

## SEISMIC RISK MITIGATION IN ABRUZZO: STATE OF THE ART, RESEARCH DEVELOPMENTS AND APPLICATIONS

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**Introduction.** The research presented in this paper springs from a collaboration between the “Dipartimento di Ingegneria Civile, Edile–Architettura e Ambientale” (DICEAA) of the University of L’Aquila and the “Servizio Prevenzione dei Rischi di Protezione Civile” of the Regione Abruzzo. Such a collaboration is focused on the seismic risk reduction and prevention. Specifically, the collaboration promotes the research and development of investigations and actions aimed at preventing the seismic risk in all the region. The central issues of the research are the “Microzonazione Sismica (MZS) Levels 1 and 3”, the “Condizione Limite per l’Emergenza comunale (CLE) e Intercomunale (CLE-I)”, and the reduction of the seismic vulnerability of strategic structures, three issues that were dealt with jointly by the National Seismic Prevention Program funded by the Law 77/2009, art. 11 (Dolce, 2012). On these topics, DICEAA and “Servizio Prevenzione dei Rischi di Protezione Civile” started an experimental program that takes the city of Sulmona (AQ) as a case study (ITC-RegAbr 2007). This paper summarizes the initial results of this interdisciplinary research and has as main topic the “seismic prevention”. In particular: *i*) the risk reduction and the consequent increase in the resilience of the territorial and urban contexts, and of the built environment; *ii*) the pre-disaster planning and the consequent proposal of new management procedures for the interventions of the Protezione Civile that account for the city planning aspect of the issue. Further research steps will focus on related topics such as: *i*) the coherent merging of plans coming from different institutions and

sectors, *ii*) the analysis of the urban and social vulnerability and infrastructural efficiency, and *iii*) the adoption of new technologies in the geologic, urbanistic and engineering fields.

**Regional Program of Seismic Risk Mitigation.** After the seismic event of the 6th of April, 2009, that involved the provinces of L'Aquila, Pescara and Teramo, the Regione Abruzzo enacted new laws on seismic prevention and seismic risk. The regional law L.R. of the 11/08/2011, n.28 defines the minimum conditions for which a MZS study is required, the technical characteristics that such a study should present, and state that the PRG should mandatorily account for the "Piani di Emergenza Comunali" (PECs) and the MZS studies. According to Article 21 of the L.R. 28/2011, MZS studies are compulsory for all the municipalities in Abruzzo. For 60% of the territory in Abruzzo, the National Technical Norms (NTC) assume a ground acceleration  $a > 0.125g$ , consequently such areas can benefit of the funds defined by the Article 11 of the DL 39/09. The remaining 40% of the territory already benefitted of the regional funds coming from the POR-FESR Asse IV, Attività 3.1.c. The Regione Abruzzo started a program of analysis of the CLE (OPCM n. 4007/2012 e DGR n. 508 del 15.09.2017) at a municipal level on all the 276 municipalities defined by Allegato 7 of the OPCM 3907/2010.

The combined use of CLE and MZS studies allows to integrate all the actions that are aimed at minimizing the seismic risk by means of improvements in the management of the emergency activities that characterize the immediate aftermath of the seismic event (post-impact phase).

**State of the art for the MZS in the Abruzzo Region.** The Abruzzo Region has 305 municipalities; such municipalities have been gradually included into the MZS studies through annual projects. In an initial phase, the early studies included the 12 macro areas that were subjected to a damage above the seventh grade of the Mercalli scale (Del Monaco *et al.*, 2013, Durante *et al.*, 2013). In a second phase, the "Servizio Prevenzione dei Rischi di Protezione Civile" of Regione Abruzzo financed five different programs of MZS (*Fig. 1 State of the art: first and third level MZS, CLE for the Abruzzo Region*, left column) that covered all the region. Up to date, only 236 of the total 305 municipalities have studies that have been validated by the "Tavolo Tecnico della Regione Abruzzo". At the same time, regional guidelines "Standard di rappresentazione cartografica e archiviazione informatica" were provided to integrate those coming from the "Commissione tecnica per la microzonazione sismica". After the seismic sequence started in 2016 and ended at the beginning of 2017, the DLgs 8/2017 allocated 6.5 million euros for the development of third level MZS studies for the locations included in the area defined as "cratere sismico" (i.e., the area that has been recognized as subjected to the

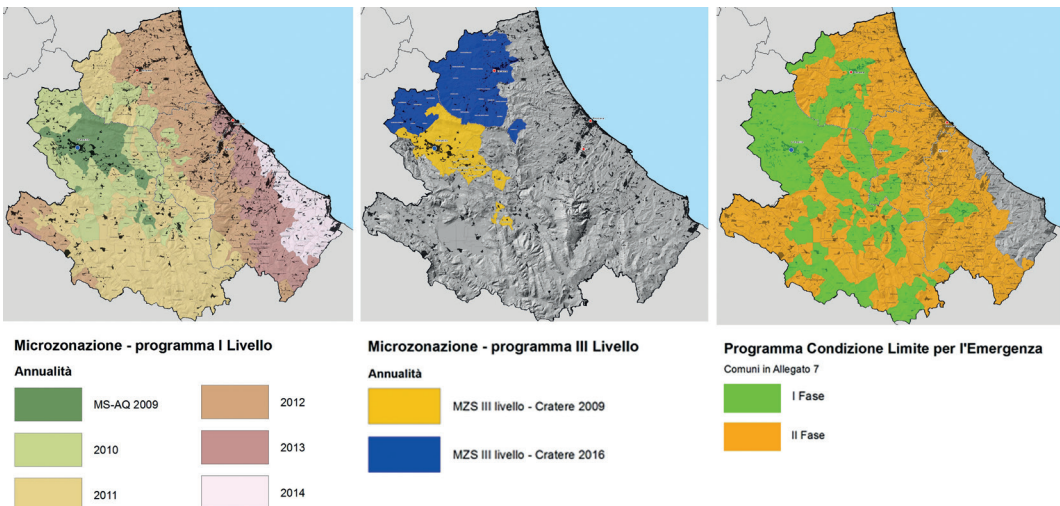


Fig. 1.

highest damage). In Abruzzo there were 23 municipalities included in such area (Berti *et al.*, 2016). Third level MZS studies are aimed at seismically characterizing homogenous zones by means of quantitative parameters. Such characterization is based on the amplifying factor FA that is defined in the “Indirizzi e criteri generali per la Microzonazione Sismica” (2008). Such studies highlighted several criticalities such as the existence of active and capable faults, natural and anthropic caves, differential settlements or liquefaction phenomena.

**CLE planning on the regional area.** *“The vulnerability of an urban system is a measure of the nonlinear correlation between the seismic intensity and the damage dealt to the urban system. Such correlation directly depends on the exposure of the elements of urban system. The CLE is the instrument that allows to verify the principal physical elements of the emergency management system defined by the plan of the Protezione Civile”* (Prot. Civ. 2014) and is a starting point to merge emergency planning and urban planning (Di Lodovico and Di Ludovico 2015). Specifically, it allows the evaluation of the urban system’s response in the immediate aftermath of the seismic event. Such evaluation entails to ascertain if and how the strategic structures and services are maintained functional, connected and accessible. In Abruzzo, the regional program for the CLE analysis on the regional territory (*Fig. 1 State of the art: first and third level MZS, CLE for the Abruzzo Region*, right column) started in 2017 (and is still ongoing) and involves the 276 municipalities included in the Allegato 7 to the OPCM 3907/2010 and following norms. To facilitate the start of the regional CLE program, the Institutions involved in the collaboration (Giunta Regionale, University of L’Aquila, and University “G. D’Annunzio” of Chieti-Pescara) produced guidelines for the development of the CLE analysis that are named “Linee di indirizzo regionali per l’elaborazione dell’analisi della Condizione Limite per l’Emergenza comunale – CLE”. Lastly, together with the CLE at the municipal level a new experimental study is being developed for groups of municipalities that share a common management for all issues related to the Protezione Civile.

**The Sulmona case study: the risk scenarios.** Sulmona, in the province of L’Aquila, is classified as a level 1 seismic zone. In history, several high intensity seismic events struck the city dealing high damage and several losses. Among the most relevant seismic events there are the earthquake of 1706, 1915 (Fucino), 1933 (Lama dei Peligni) and 1984. The multidisciplinary experimental study has been performed on the historical downtown with the aim to ensure the functionality of the urban system in the case of an emergency. The available knowhow and new technologies have been combined in the development of a pre-disaster recovery plan base on FEMA’s model (e.g., Pre-Disaster Recovery Plan). Such pre-disaster recovery plan contains the description of the possible risk scenarios (both hazard and damage scenarios): such scenarios are provided in terms of maps that show the physical and social impact of the hazards (i.e., the impact on structures, infrastructure and population).

Such risk scenarios have been developed to include the information coming from

- the social exposure (inhabitants and commuting workers) derived from the census distributions (sezioni censuarie - ISTAT 2011–datanagrafeSulmona);
- the vulnerability analysis of buildings evaluated according to the vulnerability classes defined into the MSK(ITC-RegAbr2007);
- the results of the first level MZS studies (*Fig. 1 Left column: “Micro zone omogenee in prospettiva sismica” (MOPS) of the first level MZS study. Right column: “Carta di Riduzione del Rischio”, left column*), and the critical scenarios related to the Rischio Pirologico (Opendata Regione Abruzzo) and Rischio Idrogeologico e Idraulico (from P.A.I. and P.S.D.A. produced by the Autorità di Bacino).

Using the risk scenarios, the different areas have been divided into three categories of low, medium, and high Potential Damage. The definition of the Potential Damage is a function of Exposure, Vulnerability and Hazard–  $f(E, V, H)$ . The areas with the highest Potential Damage are those with high density of highly vulnerable buildings, high density of public and populated building, high exposure, and medium-high direct or indirect level of hazard. Generally, the high-

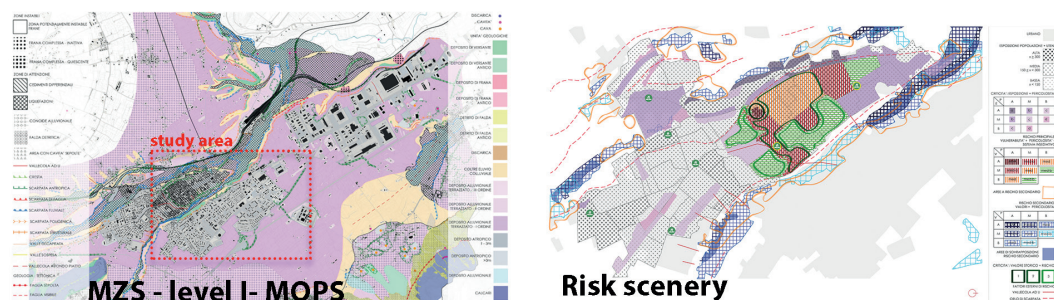


Fig. 2.

level risk areas are those that have two characteristics: the public highly-vulnerable buildings are above 35% (of the total number of buildings), there is a high density of strategic and populated buildings. The medium risk areas are those with one of these two characteristics, all the low-risk areas have none of the two. Additionally, the efficiency of the Piano di Emergenza Comunale has been evaluated with the CLE. Starting from a risk scenario, the main actions needed for the seismic risk reduction have been listed in a document that should support the territorial planning. An example of such actions is the definition and eventually enlargement of multifunctional emergency areas (not in accordance with the PRG), such areas will assume different functions in emergency and ordinary phases. Other possible actions are the seismic retrofitting for strategic or relevant structures, the seismic improvement of buildings and interfering structural aggregates; the removal of interfering obstacles and architectural barriers; the replacement of the road pavement with non-slippery and draining materials; securing railway level crossings; the seismic improvement of all covered driveways and pedestrian areas such as arches, historic gates and bridges.

**Conclusions future developments.** Seismic safety is a central topic in territorial planning that has a strong interdisciplinary connotation. Although still in the initial phase, the research presented in this paper produced some fundamental results. Among them, there is the importance of coherent and coordinated developments of MZS studies and CLE. Synergies between different Institutions, such as the DICEAA of the University of L'Aquila and the Regione Abruzzo, allowed the contributions of different skills, professionalisms, technologies and resources to be appreciated and great results in terms of municipal urban planning to be obtained. The experimental analyses highlighted the efficiency of the coordination between “Quadri Conoscitivi” (e.g., MZS, PAI, PSDA, CLE, etc...) and “Pianificazione delle operazioni di Protezione Civile e Progettazione/Pianificazione Urbanistica e dello sviluppo Territoriale” (Fabietti 1999). These instruments are often undervalued and neglected in urban plans. On the contrary, urban plans should account not only for the traditional planning instruments but also for more accurate and specific analyses (such as MZS studies and PAI), and for a planning approach more oriented to the safety “in and for” the municipality (Di Ludovico *et al.*, 2017).

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