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THE EU HORIZON 2020 PROPOSAL "RESILIENT EUROPE": TOWARDS A COMMON RESILIENT FUTURE

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Abstract

"Resilient Europe" is a project proposal, still under evaluation, submitted at the EU HORIZON 2020 Work Programme 2016-2017, Call SEC-01-DRS-2016 "Integrated tools for response planning and scenario building". It addresses all the priorities, with particular focus on cultural heritage and built environment, in order to improve research/innovation effectiveness, respond to key societal challenges, and enhance in-depth cooperation (set up in previous projects) among EU consortium partners (and 1 non-EU notable participant). "Resilient Europe" is centred on the resilience assessment with a comprehensive approach (safety, robustness, adaptive capacity, stability, sustainability, conservation), devoted to the urgent need for building up a common resilient culture, based on a reliable chain between science, humanities, public engagement, political decisions, first responders. Different fields will interact by transferring recent results from a discipline to another, integrating research, mitigation and governance.

To provide a step ahead, the main objectives are to: play the concept of multi-hazard disaster scenarios; evaluate the system overall resilience; provide a reliable/exhaustive description of selected paradigmatic World Heritage Sites; carry out effective actions regarding risk mitigation tightly linked to communication. As it is frustrating to face in an exhaustive way the ocean of questions dealing with multi-hazard and resilience, a realistic methodology, positively tested in previous researches, will be applied: the actions will walk through representative real case studies, but by following a holistic approach, identifying tangible solutions to offer to the communities involved. Accordingly, remarkable case studies have been selected, in order to reach prompt results for emblematic and valuable targets. In addition to advanced scientific investigations, specific activities involving Civil Protection organisations, experts in risk management and preservation of environment/heritage as well as concerned people (citizens, young generations of scientists, students, tourists, etc.) are planned, to strengthen the culture of awareness/prevention towards well-being communities. In situ/lab investigations, digitised inventories/frameworks, augmented reality architectures, models of human behaviour in the emergency, Serious Games Prototypes are also foreseen.

Keywords: Risks assessment impact reduction; resilience; preservation of World Heritage Sites; Smart Inventory Database

1. The "Resilient Europe" proposal in HORIZON 2020

1.1 Brief description of the proposal and consortium

"Resilient Europe", still under evaluation, has been submitted at the EU HORIZON 2020 Work Programme 2016-2017, Call SEC-01-DRS-2016 "Integrated tools for response planning and scenario building", deadline August 25, 2016. The evaluation report is expected within the end of 2016.

Table 1 – The "Resilient Europe" consortium

No.	Short name	Organisation name		Country
P01	**ENEA**	Italian National Agency for New Technologies, Energy and Sustainable Economic Development, ENEA		Italy
P02	**INSTM**	Italian National Interuniv. Consortium of Materials Science and Technology, Florence		Italy
		P02-D01	UNIPA, University of Palermo, Dept. of Civil, Environmental, Aerospatiale, Materials Engineering, DICAM	
		P02-D02	UNITS, University of Trieste, Dept. Mathematics and Geosciences, DMG	
		P02-D03	UNINA, University of Naples "Federico II", Faculty of Engineering, Dept. of Structures for Engineering and Architecture	
		P02-D04	UNIBO, University of Bologna, Dept. of Industrial Engineering, DIN	
		P02-D05	UNICAS, University of Cassino, Dept. of Civil/Mechanical Eng., DiCeM	
		P02-D06	UNIVPM, Università Politecnica delle Marche, Dept. of Construction, Civil Engineering and Architecture	
		P02-D07	UNIFI, University of Florence, Dept. of Economics and Business Adm.	
		P02-D08	UNIFE, University of Ferrara, Dept. of Economics and Management	
P03	**CNR**	The National Research Council, Rome		Italy
		P03-D01	Inst. of Applied Science and Intelligent Systems, CNR-ISASI, Lecce	
		P03-D02	Construction Technologies Institute, CNR-ITC, Bari	
		P03-D03	Construction Technologies Institute, CNR-ITC, L'Aquila	
		P03-D04	Inst. of Archaeological/Monumental Heritage, CNR-IBAM, Catania	
P04	**IURC**	Ionian University, Corfu		Greece
P05	**UPO**	Univ. Pablo de Olavide, Dept. Of Physical, Chemical/Natural Systems, Seville		Spain
P06	**TUM**	Technische Universität München, Faculty of Architecture		Germany
P07	**HELICAM**	Helicam Geospatial systems, Timisoara		Romania
P08	**RTU**	Riga Technical University, Institute of Energy System and Environment, Riga		Latvia
P09	**SBE**	Sustainable Built Environment MALTA, Msida		Malta
P10	**UAVR**	University of Aveiro, Department of Civil Engineering, Aveiro		Portugal
P11	**GEOFEM**	Geofem Ltd, Nicosia		Cyprus
P12	**UoB**	Univ. of Birmingham, Ironbridge International Institute for Cultural Heritage		U. Kingdom
P13	**CUNI**	Charles University (Karlova Univerzita), Prague, Faculty of Sciences, Dept. of Physical Geography and Geoecology		Czech Republic
P14	**BME**	Budapest University of Technology and Economics, Dept. of Engineering Geology and Geotechnics, Budapest		Hungary
P15	**NRIAG**	National Research Institute Of Astronomy And Geophysics, Cairo		Egypt
P16	**GVES**	Global Volcanic and Environmental Systems Simulation, Naples		Italy
P17	**ICCROM**	International Centre for the Study of the Preservation and Restoration of Cultural Property, Rome		Int'l. Org.
P18	**AND-CJI**	Junta de Andalucia, Consejeria de Justicia y Interior, Dirección General de Interior, Emergencias y Protección Civil		Spain

The consortium foresees an interconnected multidisciplinary cooperation (Table 1) among:
- 9 EU Universities (INSTM, IURC, UPO, TUM, RTU, UAVR, UoB, CUNI, BME) and 2 EU Research Centres (ENEA, CNR), covering a wide range of sectors, promoting productive collaborations on various projects;
- 1 International organisation devoted to cultural heritage preservation, disaster/risk management (ICCROM);
- 1 Regional Civil Protection Organisation (AND-CJI);
- 2 EU non-profit organisations (SBE, GVES);
- 2 EU SMEs (HELICAM, GEOFEM), in order to enhance the cooperation with private enterprises;
- 1 non-EU research institution (NRIAG), in order to strengthen cooperation between EU and non-EU Countries.

1.2 The project structure

"Resilient Europe" is structured in 10 Work Packages: WP1 Project coordination; WP2 Selection of case studies and *in situ*/laboratory investigations; WP3 Safety; WP4 Robustness; WP5 Adaptive capacity/stability; WP6 Sustainability; WP7 Conservation; WP8 Resilience; WP9 Smart Inventory Database; WP10 Risk mitigation, communication, dissemination, and exploitation. In order to define a clear pathway among the multitude of issues concerning resilience, "Resilient Europe" will *traverse* 12 case studies (*CSs*), chosen in EU/non-EU countries prone to high-impacting natural/human-made disasters and climatic change effects: 10 are UNESCO World Heritage Sites (WHSs); 2 are protected by inland heritage authorities and severely hit by recent earthquakes. All are prone to a variety of natural/man-made disasters in different environmental/social contexts, present concrete needs for preservation, and offer tremendous opportunities for innovative studies/skills, learning from different histories, and drawing out patterns/similarities that will assist in future planning. The *CSs* are:

Southern Europe
Italy
1) CS1, earthquake area of L'Aquila, Abruzzo (Centre) [earthquake, flood, landslide];
2) CS2, urban habitat of Modica Municipality, Sicily (South), UNESCO WHS [earthquake, landslide, fire];
3) CS3, Summa-Vesuvius area, Campania (South), UNESCO WHSs of the archaeological areas of Pompeii, Herculaneum and Torre Annunziata [volcanic eruption, earthquake, flash flood, past war damage];
4) CS4, historical landscape of the water pumping stations of the Emilia alluvial valley (North), protected by inland authorities [earthquake, fire, flood];
Greece
5) CS5, Old Town of Corfu (Greece),UNESCO WHS [earthquake, fire, tsunami, sea level rise, past war damage];
Spain
6) CS6, the Baeza monuments (UNESCO WHSs) and the territory of Cadiz (protected by inland authorities) [earthquake, fire, tsunami, coastal flooding, erosion, sea level growth];

Central Europe
Hungary
7) CS7, Castle District of Budapest, UNESCO WHS [hydrogeology, global warming, past conflict damage];
Czech Republic
8) CS8, City of Prague, UNESCO WHS [flood, global warming];

Northern Europe
United Kingdom
9) CS9, Ironbridge (United Kingdom), UNESCO WHS [flood, fire, global warming];

Third Party Countries - Middle East
Egypt
10) CS10, Thebes, UNESCO WHS [earthquake, flood, erosion];
Islamic Republic of Afghanistan
11) CS11, safety/conservation of the Archaeological Remains of the Bamiyan Valley, especially the Buddha statues in the UNESCO WHS [earthquake, armed conflict];
Syrian Arab Republic
12) CS12, archaeological area of Palmyra, UNESCO WHS [earthquake, armed conflict].

2. Introduction

The term resilience derives from the Latin verb *resilire* ["to rebound, bounce back" from re- "back" + silire "to jump, leap, spring"] [01] and has been adopted in hard sciences/humanities with multifaceted meanings [02]. A wide-ranging and consolidated definition of resilience is "the ability [of an environmental system] to cope with change" [03] or of a person/society to adapt to an adversity [04]. Current approaches merge together disaster assessment, social security, and protection assistance. Since resilience indicates the capacity "to buffer change […] as a framework for understanding how to sustain and enhance adaptive capacity in a complex world of rapid transformations" [05], "Resilient Europe" adopts this concept to survey the potential of natural, accidental, and

intentional disasters, proposing solutions that could mitigate their effects/consequences by proper management, thanks to the integrated tools that can be used by a large variety of decision-makers, back-office experts, and first responders. These tools will be demonstrated in representative and realistic environments/situations involving firefighting units, medical emergency services, police departments, and civil protection units. Recently a holistic definition of resilience, formulated by scientists participating to "Resilient Europe" through publications [06-60] and projects [61-87], involves six fundamental interconnected pillars (summarised in Fig. 1):

RESILIENCE

PILLARS	VALUES
safety	*protection of life, heritage, assets from natural/human-made disasters towards climate/social changes*
robustness	*adequacy of structural/infrastructural systems to withstand exceptional natural/human-made actions in relation to their function/exposure*
adaptive capacity	*ability to respond successfully to change and recovery with minimal consequences after catastrophic events*
stability	*achievement of a new equilibrium after traumas/disasters in emergency and post-emergency phases*
sustainability	*maintaining the natural/anthropogenic capital and fostering mature self-balanced environments*
conservation	*safe-guarding and transmitting heritage, culture, and memory intact to posterity as a drop anchor for democracy*

Fig. 1 – Holistic definition of resilience

Each pillar possesses peculiar values, that can be quantified with attributes/indicators for systems (general: (Earth, continent; specific: region, urban habitat, WHS) comparisons. Starting from these cornerstones, the concept of resilience will be defined whenever possible to better respond to the needs of our knowledge-based society, where inter-, multi-, trans-disciplinary approaches are strongly required; this is especially valuable in disaster risk management, where the disciplines and actors with different interests are not sufficiently interlinked, and where the realistic multi-disciplinary scenarios and efficient response planning are often lacking. With particular regard to WHSs, the challenge of "Resilient Europe" is to build an improved *shared resilient culture* in EU/non-EU countries by identifying situations of general interest to be tackled through actions that intertwine hard sciences/humanities, public engagement, communication, training, and political decisions. To accomplish this goal, the partners of "Resilient Europe" will generate synergies between different fields of activity and integrate research, mitigation and governance. Moreover, the crucial actors involved in the proposal will be invited to broaden their attitudes and perspectives, as follows:

- experts: *from vertical specialist skills to horizontal shared philosophy;*
- institutions: *from partial responses to inter-, multi-, trans-disciplinary approaches;*
- communities: *from puzzle fragments of knowledge to a whole vision of understanding.*

The excellence of "Resilient Europe" relies on the interaction of strong assets for understanding and managing ecological and social systems exposed to disasters, i.e.:

- focus on resilience, in order to develop innovative, ductile and polyvalent tools through which complex systems are able to face natural/human-made hazards, including climate change;
- inter-, multi-, trans-disciplinary approach, for analysing mutable socio-ecological systems;
- choice of case studies which are acknowledged for their relevance as WHSs (10 are included in the UNESCO list) as well as for their fragility due to exposure to natural/human-made disasters;
- final goal, which involves building up strategic EU/International transfer of knowledge/know how for properly managing radical changes in precious ecosystems;
- capability of the consortium to offer the suitable background for this ambitious project (skills, expertise, long-term and well-established collaboration with the partner institutions, solid partnership with universities, research centres, civil protection organisations, first responders, governmental/local authorities, policy makers, key stakeholders in the fields of natural/human-made disasters, resilience, and risk management).

3. Objectives

Focused on the innovative concept of resilience, the main objectives of "Resilient Europe" are to:

- ✓ develop/deploy the concept of multi-hazard (past/future) disaster scenarios (impact, occurrence, relationship, hierarchy and combination, from regional to local scales), by considering their complete range and avoiding omissions, by finding/utilising common languages/tools to identify, map, and quantify them; this evaluation will distinguish and combine both short-term events (earthquakes, tsunamis, landslides, volcanic eruptions, floods, war damage, technological/chemical/biological/radiological/environmental accidents, atmospheric pollution effects, mass events, acts of terrorism, etc.) and long-term events (large-scale super eruptions and earthquakes, extreme climate change effects, maintenance, decay, tourism pressure, etc.), affecting environment, urban habitats, and heritage;
  the expected scientific result is to produce rigorous emblematic multi-hazard combinations/maps for selected sites of interest, based on quantitative models/algorithms to calculate the related impact actions (definition of global hazard factors);

- ✓ evaluate the overall resilience of selected patterns (environment, urban habitat, heritage) exposed to multi-hazardous events, with an analysis of the cultural/historical contest, through data collection/elaboration using various approaches (humanities/hard sciences, in situ/laboratory survey/testing, aerial photography, high resolution satellite image analysis, structural calculations, etc.) and realising/employing specific procedures;
  the purpose is to achieve the univocal, punctual, qualitative and quantitative definition of the system overall resilience for selected sites of interest (definition of global resilience factors);

- ✓ produce a reliable/comprehensive description of the sites of interest, on the basis of an appropriate storage, classification, overlay and elaboration of the huge amount of information coming from multi-disciplinary investigations, merging together data coming from multi-hazard and resilience (digital frameworks/tools);
  the goal is the implementation of a robust digitised framework, geo-referenced, multi-source and multi-format, containing detailed inventories referred to the selected sites of interest, including 3D environmental scene reconstruction/augmented reality modelling and the simulation of human behaviour at urban and regional scales during the disaster emergency (realisation of smart digitised inventories/frameworks); the creation of *Multi-Layer Digital Archives*, *Augmented Reality Modules*, *Models of human behaviour during the disaster emergency*, *Serious Gaming Prototypes should be also foreseen;*

- ✓ carry out effective actions regarding risk mitigation (tightly interlaced to communication, dissemination, exploitation activities), aimed at increasing consciousness about disasters striking the selected areas, for a wide range of different subjects;
- ✓ create the best conditions for understanding/exchanging/training/applying protection/prevention measures, with wide use of digital technologies/resources, providing open and easy Information and Communication Technology (ICT) access points;
  the last two final objectives will be achieved with several tools, such as Guidelines and Roadmaps, Forums and Websites, Workshops and Conferences, Exhibits and Shows, Simulations, Games and Apps, addressing differentiated targets, such as first responders (firefighting units, medical emergency services, police departments, civil protection units), experts in risk management and preservation of environment/heritage, professionals, stakeholders, students from primary schools to university courses, young generations of scientists, public administrators, general public, tourists, etc.; particular attention will be paid to the resilience of schools and other strategic public buildings located in historic settlements under risk.

4. Concepts underpinning the project

"Resilient Europe" is centred on the observation that socio-ecological systems are constantly changing, often with unpredictable and drastic shifts, sometimes hard to reverse. Resilience has been defined as "the ability [of a system] to cope with change" [03]. This concept is well exemplified by a myth of the Mapuche culture (Chile), the generous god/goddess Trentren-Vilu of Earth and Fertility [88]. According to this myth, thousands of years ago, a monstrous serpent (Caicai-Vilu) appeared and caused the lowlands, valleys, and mountains to flood.

Without delay, Trentren-Vilu appeared to start a confrontation with the enemy, protecting the land from disaster. The battle went on for a long time, but finally Trentren-Vilu reached a costly victory and the natural order was restored. This legend is an example of a culturally acceptable form of explanation of a disaster framed by a community, in form of a myth, to make sense of a dreadful experience and enable the community regain emotional stability. Moreover, interpreted through the lens of resilience, it well represents the capability of a (natural/social) system to recover from a disaster. "*The lioness Ištar quieted, her heart was appeased*": this is the closing verse of "*Agushaya*", the king Hammurapi's (1792-1750 b.C.) poem dedicated to the goddess Ištar, another amazing myth that can be founded in various ancient cultures (Mesopotamian, Egyptian, West Semitic, Phoenician, Etruscan, Greek, Roman, Southern Arabian, Jewish). Warrior, Lover, Queen, Mother, she is a real complex and contradictory figure, joining procreative and destructive significance [89]. Drawing from these metaphors, "Resilient Europe" aims at exploring several aspects of global relevance to develop societal resilience to natural/human-made disasters, including climate change effects, asking research for questions about what resilience is, what it means to different societies, and how such societies might achieve greater resilience against threats. This research will be accomplished on the selected *CSs* of recognised relevance to the EU culture, as well as worldwide, for their significance for the human heritage of the world.
The climate change appears to produce increasingly unpredictable hazards. Reducing vulnerability of cities, industrial districts, rural areas, monuments, art masterpieces, museums, libraries, and archives is required for the safety of the population, minimising economic damages, and protecting the cultural identities/values of places. Facing the widespread problem of how to save cultural heritage (tangible/intangible), it is fundamental to understand which heritage connected to which local community can be preserved. From investigations carried out over the last decade [90], it emerges that humanities scholars focused their effort firstly on assessing the symbolic values of cultural heritage and secondly correlating them to economic factors, while engineers, architects, geologists predominantly devised solutions to problems regarding specific techniques/technologies. The effect of this bipolar focus on issues traditionally pertaining to the humanities or to the hard sciences has prevented a fully productive interdisciplinary sharing of methods/goals and resulted in a partial collaboration that requires widening/strengthening. Thus, the innovative aspects of "Resilient Europe" consist in:

- ✓ *an interdisciplinary approach, aimed at managing the multifaceted nature of risk, putting together geologists, seismologists, archaeologists, historians of art, architects, urban planners, engineers, sociologists, experts in risk assessment, Geomatics and ICT communication, in addition to civil protection agencies, first responders, policy makers/stakeholders, who will test and then apply the research results;*
- ✓ *a successful development/improvement in hazard assessment, from single to multi-hazard scenarios;*
- ✓ *an innovative approach towards resilience, i.e. the definition of resilience Key-Performance Indicators;*
- ✓ *a consistent upgrade in building up effective digitised inventories/frameworks, 3D virtual reality modelling, serious gaming;*
- ✓ *a reliable network encompassing hard sciences/humanities, public engagement, communication, training, and political decisions.*

5. State-of-the-art and innovation needs

5.1 Foreword

WHSs (indoor/outstanding, often enshrined in places at risk, exposed to hazards, climate change, insufficient maintenance, decay, and tourism pressure, but also to conflicts/disorders) are countless. The protection of such heritage, which must be handed down intact to posterity, is a duty not only for its fundamental values in terms of history, memory, culture and democracy, but because it bears witness to many past damaging events that can occur again in the future, as well as of the regeneration processes that have helped local populations/societies to restore their social, political, economic and cultural lives. One of the aims of "Resilient Europe" is to examine the impact that the suboptimal interaction between different sectors has had on decision makers by assessing:
- whether management of cultural heritage, involving both public entities and private actors, has been successful in ensuring a better preservation and fruition of a common good;
- how recent joint paradigms/policies interface with local cultures and their sense of belonging/identity;
- how citizens can interact with cultural heritage in modern cities also in hazardous conditions;

- which forms of participatory governance/management can/cannot ensure a better preservation/fruition of a common good through bottom-up approaches, guaranteeing the creation of resilient communities, suitable solutions to multi-hazards, as well as maintaining an environment for long-term preservation plans [91-99].

Against this background, research, preservation, management and governance through innovative/multi-disciplinary approaches emerge as key questions. The last decades have seen a rapid advancement of science and technology for better understanding, modelling and predicting the behaviour of the Earth and of construction assets. A modern usage of Geomatics and ICT (combined with technological advancement coming from the gaming industry) is certainly a great advantage. The latter is expected to become stronger, settled upon a robust humanistic background, but bridging the gap between the physical reality and the digital world.

5.2 Hazard assessment

Built environment, infrastructure, and heritage (the primary assets for society, economy, and culture) are constantly exposed to natural/human-made hazards, i.e. processes occurring in the biosphere and giving rise to a damaging event (natural: earthquake, tsunami, volcano eruption, landslide, flood, hurricane, extreme wind and snow, storm surge, sea level growth, coastal erosion, salt wedge intrusion, etc.; human-made: mass events, acts of terrorism and technological, chemical, biological, radiological or environmental accidents, etc.). Unknown climate change effects characterise some of them and wild/human-induced fires, impacts, accidental releases of toxic substances, and post-disaster diseases should be included as anthropogenic secondary events. Furthermore, disruption and loss due to conflicts always lead to impressive and long-term shocks and injuries in our culture, conscience, and experience for a long time, as happened, for example, in the heart of Europe after the World Wars I and II. The last decade has been marked by tremendous examples of catastrophes (2004: Indian Ocean, earthquake/tsunami; 2005: Pakistan, earthquake; USA, hurricane; 2006: Indonesia, earthquake; 2007: Peru, earthquake; 2008: China, earthquake; Myanmar, cyclone; Afghanistan, blizzard; Brazil, flood; 2009: Italy, earthquake; Samoa Islands, earthquake/tsunami; Sumatra, earthquake; Australia, bushfire; 2010: China, Haiti, Indonesia, earthquake; Chile, earthquake/tsunami; Russia, Japan, heatwave; 2011: Japan, earthquake/tsunami; Turkey, earthquake; 2012: Iran, earthquake; Afghanistan, avalanche; Pakistan, avalanche; 2013: Solomon Islands, earthquake/tsunami; Philippines, Pakistan, earthquake; Philippines, India, typhoon; Mexico, hurricane; USA, tornado; 2014: China, earthquake; Chile, fire; 2015: Nepal, earthquake; Chile, volcanic eruption; USA, drought; Kazakhstan, flood; Afghanistan, avalanche; 2016: Italy, earthquake; among the list of more recent losses due to human-made conflicts, it is worth highlighting here the incalculable suffering in Afghanistan, Syria, Iraq, and Libya, places of ancient civilisation belonging to stratified different cultures). The effects of these dramatic events were a huge toll in human life, collapse or severe damage to civil dwellings and crucial infrastructures, loss of cultural heritage.

In general, there is a lack of holistic approaches available for hazard assessment, because the procedures followed by experts of various disciplines need more homogeneity and cohesion. Integrated international experiences are still limited, and when an integration of science, technology, and society is required, this lack widens even more; some examples:

- HAZUS-MH (Multi-Hazard) for analysing potential losses from floods, hurricane winds, and earthquakes, developed in USA by FEMA (Federal Emergency Management Agency [100];
- MAR VASTO, led by the coordinator of “Resilient Europe” [see references 11-14; and project 61];
- some projects, relevant but not exhaustive, for multi-hazard volcanic risk, very emblematic (complex combination of various actions like earthquake, tsunami, pyroclastic flow, tephra, bombs, missiles, etc.):
  - VESUVIUS [62] regarded numerical simulation of the eruptive scenarios (pyroclastic flows and tephra deposits), providing a model for the assessment of potential impacts on the buildings and the probable number of dead/injured in the zones at risk; the study has shown the importance of the boundary elements, such as openings and claddings, in the volcanic vulnerability of a construction, as confirmed by the damages observed in Montserrat after the eruption of Soufrière Hills volcano (1998);
  - EXPLORIS [63] extended the area of interest to five European explosive volcanoes: Vesuvius (I), La Soufriere (F), Sete Cidades (P), Teide (S), Soufriere Hills (UK); it has planned a spatial-temporal (4D) supercomputer simulation of a sub-Plinian explosive eruption, together with protocols for risk assessment, which evaluate the effects of the accumulated damage on the structures; the results produced by the research have been transferred to a GIS (Geographic Information System) multimedia geographical database;

- ETNA [64] aimed at interdisciplinary collaboration between different research cultures (geologists, volcanologists, physicists, engineers) in order to evaluate volcanic eruption data, develop instrumentation for magma and lava flow measurements and physical models for magma ascent and lava flow;
- VESUVIUS 2000 [65] is an interdisciplinary research project for the Vesuvius area with the central objective of reorganising the territory surrounding the volcano, in order to prevent future catastrophes, instead of trying to manage disasters as exemplified by the Vesuvius Evacuation Plan (VAP); VESUVIUS 2000 produced, with limited resources, significant results in the fields of computer modelling of volcanic processes and promotion of volcanic risk education in Vesuvian schools and among the population, becoming a laboratory for full integration and interdisciplinary collaboration between geologists, physicist, engineers, economists, architects, urban planners, sociologists, educators, civil protection, and population [39-50];

- moreover, an EU COST Action (COST ACTION C26, *"Urban Habitat Constructions under Catastrophic Events"*, 2008-2010, organised in 4 technical Working Groups, namely: Fire resistance WG1, Earthquake resistance WG2, Impact and explosion resistance WG3, Risk Assessment for Catastrophic Scenarios in Urban Areas WG4) dealt with the outstanding topic of the protection of constructions in urban areas from exceptional loads, such as earthquakes, fire, wind, impact, explosions and so on; the *Vesuvius case study* in WG4, co-chaired by the coordinator of "Resilient Europe", saw the evaluation of the most dangerous combinations of volcanic actions in case of a sub-Plinian Vesuvius eruption affecting the pilot area of the Municipality of Torre del Greco (Naples, Italy), located in the "red" danger zone around the volcano [66];
- a strong impulse towards multi-hazard analyses is, thus, necessary and urgent; single hazard evaluation methods should be critically studied/implemented; for instance, lessons learnt from the largest earthquakes worldwide occurred during the last decade (for example: Japan 2011, with M>9) show that the performances of the standard probabilistic seismic hazard assessment (*PSHA*) are unsatisfactory, underestimating the magnitude of great seismic events; therefore, the need for an appropriate estimate of the seismic hazard is a pressing concern; it appears preferable to resort to a scenario-based method, such as the neo-deterministic seismic hazard assessment (*NDSHA*), which allows for a better integration of the available information (provided by the most updated seismological, geological, geophysical and geotechnical databases) about the site of interest with advanced physical modelling techniques; "Resilient Europe" includes a partner that is world leader and coordinator of several projects based on *NDSHA* [67-71]; a strategy for the mitigation of the earthquake impact should be oriented to cost-effective preventive measures, aimed at creating knowledge-based, hazard-resilient public assets, rather than highly expensive post-disaster rescue/relief operations, that currently prevail in many countries; time-dependent hazard scenarios (based on *NDSHA*) can be helpful in reorienting strategies toward increased earthquake preparedness; compared to other areas of timely warning (e.g. tropical cyclones, some kinds of flood/drought emergencies), earthquake warning has just reached its ''adolescence'' in science, due to the complex nature of the seismic phenomenon; therefore, we cannot know in advance the location, magnitude, and time of occurrence of an earthquake; nevertheless, the accuracy of earthquake warnings is improving and the ability to spatially define/map the zones of highest risk is advancing rapidly; in the integrated *NDSHA* method, intermediate-term middle-range earthquake prediction, performed by means of the algorithms *CN/M8*, is provided; the results of experimental testing of *CN/M8* algorithms indicate the possibility of practical earthquake forecasting, although with limited accuracy (i.e. with a characteristic alarm-time ranging from a few months to a few years and a space uncertainty of hundreds of kilometres); a reduction of space uncertainty is feasible through the combined use of seismological/geological/morphostructural information; among the possible developments towards a more accurate identification of the area of the impending earthquake, the analysis of real-time deformation patterns within alerted earthquake prone areas is expected to play a relevant role, where the newly available high quality positioning data (e.g., GPS and InSAR) would permit the compilation of real-time displacement/deformation maps within the alerted areas and combine them with routinely updated seismic information [17-30].

5.3 Resilience

Some examples of research projects where the "Resilient Europe" team expertise has been involved are:
- ANDROID, "Academic Network for Disaster Resilience to Optimise Educational Development" [06-10; 72];
- the already cited MAR VASTO and EC COST Action C26;
- PROHITECH, "Protection of Historical Buildings by Reversible Mixed Technologies" [73];

- ISTECH, "Development of Innovative Techniques for the improvement of Stability of Cultural Heritage, in particular seismic protection" [74];
- RIBUILD, "Energy strategies and solutions for deep renovation of historic buildings" [75];
- other local/National projects.

Drawing upon this expertise, "Resilient Europe" intends to apply the concept of system resilience to the environment, urban habitat and heritage. The formulation/deployment of targeted algorithms/procedures able to identify and address resilience Key-Performance Indicators (KPIs) represent not only an innovative element of this proposal, but also an added value in terms of subsequent dissemination.

5.4 Geomatics, digitised inventories, 3D virtual reality, agent-based simulations, serious gaming

In recent years, Geomatics (measuring/mapping, geodesy, photogrammetry, satellite positioning-GPS, computer systems/graphics, remote sensing/GIS, etc.) has been developed, starting with earthquake and then encompassing other hazards. *In situ*/laboratory diagnostics/testing/survey through sophisticated equipment (GPS, laser scanner, laser interferometry, thermo-chamber, remote controlled helicopter as UAS/UAV drones, shaking table, SEM analyses, etc.) or quick procedures (architecture/urban planning, vulnerability investigations, etc.) can also provide effective analyses and data. Advanced structural calculations and damage/collapse/decay models (in particular non-linear procedures for masonry/stone construction) can be obtained in a reasonable time. Among the "Resilient Europe" partners', the principal projects on this topic are the already cited MAR VASTO and EC COST Action C26, in addition to local/national projects (among them, see the **"**Piano di Ricostruzione post-sismica per il Comune di Arsita" [76]). The crucial challenge remains how to classify, overlay, organise a huge amount of information (history, geography, 3D geo-informatics, demography, statistics, archaeology, architecture, acoustics, structural engineering, diagnostics, damage, city planning, management, sustainability, energy saving, tourism pressure, etc.) in well-organised digitised inventories/frameworks that can be hazard-specific, object specific, country-specific, but compatible with multi-hazard/overall resilience approaches, integrating different conceptualisations and including a variety of disciplines in the field of disaster risk management. One experience, notable to cite, is the EU project MOVE, "Methods for the improvement of vulnerability assessment in Europe" [101]; it brings together aspects from political economy, social ecology, vulnerability and risk research, as well as from the climate change systems; additionally, it also integrates resilience within different perspectives, including physical as well as economic and institutional dimensions; MOVE arose from the need to develop methods/indicators for improving vulnerability assessments to natural hazards in Europe, and established a consistent framework. "Resilient Europe" will go further, setting up: a *Smart Inventory Database* (geo-referenced, diachronic, quantitative, multi-source/multi-format), containing digitised inventories/frameworks of the selected sites (*Multi-Layer Digital Archives*); in addition, *Augmented Reality Modules*, *Behaviour in Emergency Models*, *Serious Gaming Prototypes* will be developed.

5.5 Heritage monitoring, conservation and preservation and risk mitigation/communication

Several projects on heritage monitoring/diagnostics, informatics applied to restoration/virtual restoration are recently concluded or ongoing; some examples are: the archaeological area of Pompeii [77-79]; seismic performance and virtual reconstruction of museums [80-81]; cultural heritage restoration and preservation in Europe and outside [82-86]. Furthermore, the Project *2PxE*, promoted and funded by the Emilia-Romagna Regional Government for the reconstruction of the Italian municipalities affected by the earthquake (May-June 2012) with resources of the European Social Fund [87; 102], has been set up with two main objectives: to offer research/training seminars to investigate features and consequences of the seismic event from a scientific point of view, as well as citizen's perspective with a participatory approach; to create a successful dynamic bidirectional channel of communication/exchange of knowledge and experience between policy makers, stakeholders and citizens on multi-hazard, resilience and mitigation. All the "Resilient Europe" partners will be consistently involved in the above said activities; their expertise will be adopted/improved by carrying out real tests/simulations for selected targets among the 12 *CSs*, i.e. in detail:

- *EU/MED: Safer Heritage*,
- *Historical Nuclei: Safer Cities*,
- *"Vesuvius Pentalogue": Safer schools and population in the Summa-Vesuvius area*;

and generating specific tools:

- *Guidelines for well-being communities and sustainable life*,
- *Forum for a Common Resilient Future* and *Common Resilient Future Website*,
- *Road Map for Citizenship Awareness*,
- *Common Resilient Future Exhibits and Shows*.

6. Conclusion

Earthquake hazard assessment procedures/mapping are quite developed both for *PSHA* and *NDSHA*; the problem is how to go beyond the current dualism and widely apply the most reliable methodology (*NDSHA*). Important progress in earthquake forecasting can be reached by implementing *CN*/*M8* (*NDSHA* integrated method) algorithms. Also modelling of volcanic eruption forecasting/distribution of volcanic products will be developed. In dealing with multi-hazard scenarios, "Resilient Europe" will provide standardised procedures for the 12 selected *CSs*, that certainly represent an effective conceptual progress in a field currently poor of examples.
The development of innovative, integrated, and mobile sets for *in situ* survey/data acquisition (non-destructive/light destructive testing) is fundamental to perform quick *in situ* campaigns (architectural and structural elements preservation state, material quality, mechanical properties; mapping and indoor/outdoor measuring; etc.) on old cities, archaeological sites, monuments/architectures of cultural/historical interest with relatively low expenses. Single portable instruments are available on the market, but integrated sets are lacking. Experienced technicians in this field are not many, and very uncommon outside EU. These skills must be developed, also for creating forms of specialised employment, particularly suitable for young people. A major objective is the elaboration of reliable protocols, for cost-effective in-situ survey, structural analysis and design of strengthening actions of restoration/preservation improving the resilient level of historical cities.
Quick *in situ* surveying can be facilitated by using on-line/off-line digital acquisition of information via tablets/smartphones for GIS/WebGIS databases, but also for 3D virtual representations/augmented reality models. Outputs coming from rapid survey, deepened with further steps of structural analysis, when necessary, on single buildings or aggregates, should be coupled with attracting diachronic simulation (i.e. 4D space-time evolutive representation models of multi-hazard impact on urban habitats), as powerful tools for strengthening risk awareness, also in terms of gaming/apps to thrill young generations.
Nowadays a clear, well-structured, widely accepted theoretical approach to resilience assessment, based on punctual quantitative data, is still lacking. After defining multi-hazard scenarios for the sites of interest, "Resilient Europe" will provide a reliable methodology based on the five pillars identified above, providing procedures, algorithms, sets of indicators/weights, capable to realise maps that attract the citizen's interest on his own level of risk/protection. Furthermore, the approach adopted will be sensitive to the cultural/historical conditions in which resilience evolves.
"Resilient Europe" is fully operational with regard to Augmented Reality for construction, refurbishment, maintenance, and modelling human behaviour during the disaster emergency phases. The cooperation between systems entities (satellite, sea, land, and air-based, including but not limited to the Copernicus, Galileo and EGNOS systems, from different agencies with a large variety of capabilities and costs) will be fostered.
"Resilient Europe" will adopt the approach used in the project *2PxE* for risk mitigation/communication, with specific quantitative indicators regarding the community's sense of awareness/perception of security, the (re)construction of cultural memory, communication feedback, the impact of political decisions. The case studies will provide emblematic situations for the application of new technologies and actions for theoretical/practical training. A postdoctoral Research Fellowship will be awarded during "Resilient Europe", tackling both technical-scientific questions related to natural/ human-made hazards, and social sciences/humanities aspects.

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