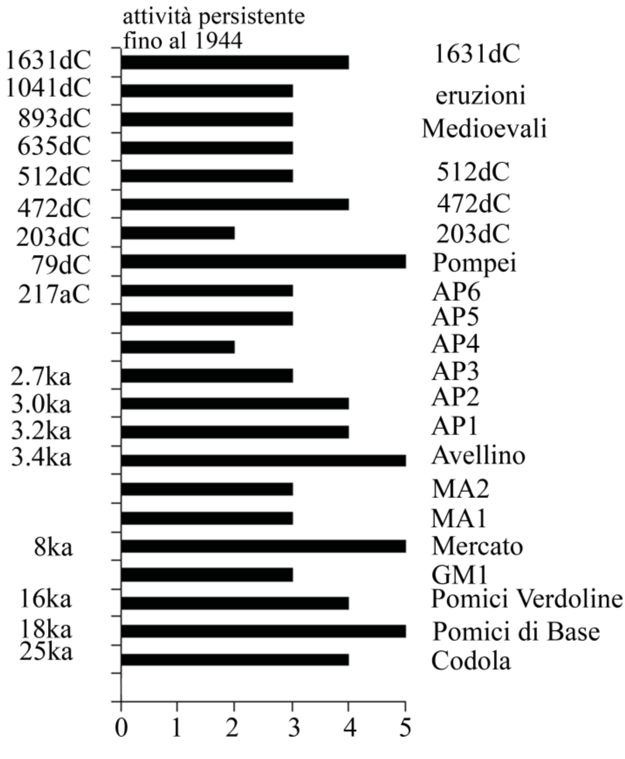

Figure 4. Chronostratigraphy of Somma-Vesuvius eruptions.

3.2 The A.D. 79 Vesuvius Eruption and its Effects on Pompeii

The A.D. 79 eruption started at about 1 p.m. on 24 August with the formation of a plinian column that was preceded by a phreatomagmatic opening phase. A thick layer of pumice lapilli resulting from this phase covered a vast area to the south of Vesuvius [30]. The pumice deposit reached its maximum depth of 2.8 m at Pompeii [31]. Numerous pyroclastic currents occurred during and after the emplacement of the upper part of the basal lapilli pumice deposit (Fig. 5). Some cities around Vesuvius received successive waves of pyroclastic currents in which material achieved temperatures of up to 400°C [32]. The phreatomagmatic final stage of the eruption is displayed by the presence of accretionary lapilli into the deposit.

The process of Pompeii's burial is here briefly reported [33,34]. It began in the early afternoon on 24 August with the initial stage of the eruption. The rate of deposition in the open areas of the city was 15 cm per hour; areas accumulating additional material, such as that falling from the sloped roofs of buildings, received 25 to 30 cm per hour. Within the first six hours of the eruption, roofs began to collapse under the weight of the pumice lapilli, causing some supporting walls to crumble as well. By the early morning on 25 August, most structures were seriously compromised. Portions of many houses had collapsed, and it appears that only those roofs whose angle were considerably sloped survived. A notable quantity of pumice lapilli had infiltrated the internal spaces of houses through the compluvia (roof openings) or collapsed roofs, forming the deposit ranging between 1-5 m thick. Approximately 3 m of material accumulated into peristyles and alleys between the houses, before the sustained pyroclastic currents overcame the town. This phase was punctuated by at least three episodes of lithic sand to lapilli fall, suggesting pauses between the passage of pyroclastic currents that allowed the deposition from the sustained column. We suggest that only the lower portions of the pyroclastic currents had contacts with the structures of the town, destroying preferentially the upper floors and the walls of the ground floors that happened to run perpendicular to the direction of the pyroclastic currents. The impact with the solid masonry of the houses caused deceleration of the currents, which consequently lost their solid matter and, hence, their kinetic energies. The ash and pumice lapilli transported by the pyroclastic currents formed compact and very hard layers upon the basal pumice lapilli deposit.

4. Conclusions

This brief overview of the eruptions of Campi Flegrei and Vesuvius volcanoes attest to the recurring and destructive nature of the hazards from these volcanoes, and to the resilience of the cohabiting populations that resettled after the destructive volcanic events. Naples and the surrounding towns are today continuously expanding and facing not only the hazards from the volcanoes but also from the human activities (household and industrial landfills). While the past Neapolitan populations managed to rebuild after the devastating volcanic events, it remains to be seen whether the future generations will also succeed in cohabiting with their volcanoes.

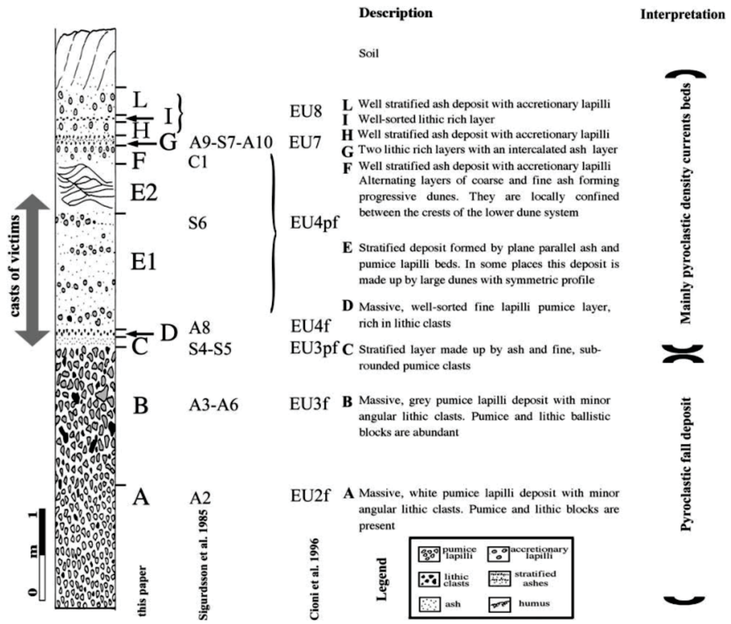

Figure 4. Stratigraphic section of A.D. 79 deposit at Pompeii.

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THEME

Risks of Cities Perceived by Schools

Rischi delle città percepiti dalle scuole

Maschio Angioino 30 November 2018. From left to right in the front row: Giovanna Tramontano, Maria Salvatore, Angela Procaccini, Maurizio Indirli, Grazia Paolella, Alessandro Attolico, Annamaria Imperatrice, Flavio Dobran, Antonio Formisano, Danila Mastronardi.

Castle Maschio Angioino and conference program, Alessandro Attolico, Annamaria Imperatrice, Grazia Paolella, Angela Procaccini, Luisa Liguoro, Flavio Dobran, flag wavers and musicians from Torre del Greco

.

Gragnano
Percezione del rischio vulcanico da parte dei cittadini

Referente
Ida Mascolo

Studenti partecipanti
Classe 4° C.L.S.

Liceo Scientifico don Lorenzo Milani
Gragnano, Italia

Il lavoro presentato tratta del rischio Vesuvio e di come sia percepito da parte dei nostri concittadini con uno sguardo, in particolare, a come si sono mosse le autorità della città di Gragnano in questi ultimi anni.
Il lavoro centrale è composto da un video alla cui realizzazione hanno partecipato gli alunni: Sara Abagnale, Monica Aponte, Luigi Busciè Santa D'Avino, Matteo Sarcinelli, Gennaro Sorrentino.

Il video si articola in due momenti: nella prima parte si riporta l'intervista fatta al capo della Protezione civile di Gragnano, mentre nella seconda si è deciso di scendere in campo ed intervistare delle persone campione, per avere un quadro complessivo della percezione del rischio Vesuvio da parte dei Gragnanesi, del loro grado di conoscenza dei piani di evacuazione predisposti dal loro Comune in situazioni di eventuali emergenze.

A questo lavoro si affiancano due cartelloni e uno striscione. Lo striscione è stato creato dalle alunne Rita Cesarano, Martina D'Apuzzo, Federica Imparato, Carmela Caiazzo, Rosa Ruocco. Il primo cartellone è stato sviluppato da Francesco Pio Guarino, Silvio Apuzzo, Paolo Francesco, Catello Coticelli, Raimondo Mansi e Mario Fusco. Il secondo cartellone è stato realizzato da Giordano Giusy, Scarfato Tina, Giulia Fontanella, Anna De Maria, Feliciana Mascolo, Basilio Naclerio e Antonio Ren. I suindicati lavori serviranno da supporto alla breve introduzione che precederà il video durante la manifestazione.

Cartelloni e striscione sviluppano alcuni elementi emersi dalle interviste esprimendo, fondamentalmente, le richieste di una sistematica educazione al rischio ancora molto incerta e confusa.

Comunque, tutti i lavori sono convergenti e finalizzati allo sviluppo della tematica affrontata e, al di là di alcune valutazioni non troppo edificanti e rassicuranti, c'è da parte di noi giovani l'auspicio che le cose cambieranno e che, gradualmente, la popolazione pervenga ad una conoscenza seria e consapevole del proprio territorio e dei rischi con i quali si ritrova a convivere.

Ercolano
Pop-up book della città a rischio

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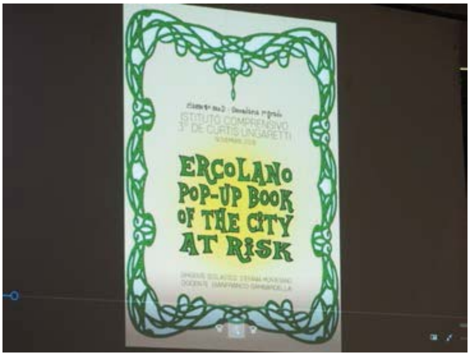
Fabiana Canna, Fabrizio Cianci, Valeria Cozzolino
Andrea Filosa, Ciro Grazioli, Giovanna Lippolis, Cosimo Pettinicchio

Istituto Comprensivo 3° De Curtis-Ungaretti
Ercolano, Italia

Presentazione di un volume con le aperture di pagina che offrono una vista tridimensionale attraverso uno studiato uso di disegni e ritagli, incollaggi tra piegature ed alette che nell'insieme vanno a comporre fantasiosi scenari dai contenuti simbolici e fiabeschi. Il libro presenta il Vesuvio anche in chiave caricaturale con riferimenti a questioni scottanti che riguardano la sicurezza della città di Ercolano esposta in pieno al più alto rischio vulcanico.

Il lavoro ha offerto, agli alunni, momenti di riflessione ed attenzione circa la pericolosità legata al Vesuvio. I passaggi creativi si sono legati a quelli di una presa d'atto del rischio e, di conseguenza, ciò che la scuola trasferisce a questi futuri cittadini è una maggiore consapevolezza del rischio che può divenire importante possibilità di ridisegnare, in questi anni, una realtà nuova di organizzazione del territorio. Le nuove generazioni, si spera, cercheranno di "ricostruire" una sicurezza della città senza perderne i contatti, magari stabilendo le proprie abitazioni ed attività lavorative in zone contrassegnate dalla più naturale resilienza per non perdere la loro identità culturale e rilanciare i propri beni di famiglia in ulteriori opportunità economico-turistiche. Ma rimane nei ragazzi, grazie a tali mirate attività didattiche, soprattutto il senso della necessaria conservazione delle ricchezze artistiche del proprio territorio che rappresentano un tesoro per tutta l'umanità anche delle generazioni delle epoche che seguiranno e che, a loro volta, dovranno confrontarsi con la forza della natura. Questo è un lavoro più difficile da realizzare per l'uomo avveduto, oltre la messa in sicurezza delle vite umane.



Gragnano
Vesuvio amico mio

Referente
Luisa Piovoso

Primo Circolo Didattico Ungaretti
Gragnano, Italia

Gragnano è un ridente paese collocato nel territorio immediatamente confinante con i paesi vesuviani tra mare, monti e sorgenti che hanno connotato il paese con forti elementi naturalistici di natura vulcanica.

Per apprezzarne la bellezza e la ricchezza del territorio si intende progettare un percorso storico-geografico , artistico , biologico e ambientale culturale e folcloristico che avvicini gli alunni alla percezione positiva e propositiva del rischio Vesuvio .

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Napoli
Attività di educazione ed informazione delle popolazioni esposte al rischio vulcanico

Referente
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Liceo Statale Pasquale Villari
Napoli, Italia

L'area vesuviana è considerata una delle più pericolose del pianeta, eppure l'elevata densità abitativa suggerisce che la popolazione percepisce il rischio vulcanico in maniera molto superficiale, sia per un approccio fatalistico alla vita che per il basso livello di informazione scientifica.

La maggioranza degli abitanti, circa l'80% del totale, è nata dopo l'ultima eruzione del 1944 e non ha memoria dell'immane potenza distruttiva del vulcano. A distanza di circa 2000 anni dal 24 agosto del 79 d.C., ci ritroviamo in una situazione che, paradossalmente, risulta essere simile a quella delle popolazioni di quel tempo, che ignoravano o sottostimavano il rischio che poteva determinare l'attività eruttiva del Vesuvio, che provocò morte e distruzione.

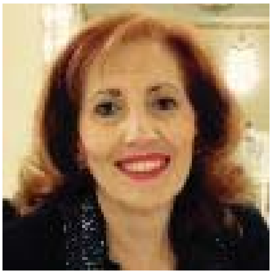
L'attività di docente in Scienze naturali in uno dei più antichi Licei napoletani, il Liceo P. Villari di Napoli, mi ha permesso di coinvolgere circa 150 allievi in uno studio esplorativo che, attraverso la formazione di Focus Group, ha svolto una indagine campionaria su una popolazione di circa 1000 persone, di diverse età, tutte abitanti nell'area metropolitana di Napoli.

A tutti è stato somministrato un questionario, con una serie di domande, che hanno voluto accertare la percezione che hanno i napoletani del Vesuvio in termini di benefici e di rischi, di timori per un'eruzione imminente e, più in particolare, delle conseguenze che potrebbero derivare da essa.
Gli esiti di questa indagine ci permetteranno di definire un percorso didattico efficace, per una corretta informazione scientifica, da proporre anche ad altre istituzioni scolastiche, che operano con studenti della fascia di età compresa tra i 14 e i 18 anni, che ci sembra la più idonea per una formazione culturale adeguata, anche in termini di protezione civile e di gestione del territorio.

GVES, Napoli – New York, ISBN 978-88-903183-1-3

La percezione del rischio ambientale da Plinio il Vecchio all'uomo contemporaneo

Referente
Maria Salvatore



Studenti partecipanti
Classe

Liceo Scientifico don Lorenzo Milani
Gragnano, Italia

Analisi percettiva ed emozionale del rischio attraverso i tempi ed i modelli di uomini.Come l'uomo di oggi si relaziona con il rischio ambientale e quali ipotesi risolutive propone.

Parco Nazionale del Vesuvio .... da riserva naturale a “contenitore” di veleni

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Liceo Scientifico don Lorenzo Milani
Gragnano, Italia

Noi alunne della classe 2°A Liceo Scientifico Scienze Applicate dell’Istituto Don Lorenzo Milani di Gragnano partecipiamo alla manifestazione del 30/11/18 nell'ambito delle iniziative promosse in occasione del Convegno Resilienza e Sostenibilità delle Città in Ambienti Pericolosi, con il lavoro dal titolo Parco Nazionale del Vesuvio .... da riserva naturale a “contenitore di veleni” ... che è una denuncia degli eventi che si verificarono nelle cittadine di Boscoreale e Terzigno, in relazione alla gestione smaltimento rifiuti, dal 2008 al 2010.

Attualmente frequentiamo la scuola a Gragnano ma, all'epoca dei fatti, eravamo residenti in quel territorio e, nonostante la nostra giovane età, conserviamo un ricordo indelebile di quella incresciosa situazione in cui si intrecciavano problemi tecnici con disperazione ed esasperazione della popolazione.

Abbiamo suddiviso il lavoro in alcune sessioni che procediamo ad illustrare:

Aurora Di Vuolo e Clotilde Cimmino esordiranno nella presentazione del Parco Nazionale del Vesuvio, ambiente dalle importanti e straordinarie ricchezze naturalistiche, ma “umiliato” dalla presenza della discarica chiamata Cava Sari. Quest’ultima, oltre ad aver rovinato “esteticamente” l’ambiente del Parco, ha creato problemi alle cittadine circostanti inquinandole con conseguente aumento di incidenza di malattie tumorali.

La nostra compagna Eleonora Fontana aggiungerà altre informazioni sull'aumento di alcune patologie per poi passare la parola a Giusy Brancaccio che parlerà delle falde acquifere inquinate che determinarono l'impossibilità a prelevare acqua per diversi mesi a causa della presenza di sostanza tossiche nei pozzi delle cittadine.

A causa di questi problemi ci furono molte proteste per chiudere la suindicata cava, anche se con scarsi risultati, anzi venne fatto un ulteriore progetto di una cava che fosse circa 3 volte più grande, chiamata "Cava Vitiello". Tutto ciò verrà raccontato da Clotilde Cimmino.

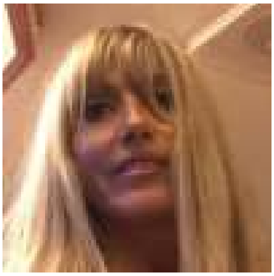
Aurora Di Vuolo e Giusy Brancaccio continueranno raccontando come i boschesi, una volta venuti a conoscenza della notizia, intervennero prontamente con proteste e scioperi per evitare la costruzione della Cava Vitiello, anche se inutilmente, nonostante lo sciopero della fame del sindaco Gennaro Langella.

Per avere maggiori informazioni sullo sciopero del Sindaco, Eleonora Fontana si è cimentata nel ruolo di giornalista intervistandolo così da sentire dalla sua viva voce come si svolsero i fatti. Dal dettagliato racconto sono emersi sia gli aspetti di varia natura che non si conciliano con una buona gestione del territorio, anzi ne ostacolano lo svolgimento, sia le emozioni di quei momenti che lo coinvolgevano non solo come Autorità ma anche e soprattutto come uomo legato alla sua terra e alle sue radici.

Per raccontare tutta questa storia utilizzeremo un PowerPoint prodotto da Katia Gargiulo che conterrà anche l'intervista al sindaco

Terre rosse

Referente
Giovanna Tramontano



Studenti partecipanti
Mariateresa Gargliulo, Federica Milo, Giuliana Cassese, Fabiana Attianese Flaminia D'Orso, Annachiara Carpinelli, Michela Carpinelli, Gerardo Carpinelli Federica Poccirillo, Lucia Russo, Diana Alberico, Roberta Ingenito, Marianna Baselice, Carla Roseo, Ilaria Zullo, Valentina Aprea

Liceo Scientifico don Lorenzo Milani
Gragnano, Italia

Un tempo, le parole “vita”, “salute” e “ambiente" erano imprescindibilmente collegate al nostro territorio. Oggi, per la nostra terra un tempo “Campania Felix” il concetto di "benessere "è diventato utopistico. Il fenomeno dello scorretto smaltimento dei rifiuti tossici rappresenta un vero e proprio “sistema criminale” su vasta scala ben più esteso e grave di quanto erroneamente descritto in passato.

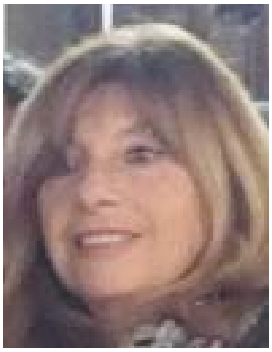
La pratica criminale di smaltire o riciclare i rifiuti speciali bruciandoli, oramai va avanti da molti anni. È stato documentato tutti i giorni con foto e video che, denunciando questo scempio a ogni istituzione politica e giudiziaria, raccontano storie di ormai ordinario degrado: i campi nomadi autorizzati sui cumuli di immondizia, colonne di fumo nero, discariche illegali aperte come enormi voragini, bambini ammalati, uomini e donne costretti a convivere con il veleno, ogni giorno, simboli sacri sparsi come segnali su un territorio avvelenato. Sono trascorsi diversi anni. Tuttavia, senza che nulla sia realmente cambiato! Inizia così, un'altra stagione di roghi, fumi tossici e di altri veleni. Si continua come se nulla fosse. Sempre negli stessi luoghi. Spesso sentiamo parlare di cancro, ma a cosa serve curare i tumori o donare soldi alla ricerca, se nessuno si occupa concretamente della nostra prevenzione primaria? Lo smaltimento illegale dei rifiuti tossici, non è soltanto un problema economico e sanitario, ma, è un fattore che chiama in causa le nostre coscienze, il nostro senso civico e la nostra appartenenza ad una comunità. É un problema principalmente " etico"che da anni ci vede spettatori inermi ed indifesi.

La coreografia "Terre Rosse" interpretata su un vecchio brano della Premiata Forneria Marconi, dai giovani allievi del liceo scientifico "Don Milani", vuole dare comunque un messaggio di speranza attraverso la rappresentazione della rinascita della natura dopo essere stata attaccata e flagellata dal l'inquinamento ambientale. La salvaguardia del territorio campano, deve essere un impegno nostro per la tutela della salute delle nuove generazioni.

GVES, Napoli – New York, ISBN 978-88-903183-1-3

I giovani di Pozzuoli e i Campi Flegrei

Referente
Danila Mastronardi



Studenti partecipanti
Classe IV A, IV B, III B

Liceo Scientifico I.S. Giovanni Falcone
Pozzuoli, Italia

Focus del lavoro sono i luoghi di interesse dei giovani di Pozzuoli (ricreativi, sportivi, culturali). Di tali luoghi, familiari ai ragazzi, si recupera il genius loci, attraverso la contestualizzazione morfologica e geologica, in riferimento al campo vulcanico flegreo, e al recupero delle fonti storiche sullo stato di tali luoghi nel passato. L'analisi storica potrà essere sorprendente in un territorio mutevole come quello dei Campi Flegrei.

Our Past, Our Roots
Flag Wavers and Musicians from Torre del Greco

Il nostro passato, le nostre radici
Sbandieratori e musici di Torre del Greco

Associazione Sbandieratori e Musici
Torre del Greco, Italia


Sbandieratori e Musici
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Sbandieratori e Musici
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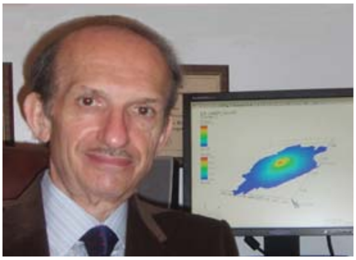
Profiles of Lead Authors

Profili di autori principali

Profiles of Organizers and Authors of Keynote Papers



Flavio Dobran

Flavio Dobran earned Ph.D. in engineering from Polytechnic Institute of New York University in 1978. He held academic positions at New York University, Polytechnic Institute of New York, Stevens Institute of Technology, and Hofstra University. Dr. Dobran was Visiting Professor, Scholar and Scientist in the Department of Theoretical Mechanics of University of Paris, ISPRA Research Centre of the European Union, Polytechnic Institute of University of Grenoble, NYS Department of Environmental Conservation, Argonne National Laboratory, Departments of Energetics and Geology at the University of Pisa, and Energy and Nuclear Engineering Research Centre of ENEA and Italian National Institute of Geophysics in Rome. In 1994 he founded GVES for the purpose of promoting the development of resilient and sustainable habitats in the Neapolitan area. Dr. Dobran delivered over two hundred seminars to the public and K-12 school children in the Summa-Vesuvius and Campi Flegrei areas on hazards from volcanic eruptions, volcanic and anthropogenic risks, safety, resilience, sustainability, and environmental conservation; organized since 1995 yearly manifestations of Vesuvius area schools to promote Vesuvius consciousness among the school children and teachers; appeared in national and international television documentaries and received many recognitions from schools, organizations, and civil protection for his work on Neapolitan volcanoes; organized several national and international conferences on energy conversion, theoretical mechanics, volcanic processes, Vesuvius, and environmental risk assessment; delivered numerous technical presentations to engineers, earth scientists, and authorities; authored ten books and over 150 peer reviewed technical and educational publications; served as a reviewer for engineering, physics, and earth science journals; coordinated research projects in the United States and for the European Union; guided undergraduate and graduate students on theses; received best technical paper awards and was invited to contribute to technical and mass media publications.

Grazia Paolella

Grazia Paolella earned the degrees in letters in 1978 and sociology in 1982 with highest distinction from the University of Naples Federico II and is currently a Professor at the University Suor Orsola Benincasa in Naples, Italy. Her positions included the school principal of ICS Don Bosco-F. DAssisi in Torre del Greco where she actively promoted many cultural events and projects; president and member of the state commission on examinations of I and II cycle;

lecturer at state and private organizations on the subjects of school legislation, Italian literature, humanistic laboratory, laboratory for simulation of scholastic teaching, linguistic education, psychopedagogy of education, and social politics for the disabled; consultant at the Scholastic Orientational Consultancy CONSVIP; researcher at the Regional Education Research Institute of Campania IRRE where she consulted and guided experimental teachings and formations of teachers; teacher at several middle level and high schools in the Neapolitan area; principal director of Public Administration; and director of formative courses for teachers. Paolellas research, experimentation, and autonomous activities earned her many positions in psychopedagogy, project leadership, and public administration, and was awarded gold medal for Good Teaching Methods and meritorious citations by the President of the Republic, Giorgio Napolitano, and Ministry of Public Education. In 2011 she represented Italy at the European Unions sponsored conference on Leadership and Management in the School. She also participated at numerous school manifestations, Universal Forum of Cultures in Naples, was responsible for her schools winning numerous awards on different subjects and enlarged the cultural horizons of students by touring several European countries and promoting European citizenship. The school books publisher Ferraro published Paolellas book The Bandit and Synthesis and Hologram manual of scholastic rules, and she has been collaborating with numerous school magazines and newspapers.

Antonio Formisano

Antonio Formisano earned Ph.D. in construction engineering from the University of Naples Federico II in 2007. He is currently an Associate Professor of structural engineering in the Department of Structures for Engineering and Architecture at the same university. From 2011 he has been an Aggregate Professor of theory and design of steel constructions and from 2014 has taught structural design. He teaches the II level International Masters: Design of steel structures, emerging technologies for construction, and sustainable constructions under natural hazard and catastrophic events. In 2014 he became a tutor within the Ph.D. program of the Portugal Universities (Management System FCT Fundacao para a Ciencia e Tecnologia). Dr. Formisano participated at many national and international conferences and coordinated numerous research projects. From 2015 to 2016 he was involved on a project dealing with innovative systems of welded steel beams for floors and light roofing for applications in monument buildings and archaeological sites. Dr. Formisano is a reviewer of many international scientific journals and a member of the editorial board of a dozen of national and international journals.

Maurizio Indirli obtained the nuclear and mechanical engineering degree from the University of Bologna in 1985 and earned Ph.D. in structural engineering from the University of Trento in 2010. From 1985-1988 Dr. Indirli worked for

Maurizio Indirli

private and consulting companies and in 1988 joined the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA). Since 2000 he worked on the preventions of natural catastrophes, conducted structural engineering evaluations, and employed antiseismic innovative techniques (including base isolation and energy dissipation) for the improvement of industrial plants, strategic constructions of infrastructures, residential housing, and cultural heritage. Dr. Indirli's experiences with numerical structural analyses, experimental campaigns (in situ and laboratory), and construction materials, such as shape memory alloys and antiseismic rubber devices, allowed him to participate on the restoration of San Francesco Basilica in Assisi and Roman wooden ship in Herculaneum, participate on ENEA's teams for in situ investigations of great seismic events of Northridge 1994, Kobe 1995, and Chile 2010, and earthquake damage evaluation with particular regard to cultural heritage and historical centres in Reggio Emilia-Modena 1996, Umbria-Marche 1997-1998, Molise 2002-2003, Abruzzo 2009, and Emilia-Romagna 2012. Dr. Indirli also organized and coordinated technical groups supporting the reconstructions of San Giuliano di Puglia, Abruzzo towns, and Emilia-Romagna municipalities. From 2007-2009 he coordinated the International MAR VASTO project dealing with the evaluation of natural and anthropogenic hazards in Valparaiso, Chile, and from 2008-2010 was a coordinator on the European Unions sponsored COST C26 project dealing with Urban Habitat Constructions Under Catastrophic Events. Dr. Indirli also participated on many other ENEA projects, appeared on national and foreign mass media programs and publications, collaborated with universities, has been a reviewer for several international technical journals, and is the author/coauthor of more than 130 technical publications.

Alessandro Attolico

Alessandro Attolico has a degree in Civil Engineering and Ph.D. in Earthquake Engineering. Dr. Attolico has also an international post-graduate degree in European Construction Engineering. He currently holds the positions of the Executive Director of Territorial Planning and Development of the Environment and Civil Protection Office of the Province of Potenza and Local Authority, and in 2014 was appointed as the United Nations International Strategy for Disaster Reduction Advocate and Sendai Framework for Disaster Risk Reduction Local Focal Point for Making Cities Resilient. Dr. Attolico is responsible for orienting political decision-making processes, drawing and implementing plans, programs, projects, and actions associated with territorial and environmental policies at local, regional, national, and international levels. He holds extensive expertise and experience in territorial Sustainable Development, DRM/DRR and climate and multi-year engagements in decision-making and policy-oriented processes. Among many achievements, Dr. Attolico coordinated the construction of the first Provincial Civil Protection System for the Province of Potenza and was involved in the drafting of the Provincial Master Plan (TCP) in 2013, outlining governmental proposals for the implementation of broad Sustainable Development Goals of Province of Potenza. Both of these projects have been acknowledged as national and international models and are producing tangible effects in terms of the strategic positive policy-making. Province of Potenza is an UNISDR World Role Model for Inclusive Resilience and Territorial Safety (2015), Community Champion of Knowledge for Life - IDDR2015 (2015), since 2016 is the coordinator of EU Covenant of Mayors for Climate and Energy and is addressing and coordinating 100 Cities and Municipalities initiative.

Stefano Lenci

Stefano Lenci graduated in Civil Engineering at the University of Ancona in 1992 and earned Ph.D. in Structural Engineering at the University of Florence in 1997. He conducted post-doctoral work at the University Pierre and Marie Curie in Paris (1998-2000), was an assistant professor at the University of Rome La Sapienza (2000-2001) and associate professor at the University of Ancona (2001-2005). Since 2005 Dr. Lenci has been full professor of structural engineering at the Polytechnic University of Marche in Ancona and the Head of the Department of Civil and Building Engineering, and Architecture, and Member of the Academic Senate. Since 2018, he has been the President of the Italian Association for Theoretical and Applied Mechanics (AIMETA) and secretary of the Technical Committee on Multibody Systems and Nonlinear Dynamics of the American Society of Mechanical Engineering (ASME). Dr. Lenci is an associate editor of Nonlinear Dynamics, European Journal of Mechanics A/Solids, ASME Journal of Vibration and Acoustics, and International Journal of Dynamics and Control, and has been an associate editor of Meccanica, ASME Journal of Computational and Nonlinear Dynamics and Mathematical Problems in Engineering. Dr. Lenci delivered more than 20 invited and keynote lectures at the international scientific conferences and is the author of about 350 publications, where 153 of them have appeared in peer-reviewed international scientific journals.

Rohit Magotra is the Deputy Director of Integrated Research and Action for Development (IRADe). He has more than 18 years of technical and managerial experience working on thematic areas of disaster management, vulnerability assessment, climate vulnerability index, smart cities, heat stress, public health, etc. Mr. Magotra has experience in policy research, advocacy, consensus building, program management, setting multi-stakeholder consortiums of government, public and private sector. He has Masters in Environmental Sciences with advanced degree in management from IIFM, Bhopal.

Rohit Magotra

Rohit Magotra has authored/co-authored/contributed several papers and publications related to disaster resilience, climate resilience, public health, energy, environment, smart cities, e-governance & SME supply chains. He is on the board of directors of companies working in agriculture supply chains and block chain technologies domain. Mr. Magotra leads the Think Tank Forum for South Asia Regional co-operation in South Asia.

Giuliano Panza

Giuliano Panza earned Laurea in Physics from the University of Bologna in 1967 and is a former professor of Seismology at the University of Trieste and Head of Group at Abdus Salam ICTP, Italy. He is Emeritus Honorary Professor at IGG, CEA-Beijing, member of the Accademia dei Lincei, Rome, Russian Academy, Moscow, and 5th Class/Knight OMRI. His teaching career includes guidance to 22 Ph.D. students and 26 postdoctoral scholars from 15 countries. Dr. Panza developed a powerful theoretical-numerical tool for the computation of complete synthetic seismograms that is the basis of the methodology for the Neodeterministic Seismic Hazard Assessment (NDSHA) which is currently considered in several large urban centers and megacities. In cooperation with the Italian space agency ASI, Panza has been involved in the simultaneous use of NDSHA for the ground motion estimation, in the monitoring of the space-time variation of hazard, and in the analysis of the Earth observation data. These led to the construction of time-dependent hazard models for strong ground motions and generated particular interest within the Italian Civil Defense authorities. Prof. Panza served on the editorial boards of several international journals and is currently Editor-in-Chief of Earth Sciences Review and Co-Editor of Journal of Seismology and Earthquake Engineering. He is the author/coauthor of more than 550 scientific peer reviewed papers and more than 10 books. For his achievements Panza received the Laurea ad honorem in Physics from the University of Bucharest, the Beno Gutenberg medal from EGU, the Central European Initiative Medal of Honour, the Commemorative Medal from the Vietnam Academy of S&T, the NRIAG (Egypt) Medal of Honor. Prof. Panza was recently elected as an Honorary Professor at BUCEA (Beijing University of Civil Engineering and Architecture, China). Prof. Panza was awarded the 2018 Union International Award of the American Geophysical Union.

Claudio Scarpati

Claudio Scarpati received M.Sc. in Geology in 1985 and earned Ph.D. in Geophysics and Volcanology in 1990 from the University of Naples Federico II. Dr. Scarpati has been a researcher at the University of Napoli Federico II and currently is an aggregate Professor of Physical Volcanology at the same university and was appointed a Visiting Professor of Volcanology at Brigham Young University in the United States. He is the author of more than 160 technical papers and conference presentations. Dr. Scarpati is also a reviewer of the Bulletin of Volcanology and Journal of Volcanology and Geothermal Research, and was invited to lecture in France, Japan, U.S.A., and Indonesia. He has been a scientific consultant for numerous international exhibitions and scientific television documentaries (Discovery Channel, National Geographic, Channel ARTE, RAI). Dr. Scarpati has investigated the deposits of the eruptions of the Neapolitan volcanoes Vesuvius and Campi Flegrei (Phlegraean Fields) where several million people live and can be affected by future eruptions. This information should be useful to urban planners and developers for producing safer habitats and to risk managers for producing a safer territory. He also developed volcanological models to assess the potential consequences of future eruptions for the purpose of avoiding future catastrophes.

Andrea Young

Andrea Young graduated from the Catholic University of Campinas (PUC-Campinas) in 2000 with a degree in Architecture and Urban Planning and is currently a researcher at the Brazilian National Center for Monitoring and Early Warning of Environmental Disasters (CEMADEN) of the Ministry of Science, Technology, Innovation and Communication (MCTIC) located in So Jose dos Campos (SP). For the last 10 years, Andrea has been involved in scientific programs at both the national and international levels and has been associated with the institutions such as Kings College London (2012-2013), Earth System Science Center (CCST-INPE - 2009-2012), and Population Studies Center (NEPO-UNICAMP - 2006-2012). As an architect and urban planner, Andrea is especially interested in interdisciplinary issues, including climate change, adaptation, urban resilience and low carbon development with the focus on urbanization, ecology, and agriculture. She is the author of 21 technical papers/books and served as a reviewer for several international scientific journals.

Profiles of Authors of Regular Papers

Lyuba Alboul

Dr. Lyuba Alboul is a mathematician with a strong fundamental training in Pure and Applied Mathematics and a broad research experience in Computer Science, Engineering, and AI. Her research involves the interplay of discrete and continuous representation of reality, perception and interaction with real and virtual worlds, by both humans and machines. Lyuba has been involved in a number of research projects as a primary investigator. In 2007-2010, she has been a co-investigator of the EU-funded projects GUARDIANS and View-Finder, where she conducted research on 3-D representation of reality by fusing several sensor modalities. She developed a low-cost multi-sensor system to acquire and simultaneously visualise 3-D environmental scenes. This system allows capturing 3-D objects together with image information, thus providing a photo-realistic three-dimensional snapshot of the environment. Dr. Lyuba has also been actively working on developing a multi-modality approach to data association and processing based on discrete curvatures and texture and colour analyses. Another research interest involves inverse dynamic problems and concerns comparison of robot team's interaction patterns with behaviour of classical mechanics particle systems. She has been also an active participant in Engineering for Life EPSRC-funded project, where she focused on the development of 'human-centred' vision and measurement technologies for people with special needs, in particular on the autism spectrum. In 2013-2014 she participates in the nationally funded project The Medic of the Future: Training and Support by developing a novel training system combining a custom haptic feedback and 3-D computer-generated environment for training medical personnel. In 2016, she was the lead organiser of 'Fictional human and real robot: Sharing spaces with robots' and is the author/co-author of more than 80 technical publications.

Luigi Altavilla

Luigi Altavilla graduated in Biological Sciences at the University of Naples in 1981 and since 1987 taught natural sciences in high schools. He is the coauthor of the textbook Easy Chemistry, has been a member of many committees and coordinator of departments in high schools. Luigi Altavilla is currently a professor at Liceo P. Villari high school in Naples and participated in numerous refresher courses dealing with different science disciplines and educating students in science. His most recent project deals with educating the students on Neapolitan volcanoes and the risk that they pose to the people living in the area. Prof. Altavilla believes that a Focus Group of his students who produced a volcanic risk questionnaire and conducted a survey on a sample of the citizens of Naples produced useful information on the perception of Vesuvius risk among the population and will aid in producing a more effective scientific teaching methodology of volcanic risk for the students between 14 and 18 years old.

Nicola Chieffo

Nicola Chieffo graduated in Civil Engineering at the University of Naples Federico II in 2013 and until 2017 was a researcher in the Department of Structures for Engineering and Architecture at the same university where he worked on large scale vulnerability assessment and risk analysis. Since 2017 Nicola Chieffo has been a Ph.D. candidate at the Polytechnic University of Timisoara in Romania and working in the field of Seismic Vulnerability of Historical Buildings. During the first half of 2018 he was a researcher at the University of Minho in Portugal and working on the nonlinear analysis of seismic vulnerability of historical masonry buildings. At the same university he collaborates with T.M. Ferreira of the Institute of Sustainability and Innovation in Structural Engineering (ISISE) and works on large-scale vulnerability assessment, seismic impact damage scenario and expected loss estimation in urban areas by means of parametric-probabilistic approach integrated with GIS technology. Nicola Chieffo is the author/coauthor of several scientific articles on seismic risk and urban resilience.

In 2009 Michele DAmato earned Ph.D. in Mathematical Methods and Models for Dynamic Systems at University of Basilicata. Dr. D'Amato is currently a researcher in structural engineering at the University of Basilicata Department of European and Mediterranean Cultures: Architecture, Environment, Cultural Heritage (DICEM), and since 2016 taught university courses Mechanics of Materials and of Structures and Principles and Structural Systems for Architecture at the University of Basilicata in Matera.

Michele D'Amato

Dr. D'Amato participates on different research projects focused on seismic protection of existing and historical constructions and since 2016 has been an adjunct coordinator for the Euro-Latin America Partnership in Natural Risk Mitigation and Protection of the Cultural Heritage (ELARCH, www.elarch.org) - a scientific project focused on the protection of cultural heritage in European and Latin American countries. Dr. DAmato lectured at different national and international conferences and served as a reviewer of many international scientific journals involving structural engineering.

Francesco Clementi

Francesco Clementi earned MS in Civil Engineering in 2005 and Ph.D. in Architecture, Buildings and Structures in 2009 at the Polytechnic University of Marche (UNIVPM). Since 2012 Dr. Clementi has been an Assistant Professor of Solids and Structural Mechanics at the Department of Civil and Building Engineering, and Architecture at UNIVPM. He has developed research and teaching activities at the Universities of Ancona, Camerino, Lublin, and Sao Paulo, and is the author and coauthor of more than 50 refereed scientific papers published in international journals and conferences and is a reviewer of research projects and technical papers for many international journals. Dr. Clementi is a member of scientific committees of several international conferences and a member of the Editorial Boards of Mathematical Problems in Engineering, Computational Methods in Structural Engineering, Journal of Modern Mechanical Engineering and Technology, and Vibration Testing and System Dynamics.

Giuseppe De Natale

Giuseppe De Natale graduated in physics at the University of Naples Federico II and earned Ph.D. at Institut de Physique du Globe at the University Paris 7. From 1996 to 2001 Dr. De Natale has been a member of the Board of Directors of Osservatorio Vesuviano of the National Institute of Geophysics and Volcanology (INGV) in Naples and of the National Council for Geophysics (Ministry for Research). From 2013-2016 he served as the Director of Osservatorio Vesuviano and currently is a research director and professor in geophysics at the same institution. Dr. De Natale was appointed a member of Academia Europaea in 2005 for his outstanding contributions to research in volcano physics and was awarded the Sergey Soloviev Medal by the European Geoscience Union for outstanding contributions to research and mitigation of seismic and volcanic hazards. He is the author/coauthor of about 200 scientific publications, has edited several books and special issues on seismology and volcanology, taught Solid Earth Physics at the Universities of Potenza and Rome La Sapienza, is a member of the IUGG-CNR Commission, and is an Italian representative for IAVCEI.

Gianfranco Gambardella graduated in 1979 from Conservatorio (Italian State Music Academy) of San Pietro a Majella in Naples, and since has been a teacher of music at the Secondary Schools of De Amicis in San Giuseppe Vesuviano, Don Milani in Portici, Scotellaro in Ercolano, Scotellaro-Ungaretti in Ercolano, and De Curtis-Ungaretti in Ercolano. He participated in many concerts and as an educator took diverse refresher courses and has been the referent of schools on the mitigation of volcanic risk and security culture in the Vesuvius area.

Gianfranco Gambardella

Prof. Gambardellas students worked on such projects as the Magic Cube that reveals Vesuvius and its hazards, Vesuvius Risk Education in the Middle Level Schools, The Volcano Caged, Thinking Back To He has extensively collaborated with GVES and on other interdisciplinary projects.

Annamaria Imperatrice

Annamaria Imperatrice earned the degree in Modern Literature from the University of Naples Federico II and from 1976 to 1982 taught literary subjects in various secondary schools of Friuli Venezia Giulia. In 1982 she returned to Campania where she taught at the secondary schools of Guglielmo Massaia, Raffaello Morghen and Orazio Comes of Portici. Annamaria has been active both at the planning level and as a member of school councils, has carried out various environmental education projects and in 1994 started working with the Naples 99 Foundation of Mirella Barracco as a part of the initiative The School Adopts a Monument, with her pupils taking parts at the annual public events and collaborating with the educational initiatives promoted by Naples. Her environmental education project associated with the monument Villa of Elboeuf in Portici also involved Vesuvius risk education. From 1995-2007 Annamaria was involved on such projects as: Monuments and School - The Roots of the Future - Journey Through the Realities of the Future; Neapolitan Walks Through Art, History and Culture; Knowing the City to Discover its Roots and Build Our Collective Identity; Journey Around Vesuvius, Villa of Elboeuf and the Three Centuries in the Shadow of Vesuvius; Commemoration of the Neapolitan Revolution of 1799; The Becoming of the City and the City of Becoming; The School Plans the City: The Port of Granatello; Religion, Culture and Magic; Manifestation at the Chapel of the Banco di Napoli; The Sea Between the Lands of Fire; Mediterranean Naples - Comparing Cultures; The Signs of Dreams - The Sea: A Dream of New Horizons; Vesuvius, Stories, Music and Folklore. From 1996 until the present Annamaria has been collaborating with GVES on the projects: Vesuvius at School: Didactic Experiences; The Villas of the Golden Mile and Vesuvius; Life and Death at the Foot of Mount Vesuvius; Education for Security Culture; In the Shadow of Vesuvius: Vesuvius and the Vesuvian Villas; Organization of the events promoted by GVES in the Vesuvius area, together with Gelsomina Sorrentinpo and Ida Mascolo; Vesuvius 2000, presentation at the 32nd International Geological Congress in Florence; Vesuvius 2000: Forum 2004, Villa Campolieto, Ercolano; Meeting-Debate of Schools with F. Dobran at Villa Savonarola, Portici; Discovery Channel filming at S.M.S.

Comes, Portici; Vesuvius: Education, Security and Prosperity, presentation of the volume, Torre del Greco; Vesuvius at School: Cognitive Tools and Educational Methodologies, presentation of the volume, Torre del Greco; Education for Cohabitation with Vesuvius, Nobel High School, Torre del Greco; Vesuvius and Sustainability manifestation at Liceo Scientifico Pantaleo, Torre del Greco; Vesuvius: Let's Talk About it Again, school manifestation at I.S. Scotellaro-Ungaretti, Ercolano; Vesuvius Risk Yesterday, Today ... and Tomorrow?, presentation at VESUVIUS 2014 Conference: What progress? Scientific, Social, Economic, Educational and Cultural Activities Aimed at the Sustainability of the Cities Around Vesuvius, Castellammare di Stabia; Vesuviando, with F. Dobran, collected works on the educational activities on Vesuvius 1995-2015.

Michelange Laterza

Michelangello Laterza earned Ph.D. in Civil Engineering at the University of Salerno in 1996. Dr. Laterza is currently Associate Professor of Structural Engineering at the Department of European and Mediterranean Cultures: Architecture, Environment, Cultural Heritage (DICEM) at the University of Basilicata. Since 2001 he lectured at the University of Basilicata in Matera and Potenza, and instructed such courses as Reinforced Concrete Structures, Principles and Structural Systems for Architecture, and Structural Design. Dr. Laterza participated and coordinated different research projects focusing on seismic protection of existing and historical constructions and since 2014 has been the general coordinator of the Euro-Latin American Partnership in Natural Risk Mitigation and Protection of the Cultural Heritage (the ELARCH project) - a scientific project focusing on the protection of cultural heritage in European and Latin American countries. Dr. Laterza lectured at different national and international conferences, served as a reviewer of many international scientific journals addressing structural engineering, and is the author of over 80 scientific publications.

Ida Mascolo

Ida Mascolo graduated in 1978 from the University of Naples Federico II with a degree in Biological Sciences, and in 1989 became a professor of Natural Sciences, Chemistry, and Geography in high schools. She taught at Istituto Tecnico Comerciale Sturzo in Castellammare di Stabia and since 2008 at Liceo Scientifico Don Milani in Gragnano, served as the external commissioner on exams at Liceo Classico Pitagora and I.T.I. Marconi in Torre Annunziata and Liceo Scientifico Silvestri in Portici. Prof. Mascolo took numerous refresher courses on environmental hazards and has been an active collaborator of GVES for over two decades. She has guided her students on the projects dealing with prevention and protection, volcanic risk assessment and management, distribution of radon in houses, excursions to the crater of Vesuvius, and her students regularly participated with projects at school manifestations organized by GVES.

Filomena Nocera

Filomena Nocera graduated in Literary Subjects at the University in Salerno in 1999 and for the following 19 years devoted herself to teaching. In 2015 she was promoted to the position of Headmaster of State Schools and since has served as the Principal of Istituto Comprensivo Radice Sanzio Ammaturo of Naples. At the University Suor Orsola Benincasa Prof. Nocera participated in the two-year Master (II level) for the professional development of teachers in didactics of verbal and non-verbal languages (Professione formatore in didattica dei linguaggi verbali e non verbali), and at the University Roma 3 participated in a two-year Master (II level) for the professional development of teachers of Italian in didactics (Formazione professionale degli insegnanti di Lettere: didattiche disciplinari) and earned a post-lauream certificate in Learning Assessment and School Self-Evaluation (Valutazione degli apprendimenti e autovalutazione dIstituto nella scuola dellautonomia). For the past 18 years she worked as an expert in courses promoted by the Ministry of Education, INVALSI and INDIRE, for the purpose of implementing the professional development of Italian teachers and spreading of the results of the national and international surveys OCSE Pisa. She also served on a board of experts with the task of evaluating the school standards, monitoring performance and analyse self-improvement of some Italian schools on such projects as VALES and Valutazione e Miglioramento promoted by MIUR and INVALSI. Prof. Nocera belongs to the list of experts included in the databases of INVALSI for the evaluation of schools and of the National Plan for the Professional Development of Teachers of Italian (decree 1582, 9th February 2012: Educazione linguistica e letteraria in unottica plurilingue ITALIANO, known as POSEIDON). She published various essays and articles dealing with the teaching and learning processes and with the professional development of teachers and adults (cognitive autobiography, reading literacy, self-monitoring and self-evaluating learning processes, sustainability and social and civic competences).

Concettina Nunziata graduated cum laude in Physics at the University of Naples Federico II and currently is professor of Seismology at the Department of Earth Sciences, Environment and Resources at the same university. She conducted research in Italy and U.S. and worked on numerous projects mainly dealing with earth structure modeling and seismic monitoring and microzoning. Prof. Nunziata is the scientist responsible of the seismic monitoring at the Geophysical Observatory where the research is focused on the definition of shear wave velocity (VS) models at depths ranging from shallow (to hundred meters), in urban

Tina Nunziata

areas, to deep (tens of kilometers) depths, and ground motion modeling with the Neo-Deterministic Seismic Hazard Assessment (NDSHA) approach. This modeling approach has allowed, among the most relevant results, for reconstructing the Campanian crust (Vesuvio, Campi Flegrei, Ischia, Bay of Naples, Campanian Plain, Roccamonfina) and the seismic microzoning of Naples. Prof. Nunziata has guided students on theses, is the author/coauthor of more than 100 scientific publications appearing in international journals and edited books and participated in the development of several multimedia works.

Pilar Ortiz

Pilar Ortiz earned Ph.D. in Chemistry from the University of Seville in 1999 and is a Senior Lecturer at the University Pablo de Olavide in Seville, Spain. Her expertise lies in the diagnosis of cultural heritage, quality management, and e-learning. Dr. Ortiz leads the Cultural Heritage, Technology, and Environment research group and her professional publications appeared in 23 books, conference proceedings, and journals. Her projects have been supported by the European Union, national and regional governments, and private organizations. In 2015 Dr. Ortiz received an award from EMRS for science dissemination.

Rocio Ortiz

Rocio Ortiz earned Ph.D. in Architecture from the University Pablo de Olavide in 2014 and is a Senior Lecturer at University Pablo de Olavide in Sevelle, Spain. Dr. Ortizs expertise is in diagnosis of Cultural Heritage, management, e-learning, and her scientific works appeared in 20 books, conference proceedings, and journals. Dr. Ortiz's research projects have been supported by the European Union, national and regional governments, and private organizations. In 2015 Dr. Ortiz received an award from EMRS for science dissemination.

Antonella Peresan graduated from the University of Trieste in 1996 with a degree in Physics and earned Ph.D. from the University of Trieste in 2001. Dr. Peresan is currently a seismologist at the National Institute of Oceanography and Experimental Geophysics and a Science Officer of the European Geosciences Union's Earthquake Hazards division. She actively contributed for more than two decades to the research activities of the Department of Mathematics and Geosciences at the University of Trieste, as well as of the SAND Group at the Abdus Salam International Centre for Theoretical Physics (ICTP).

Antonella Peresan

As an adjunct professor she lectured at the universities of Trieste and Roma Tre, and at ICTP. Dr. Peresan has been involved in a number of international and national projects, and on the pilot project SISMA funded by the Italian Space Agency contributed to the development of a fully formalized prototype system for the time dependent neo-deterministic seismic hazard assessment that integrates the space and time information provided by real-time monitoring of seismic flow and earth observation (GNSS, SAR) data analysis. She coordinated an Indo-Italian cooperation project aimed at neo-deterministic seismic and tsunami hazard assessment in Gujarat and collaborated as a scientific advisor with an innovative technological startup specialized in high performance computing and on demand service for the realistic modeling of seismic input. As an expert in seismic hazard assessment, Dr. Peresan reported to the Italian Parliament on the state of knowledge of seismic safety in Italy and is the author/coauthor of more than 70 scientific publications.

Fabio Romanelli

Fabio Romanelli graduated in Physics at the University of Trieste where he earned Ph.D. in Geophysics. From 1996 to 2000 he was enrolled by the Italian National Group for the Defense of Earthquakes (GNDT), where he worked on ground and tsunami motions in laterally heterogeneous media, and participated at several national and international projects on seismic and tsunami hazards. In 2000 he joined the Department of Mathematics and Geosciences of the University of Trieste, where is currently Professor of Seismology, Seismic Risk and of Institutions of Physics of the Earth and where he has been mentoring several undergraduate and postgraduate students. Dr. Romanelli has participated in several initiatives on student education in developing countries, organized by the international bodies of the Asian and of the African Seismological Commission and the Abdus Salam International Center for Theoretical Physics (ICTP). Fabio Romanelli has been involved in a number of national, bilateral (Bangladesh, Bulgaria, China, Egypt, India, Iran, Moldova, Romania, Russia, Spain, Vietnam), and international projects dealing with physics-based seismic and tsunami hazard assessment, engineering seismic input definition, and studies of the lithosphere-asthenosphere system using surface waves. He is an Editor of Pure and Applied Geophysics and is the author of more than 50 peer-reviewed publications.

Maria Salvatore

Maria Salvatore graduated in 1977 in Pedagogy at the University Suor Orsola Benincasa in Naples and in 1979 in Literary Subjects at the same university. She taught at I Circolo Didattico and Scuola Media Statale Cosenza at Castellammare di Stabia, and since 1998 holds a permanent position at Istituto di Istruzione Superiore at Liceo Scientifico don Lorenzo Milani of Gragnano. Prof. Salvatore collaborated with the Presidency on the Objective and Instrumental Functions for the achievement of organizational and training objectives related to Area 3 Intervention and Services for Students, and has taught history and philosophy. From 1988-2002 and as extra-curriculum activities she lectured to teachers in Gragnano, S. Agnello, and Castellammare di Stabia on dealing with the disabled students and in the areas such a didactics of learning and methodology, pedagogy, psychomotor education and extraverbal languages, non-verbal communication codes, and organization of professional skills. In 2011 Prof. Salvatore won the title of the School Master. Some of her other achievements are: Coordinator of visits to the European Parliament in Strasburg, referent for many school projects, member of the commissions on regulations and teacher evaluations, coordinator of the Department of Philosophy and History, organizer and speaker at Conventions for the Memorial Day, co-organizer and speaker celebrating the birth of Giuseppe Mazzini, elaborator on projects dealing with Crisis of Modernity and Metaphysics and Italian Constitution, and editor and curator of the project Orienting Oneself in Nature.

Franco Vaccari

Franco Vaccari graduated in Geology at the University of Trieste in 1986 where he also earned Ph.D. in Geophysics. He was a Research Fellow at Gruppo Nazionale per la Difesa dai Terremoti (GNDT) under (CNR) (1990-1999) and at Istituto Nazionale di Geofisica e Vulcanologia (INGV) (2000-2002), collaborator at University of Trieste in the Department of Earth Sciences (20032006), contract researcher at University of Trieste, Department of Mathematics and Geosciences (2007-2010) and Visiting Scientist at ICTP ESP-SAND Group (1990-2015). Dr. Vaccari is the author of more than 100 peer-reviewed technical publications.

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Index of Authors

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Habitat for Humanity International

Cities can concentrate disaster risk not only due to the aggregation of people, infrastructure, assets, expansion, and inadequate management, but also from the surrounding hazardous environments. Cities on volcanoes and on geologic faults, cities exposed to meteorological and climatological conditions, cities in the vicinity of nuclear, chemical and biological facilities, and cities neighboring hazardous landfills containing industrial and medical waste can be found all over the world. Many coastal cities of North and South America, Africa, Mediterranean, Bay of Bengal, and South China Sea are exposed to tropical cyclones, inundations, and tsunamis. The global warming will increase the potential hazards from the sea-level rise and changes in atmospheric circulations. Promoting sustainability is the challenge of the future. Adopting a sustainable model of life aims to preserve natural resources, curb the problems related to natural hazards and ensure well-being for the population of today and that of the future. The main objectives are: To defeat world poverty, to reduce inequalities, to spread health and wellbeing, to protect decent work, to adopt a model of sustainable development. Thinking of the future world, the model of today's development is unsustainable. Four are the pillars of sustainable development: Economic, environmental, social, and institutional. The world around us is plagued by evils that bring enormous damage: From the inequality arise revolutions, environmental unsustainability, global migration, increase in debt, economic precariousness – all factors that determine institutional fragility. All countries of the world should work to bring about sustainable development, without distinction between the developed and developing nations. The aim of this volume is to use research for making a step towards sustainable development.

Le città possono concentrare il rischio di catastrofi non solo a causa dell'aggregazione di persone, infrastrutture, risorse, espansione e gestione inadeguata, ma anche per gli ambienti pericolosi circostanti. Le città sui vulcani e sulle faglie geologiche, le città esposte a condizioni meteorologiche e climatiche, le città nelle vicinanze di impianti nucleari, chimici e biologici e le vicine discariche pericolose contenenti rifiuti industriali e medici, possono essere trovate in tutto il mondo. Molte città costiere del Nord e del Sud America, Africa, Mediterraneo, Golfo del Bengala e Mar Cinese Meridionale sono esposte ai cicloni tropicali, alle inondazioni ed ai tsunami. Il riscaldamento globale aumenterà i potenziali pericoli derivanti dall'innalzamento del livello del mare e dai cambiamenti nelle circolazioni atmosferiche. Promuovere la sostenibilità è la sfida del futuro. Adottare un modello di vita sostenibile ha come fine preservare le risorse naturali, arginare le problematiche legate ai pericoli naturali e garantire benessere per la popolazione di oggi e per quella futura. Obiettivi principali sono: sconfiggere la povertà del mondo, abbattere le diseguaglianze, diffondere salute e benessere, tutelare un lavoro dignitoso, adottare un modello di sviluppo sostenibile. Pensando al mondo futuro il modello di sviluppo odierno è insostenibile. Quattro sono i pilastri dello sviluppo sostenibile: l'economico, l'ambientale, il sociale, e l'istituzionale. Il mondo che ci circonda è afflitto da mali che portano enormi danni: dalle diseguaglianze nascono le rivoluzioni, dall'insostenibilità ambientali le migrazioni globali, dall'aumento del debito la precarietà economica, tutti fattori che determinano fragilità istituzionali. Tutti i paesi del mondo dovrebbero lavorare per portare a uno sviluppo sostenibile, senza distinzione tra paesi industrializzati o in via di sviluppo. Scopo di questo volume è fare, con la ricerca, un passo in avanti verso lo sviluppo sostenibile.

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