Urban Disaster-Prevention Strategies Using Macroseismic Fields and Fault Sources

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SUMMARY
This contribution presents the general framework of the European project UPStrat-MAFA *"**U**rban disaster **P**revention **Strat**egies using **MA**croseismic Fields and **FA**ult Sources"* and its ongoing activities. A unique probabilistic procedure is being used for seismic hazard evaluation, using both macroseismic fields and characteristics of fault sources for the analysis of data from volcanic and tectonic areas: Mt. Etna, Mt. Vesuvius and Campi Flegrei (Italy), Azores Islands (Portugal), South Iceland (Iceland), Alicante-Murcia (Spain), and mainland and offshore Portugal. An improvement of urban scale vulnerability information on building and network systems (typologies, schools, strategic buildings, lifelines, and others) is proposed in the form of a global *Disruption Index*, with the objective to provide a systematic way of measuring earthquake impact in urbanized areas considered as complex networks. Disaster prevention strategies are considered based on an education information system, another effective component of the disaster risk reduction given by long-term activities.

Keywords: Probabilistic hazard, seismic risk, urban disaster prevention strategies, project UPStrat-MAFA

1. GENERAL PRESENTATION

This UPStrat-MAFA project, *"**U**rban disaster **P**revention **Strat**egies using **MA**croseismic Fields and **FA**ult Sources"*, addresses specific problems concerning three main steps: hazard assessment, risk assessment and prevention strategies. It aims to study, design, develop, test and implement innovative approaches, techniques and tools, to consistently link prevention measures to preparedness and response needs. This will be achieved through macroseismic data collection and treatment, seismic signals data collection, damage scenario simulation, creation of synthetic databases, hazard assessment, vulnerability data and risk analysis, to provide a final product as a tool to support decisions in risk-reduction policies.

In the following, we will present the main activities of the project (listed in Fig. 1) along with a brief description of the data and in the chapter 2 the description of the ongoing activities, with preliminary results.

- **Forecast of damage scenarios**
  - Task A : Data collection (instrumental, macroseismic fields ... ect.)
  - Task B : Probabilistic Analysis of Macroseismic Data
- **Evaluation of the seismic hazard at site**
  - Task C : Calibration of the input source parameters for simulation
  - Task D : Probability Hazard Assessment
- **Evaluation of the Risk**
  - Task E : Assessment of vulnerability of buildings, infrastructures and system
  - Task F : Quantitative risk evaluation and mapping (*i.e. Disruption Index*)
- **Definition of prevention strategies**
  - Task G : Disaster prevention strategies based on the level of risk
  - Task H : Disaster prevention strategies based on education information system
- **Activity of publicity & management**
  - Task I : Publicity
  - Task J : Management of the project and report of the requirements to EC

Figure 1. List of the five main activities and the ten related Tasks of the UPStrat-MAFA project.

1.1. Forecast damage scenarios

As hazard evaluation is a key point in an effective risk mitigation plan, this first activity is designed to implement a procedure to forecast damage scenarios by the simulation of intensity shake maps, given the parameters of the location and intensity of an earthquake.

1.1.1 Data collection

This activity involves the compilation of a database of macroseismic fields (MFs) of fault sources and instrumental data for the selected areas: 1) the Mt. Etna area, Mt. Vesuvius and Campi Flegrei areas (Italy); 2) the Azores Islands, mainland Portugal (Algarve and Lower Tagus Valley), and the offshore source area, the Marques de Pombal Fault (Portugal); 3) southeast Spain (i.e. the Alicante-Murcia region); and 4) South Iceland, including Reykjavik and the surrounding urban area (Iceland), as indicated in Figure 2. Furthermore, an efficient data structure will be designed and validated for geographically referenced information on buildings and urban infrastructure.

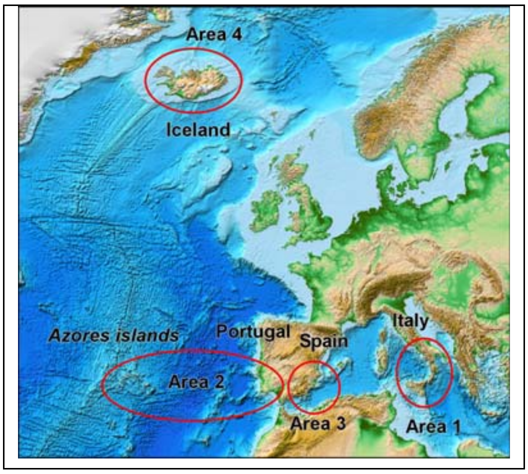

Figure 2. Three EU Member States (Italy, Spain and Portugal) and one from EFTA/EEA countries (Iceland) are involved in the UPSTrat-MAFA project. The red circles indicate the areas (1, 2, 3 and 4) where the data will be collected.

1.1.2 Probabilistic analysis of macroseismic data

The key idea of the methodology proposed for the analysis of the macroseismic attenuation is to model the intensity decay as a random variable so as to be able to give, without filtering information through empirical attenuation relationships, the probability distribution of intensity at any site given the epicentral intensity and information on the point-wise or linear properties of the earthquake source. A first version of the method was presented in Rotondi and Zonno (2004) and extended in Zonno et al. (2009). The procedure consists of the following steps: a) perform an exploratory analysis of MFs representative of the historical seismicity of the region under study in order to recognize possible trends of attenuation, b) assign the prior distribution of the model parameters on the basis of similarities identified between the current attenuation trend and the ones studied in previous settings, c) estimate the binomial probability distribution of the site-intensity Is, given epicentral intensity and distance from epicenter under the isotropic assumption, d) forecast damage scenarios in terms of expected macroseismic intensity for a fixed epicentral intensity and test the performance of the forecasting method on historical earthquakes, and finally e) repeat the procedure both where information on the length and directivity of the source fault is known (hence under the assumption of anisotropy) and on synthetic MFs generated by the EXSIM finite-fault simulations.

1.2. Evaluation of the seismic hazard at site

1.2.1 Calibration of the input source parameters for simulation

Seismic histories at the site will be integrated with synthetic effects deduced using EXSIM finite-fault simulations. In most of the member states stochastic finite-fault simulations and determined regional parameters have already been performed, but in this task it will be developed by comparisons or calibrations of parameters in a few pilot test areas. In this project we want to share methodologies and convey experience of data analysis and simulation using the knowledge developed in piloted test areas as guidance. The aim is to create a common approach for the analysis of data and results in all of the study areas.

1.2.2 Probabilistic hazard assessment

In many countries (and first and foremost, in Italy), the bulk of the seismic database is macroseismic data, and thus the application of the standard Cornell-McGuire method for probabilistic seismic hazard assessment (PSHA) requires a "forcing" of macroseismic information into a para-instrumental format. To avoid this problem, a probabilistic for-purpose procedure was developed and implemented in the SASHA numerical code (D’Amico and Albarello, 2008). In this procedure, hazard evaluations are performed by considering a time series of macroseismic intensities at the site of interest (local seismic history). This time series is built up by considering seismic effects observed at the site during past earthquakes (observed MFs), or “virtual” intensity data deduced from epicentral data via statistical modelling (expected MFs), or physical/ numerical simulations (synthetic MFs).

Figure 3 illustrates the procedures to follow for the probability hazard assessment within Task D of the UPStrat-MAFA project. The procedure develops in two steps. In the first step, the local seismic history is determined by merging observed, virtual and synthetic intensities. In the second step, this history is analysed by a specific statistical procedure to provide hazard estimates at the site.

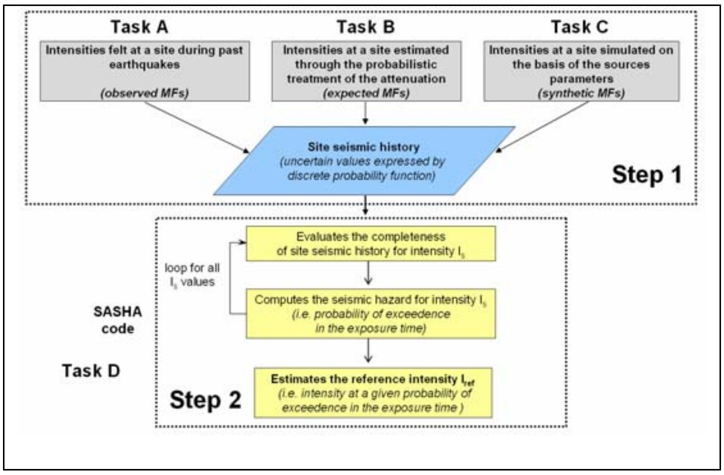

Figure 3. The two steps (1 & 2) of the adopted procedure for probability hazard assessment in the UPStrat-MAFA project (re-drawn from Zonno (2012), Civil Protection Financial Instrument (2012)).

1.3. Evaluation of the risk

Two steps have to be considered to evaluate the seismic risk at the urban level: a) the assessment of the vulnerability of buildings, infrastructure and systems; and b) the quantitative risk evaluation and mapping.

1.3.1 Assessment of vulnerability of buildings, infrastructure and systems
The main expected achievement of this step is the development a methodology to characterize the vulnerability of urban regions, following a systemic approach. A framework is provided where urbanized areas are seen as a complex network where nodes have the roles of sources and sinks that interact together in an interdependent fashion. Here, each player (urban functions or physical assets) has its unique dependencies and interaction behavior. Particular attention is also given to some urban vulnerable elements like schools facilities.

1.3.2 Quantitative risk evaluation and mapping (the Disruption Index)
The objective of this step is to perform seismic loss assessment and to provide a systematic way to measure earthquake impacts in urban areas. In this context, a new concept of a global Disruption Index (DI) (Oliveira et al., 2012) will be introduced that can be used to quantify the state of disorder induced by earthquakes in urban structures and their functions. Some functions should be established and classified using fundamental dimensions of human needs, namely, environment, shelter, healthcare, education, employment and food. The classification system used to characterize the vulnerability of the elements at risk must correspond to the format used to characterize damages in order to ensure uniform interpretation of data and results. The question on uniformity will be addressed by identifying critical risk measures common to the four study areas, as well as those that are distinctive features of each of the study areas. This approach provides civil protection, authorities and local decision makers with a new tool that goes beyond the "What happens" dipping into the "What should we do in order to minimize the consequences of what is expected to happen", in order to prioritize mitigation and response actions.

1.4. Definition of urban prevention strategies

We are planning to define disaster prevention strategies based on the level of risk (typologies, schools, strategic buildings, critical infrastructure, and others) and based on an education management information system linked to information about the areas and population groups that are prone to particular kinds of emergencies. A few case studies will be considered, with all of the data and procedures implemented at an urban scale. It is intended to reach harmonisation at the urban risk level, with merging of the best practices and available data from the countries participating in the project (Italy, Portugal, Spain and Iceland).

1.4.1 Disaster prevention strategies based on the level of risk
Mitigation is a key element in disaster risk management. Through the implementation of a disaster mitigation strategy, disaster risk-reduction benefits can be achieved to the advantage of individuals and communities, and even across borders. In this project, a tool designed to identify priorities will be delivered through an external iterative procedure. This procedure allows analysis and optimisation of specific seismic risk-mitigation strategies, based on the quantification of costs and benefits of possible interventions regarding, for example, building stock, non-structural components, critical assets, critical infrastructure, and lifelines.

1.4.2 Disaster prevention strategies based on education information systems
Effective disaster-risk reduction awareness can be developed, for example, through long-term activities, such as education. Often, people have the idea that natural hazards will strike others, but not them. In part, this is connected with the education sysem itself: textbooks often present "horrible" cases from far away, compared to which local disasters appear trivial. Consequently, there is an absence of risk awareness in people's lives, which results in a lack of attention being paid to risk reduction in community and state development planning, in the educational curriculum, and as media

priorities. As this knowledge is clearly connected with the understanding of the risks, the perception of the natural hazards and the risks in the local environment should be developed with the help of the education system.

This information within the education system needs to be easily understood and accessible to all, and should be directed to the diverse needs of different population groups in areas prone to particular kinds of hazards. This task will include a comparative study on how the education information system, with particular reference to earthquakes, is organised in the different EU countries that are participating in the project. With a clear view of what the shadow zones are on this subject, specific teaching modules to introduce Earth Science related to seismic hazard communities will be built.

2. DESCRIPTION OF THE ONGOING ACTIVITIES

Earthquakes have been the cause of the deadliest natural disasters over the past century, with the first decade of the 21st century being one of the most devastating periods. Due to the high number of uncertain factors that contribute to earthquake occurrence, earthquake prediction is extremely difficult, if not impossible. At the moment, large efforts are being made by the international community, in both scientific and economic terms, for studies related to short-term and long-term probabilistic earthquake forecasting, and simulation aspects of the generation process to reduce earthquake risk by mitigating the risk of damage and the associated consequences.

The on-going activities of the UPStrat-MAFA project have been summarised in several papers submitted to the 15WCEE, which are briefly outlined in the following.

2.1. Disaster prevention strategies based on quantified levels of risk

The first phase, Task A, encompassed the collection of the available data, the definition of the data structures applied, and the development of a uniformly structured databank. The data considered were: (i) seismological data; (ii) strong-motion accelerometric data; (iii) MF data; and (iv) available damage data.

The paper by Galluzzo et al. (2012) outlines and summarises the first phase of the on-going activities related to "Calibration of input parameters in volcanic areas and enlarged dataset by stochastic finite-fault simulations". Preliminary results have been obtained by applying the stochastic method to data from the pilot areas: Mt. Etna, Mt. Vesuvius and Campi Flegrei, and by also performing two applications for large magnitude events in the Azores Islands and South Iceland. A general preliminary database of ground-motion records has been collected in all of these test areas in order to set up the empirical laws of ground-motion parameters. The results of the simulations are compared with observed waveforms and response spectra, to evaluate the suitability of the parameters used, taking into account the peculiar parameterisation of the source, the path parameters, the local site effects and the duration parameters. The results indicate the need to include site effects and to adopt a more accurate stochastic procedure to reproduce the low-frequency content of large earthquake radiation. In general, the preliminary results show good agreement between observed and simulated time histories and response spectra, which encourages further efforts towards quantitative high-resolution studies on input parameters.

The paper by Rotondi et al. (2012) presents the first phase of the on-going activities related to the probabilistic modelling of MFs. The first region examined is the South Iceland Seismic Zone (SISZ), and in particular, two recent damaging earthquakes in the SISZ; namely, the earthquakes on 17 June, 2000 and 29 May, 2008. Both events had assessed epicentral intensity of MMI X. The main finding related to the Icelandic data is that the current probabilistic model forecasts the two MFs reasonably well, and the use of three different validation criteria strengthens this finding. However, we observed certain systematic deviations that can be traced back to the specific nature of these two earthquakes, and which therefore suggests some modifications to the model. In particular, it is desirable to enhance the representation of finite sources, and to address the problems of directivity effects and of multiple causative faults.

The paper by Sousa et al. (2012) outlines and summarizes the on-going activities especially related to “Quantitative risk evaluation and mapping” and “vulnerability of buildings, urban infrastructure and systems”. Special emphasis is placed on the vulnerability assessment of residential buildings and schools, based on the Portuguese experience. This includes: (i) steps for vulnerability assessment; (ii) inventory and vulnerability of Lisbon elementary public school facilities; and (iii) inventory and vulnerability of Lisbon and Algarve residential stock. This paper gives a good overview of the current state of knowledge regarding seismic vulnerability and risk assessment in Portugal. This initial presentation will serve as a model for the other pilot sites considered.

The paper by Azzaro et al. (2012) presents the on-going activities for the assessment of the urban seismic risk at the Mt. Etna volcano test site, with the introduction of the concept of the DI. The required probabilistic seismic hazard maps and scenarios are expressed in terms of macroseismic intensities, which are derived using up-dated information on historic seismicity, seismogenic faults, and intensity attenuation. The application of the DI approach at the Mt. Etna volcano test site is based on a probabilistic procedure using jointly MFs and fault parameters. For information on the urban scale vulnerability, the geographic information system (GIS) is used to organise the data related to buildings and network systems (e.g. typologies, schools, strategic structures, lifelines) for the exposed municipalities. The convolution of ground motion and vulnerability/impact is obtained using a Monte Carlo simulation procedure. Some preliminary results are presented on the identification of the critical nodes that are the governing factors for major disruption in the urban systems considered. This paper outlines and summarizes the elements needed to apply the DI approach in a near future to obtain the levels of disruption. Some modifications of the procedure may, however, be needed to cover all eventualities of critical infrastructure systems, e.g. geothermal district heating systems and geothermal sources.

The paper by Mota de Sá et al. (2012) “DI: The concept of Disruption Index in urban systems” outlines and summarises the theoretical basis of the DI. This tool will be used in the UPStrat-MAFA project.

2.2. Disaster prevention strategies based on an education information systems

Regions that adopt and enforce strict building codes that aim to control structural failures (e.g., Eurocode, 2002) reduce the risk of structural collapse and increase the likelihood that the structural damage will be minor and repairable. As a result, other types of earthquake damage, such as non-structural damage, utility systems failure, infrastructure failure and loss of functional performance, gain greater attention; there is no sense in fixing the utility system in a collapsed building. Although the general public have little control over the structural integrity of buildings, they can significantly reduce the risk of the other failures listed above. Thus, a prerequisite for more effective disaster-risk reduction is increased risk awareness among the public, in the community and for state development planers, educators, and media personnel. Raising seismic risk awareness also means to ensure that risk is being perceived in a manner that corresponds to current scientific knowledge. Hence, perception of natural hazards and the associated risks in the local environment should be developed with the help of education and training.

The paper by Benhardsdóttir et al. (2012) introduces and summarises the first phase of the on-going activities related to a comparative study on the current educational curriculum on natural hazards within the school systems in Italy, Portugal, Spain and Iceland. Additionally, current activities on prevention strategies carried out in Iceland over the last decades are summarised by Thorvaldsdóttir et al. (2012) in a paper entitled: “Dissemination of information on hazards and risks: the Icelandic experience”. Here, general information regarding the response to natural disasters is described, which can be found in the national telephone directory as well as on the internet. Furthermore, an earthquake booklet for teachers at kindergartens and primary schools is discussed, as well as a colouring book for children. The awareness raising at the Earthquake Engineering Centre, which is located in the SISZ, is described. This includes training for 10- to 12-year-old children. The activities of museums giving special exhibitions are also outlined. Hands-on experience provided by local communities is also discussed and exemplified. This experience will be applied along with planned surveys (Bernhardsdóttir et al., 2012), to formulate constructive prevention strategies.

The paper by Nave et al. (2012) outlines and summarises the first phase of the on-going activities related to “An interactive travelling educational path on earthquakes and volcanoes”. One of the tasks of the European UPStrat-MAFA project is to develop an educational system aimed at long-term training, mainly for seismic hazard and risk. This task will be carried out by sharing the expertise of the partners of the project, to set different actions, encompassing programmes and educational material for students, teachers and the general public, and to design an interactive travelling educational path.

Starting from the Icelandic educational programme tested in schools over the last decade by the Earthquake Engineering Research Centre, the task will develop educational tools that are especially designed for children, and also new tools using the widest of information channels, to outreach information on seismic risk and on how to cope with earthquakes.

The interactive travelling educational path on earthquakes and volcanoes is aimed at risk-reduction by increasing awareness, and it is an interactive experience that uses a multimedia approach to provide a very flexible, easy-to-share and appealing set of educational tools (e.g. videos, simulations, games), as also developed for "edutainment". The educational path, which is also a travelling exhibition, has to deal with issues related to seismic and volcanic hazard and risks, especially in urban areas.

The whole education-information system developed in the framework of the UPStrat-MAFA project is structured to represent both a way to convey project results to the scientific community and to strengthen people's risk awareness and their training to face up to seismic and/or volcanic events.
Additional activities worth mentioning are related to the application of a shake table for demonstration purposes, both for children and adults. This includes the modelling of typical living quarters on a shake table, and then investigates the effects of the shaking on toppling and falling objects, in addition to the presentation of more traditional structural damage effects.

http://upstrat-mafa.ov.ingv.it/UPStrat/ (2012) is the official uniform resource locator (URL) of the UPStrat-MAFA project. The website, the home page of which is displayed in Figure 4, has a special role in the project, as it will be the portal of communication among the team and the tools of the study (i.e. FORUM; see Figure 4). Furthermore, the website serves as a public relation gateway for the dissemination of scientific information obtained throughout the project, as well as a multimedia tool for educational purposes. It is anticipated that the website will be kept operational after the project is finished.

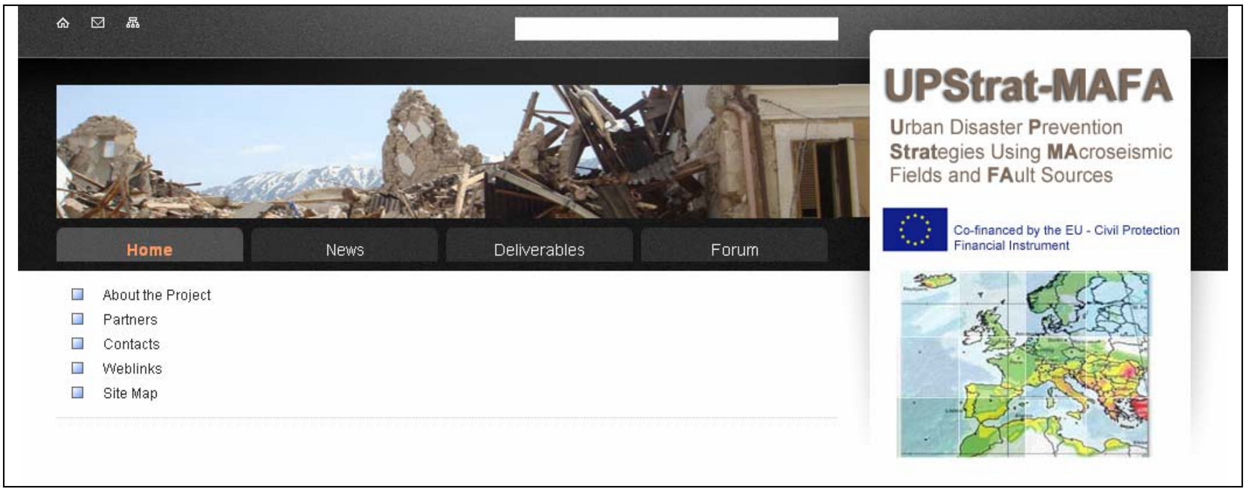

Figure 4. The official webpage of the UPStrat-MAFA project, at http://upstrat-mafa.ov.ingv.it/UPStrat/

3. CONCLUSIONS

The whole infrastructure that is being set up through the project, including in particular the methodologies and databases, will remain active beyond its completion. As the urban disaster prevention strategies are here based on the level of risk and the education management information system, the first action at the end of this project will be to consolidate these approaches with the testing of other areas, to encourage more cooperation and interchange between the Member States and

Civil Protection. Indeed, in the framework of the European risk assessment and mapping guidelines for disaster management, it is crucial to improve the coherence across risk assessment in the Member States. The actions that need to be continued include risk assessment through the study of the vulnerability of buildings and of the urban infrastructure, and improved dissemination strategies to increase citizen awareness, in terms of how they can reduce disaster risk.

The necessary resources to continue the actions will be achieved with the help of dedicated funds that will allow the dissemination of the strategies adopted, and the involvement of new partners from Member States and/or other EFTA/EEA countries. Moreover, it will be possible to build a network of actions that will be aimed at merging the educational resources available with similar and complementary projects.

All of the partners will continue to interact closely with other national and international projects, to continue to promote the transfer the project methodologies and knowledge. We strongly believe that this will also trigger further collaboration initiatives across all of the relevant domains of this project.

This study is being carried out without taking into account one fundamental aspect of the risk assessment that is having a nearby volcano. This is included in the educational approach, but not in the vulnerability studies. In the future, it will be crucial to include the effects of the on-going volcanic risk assessment.

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