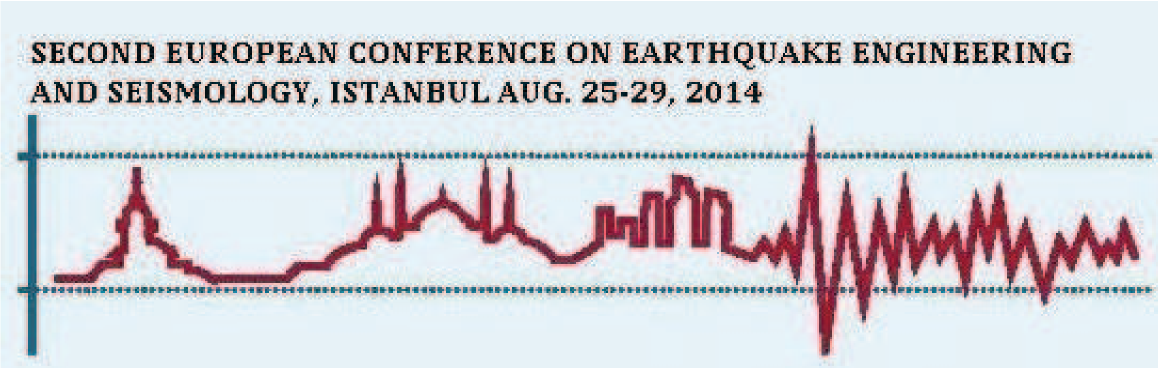

ON ASSESSING IMPORTANCE OF COMPONENTS IN DYSFUNCTION URBAN SYSTEMS GIVEN AN EARTHQUAKE: THE CASE OF MT ETNA REGION

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T Mt Etna region (Sicily, Italy) is one of the test areas studied in the European Project "Urban disaster Prevention Strategies using MAcroseismic fields and FAult sources" (UPStrat-MAFA) to which the methodology of Disruption Index (hereafter DI), recently developed to evaluate the dysfunction of urban systems caused by earthquakes (Ferreira et al., 2014), has been applied on a trial basis.

The central idea underlying the definition of DI is the identification of fundamental areas of human needs (housing, education, employment, food processing and distribution, and so on) which may be affected by earthquakes occurrence, of the functions (electricity and water supply, transportation, and so on) whose dysfunction can affect them, and of their dependencies network. The network of the dependencies is complex; disruption of one of the functions may affect one or more of the general areas of human needs, and a function may depend on other functions. All functions in turn depend on the physical structures exposed to damage. As for the evaluation of DI, key elements are the characterization of the earthquake impact in severity levels and the impact severity propagation, which is modelled in a bottom-up sequence, starting from the physical damages directly suffered from the exposed assets. Damages depend on the vulnerability of the exposed assets and on earthquake intensity and can be obtained from field reports after the occurrence of the event or from simulators.

Specially if used in combination with simulators, DI is be a very powerful tool for the development of prevention strategies to minimize risks since it helps to understand the importance of individual components of a system on its dysfunction. Its usefulness may be even amplified by using the so called Risk importance measures, typically used in the nuclear sector for design and maintenance of the nuclear plans. In particular we refer here to Risk Reduction Worth (RRW) and Risk Achievement Worth (RAW), and to the Birbaum Index (Van der Borst, 2001). RRW compares a reference risk with one which would be achieved if the component of interest was not dysfunction, or dysfunction to a less extent, whereas RAW compares a reference risk with one which would be achieved if the component of interest increased its level of dysfunction. The Birbaum Index compares the levels of

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risk derived from changes in the state of dysfunction of individual components of a system whitout considering a reference level of risk. This is a very suitable measure when the physical damages suffered by exposed elements are obtained by simulators. The key idea underlying the use of the Risk importance measures is to conjecture different vulnerability values for physical assets exposed at risk, to derive the corresponding damage scenarios and the corresponding DI values, and to compare them through the selected measure.

In Mt Etna region DI has been estimated for the May 8, 1914 Mt Etna earthquake, a very strong earthquake (IX/X on the EMS scale). Its seismic scenario (Figure 1, left) has been estimated by the PROSCEN package, according to the assumptions that there is a point seismic source or a linear seismic source (Azzaro et al., 2013).

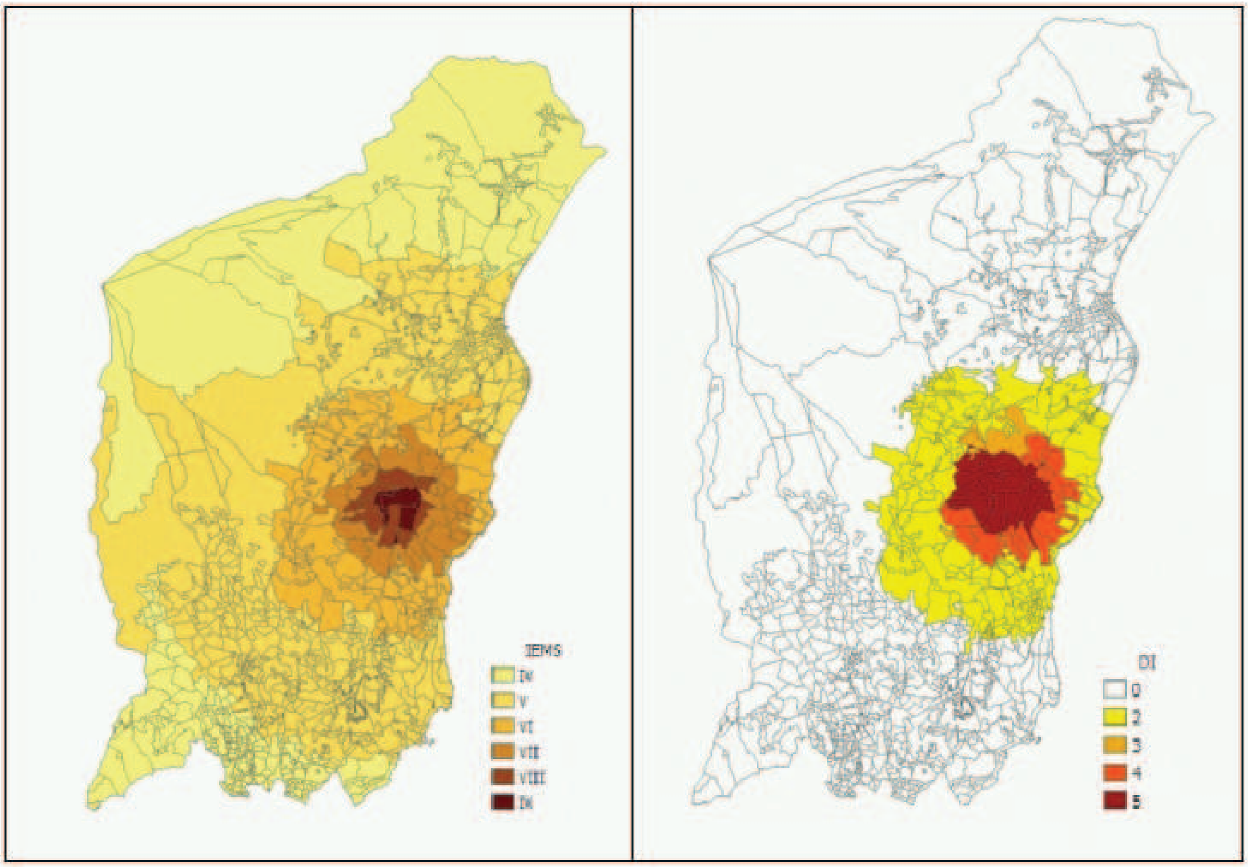

Figure 1. May 5, 1914 earthquake intensity (EMS) scenario and DI relative pattern

The damage data used to compute the DI refers to residential buildings, hospitals, schools, police stations, lifeline services (electricity, water, gas, wastewater) and roads. The data about the buildings were extracted from the 1991 and 2001 Italian National Institute of Statistics (ISTAT) census and vulnerability indices were evaluated using the approach proposed by Lagomarsino and Giovinazzi (2006). The data about public buildings, strategic facilities derived from a project carried out from 1996 to 2001 by the Civil Defence Protection (Cherubini et al., 1999). In the Figure 1 (right) has been shown the resulting pattern of the DI

The quantification of the estimated effects of the 8 May, 1914 earthquake in the study area can be summarized as follows: 70% of the area is expected to suffer a mild level of disruption (DI=II), mainly related to damages to buildings; 8% a level of disruption equal to III, characterized by significant problems in mobility in the most affected areas, due to damages to the road network; 17% quite a severe level of disruption (DI=IV), meaning that there is a considerable number of homeless and normal daily activities, including school and economic activities, are disrupted. Finally, 5% of the area is expected to suffer the highest level (V) of disruption, which means the paralysis of the entire system, with a high cost for recover.

If we consider for example DI=V, from the definition of DI (Ferreira et al., 2014) we know that it may derive from level V of dysfunction of the housing area of human needs or from level III of dysfunction of the food area, or from both. Following the network of dependencies in a up-bottom sequence until reaching the physical assets exposed to risk, we see therefore that DI cannot be less than V if the level of dysfunction of the transportation facilities is IV or the level of dysfunction of the buildings stock is V. Similarly, we see that the level of disruption of the transportation facilities cannot be III or greater if we want to preserve level II of DI, and so on.

The above information, and other similar information, can drive actions aimed to reduce consequences, or to maintain an acceptable level of disruption for future earthquakes of the same intensity in the area. However, it is clear how many degrees of freedom prevention strategies can have, given the complexity of the system of the physical assets exposed to risk in the area. Indeed, there are more than 300 typological classes of buildings with different vulnerability indices, the road network include 50 vulnerability forms of bridges, there are more than 400 vulnerability forms of schools, 16 vulnerability forms of healthcare facilities, more than 60 vulnerability forms of security buildings, a certain number of electric and gas stations, more than 300 water pipelines branches, and other physical assets exposed to risk. The idea which may be pursued in order to explore the importance of the different components is that of to speculating different vulnerability scenarios for the physical assets of the system exposed to risk, or at least for the ones regarded as very important a priori, and of deriving from them the corresponding damage scenarios and the corresponding expected levels of disruption. The use of the Risk importance measures integrate and refine this process.

REFERENCES

Ferreira, M.A., Mota de Sa', F., Oliveira, C.S. (2014). Disruption index, DI: an approach for assessing seismic risk in urban systems (theoretical aspects). Bulletin of Earthquake Engineering, DOI 10.1007/s10518-013-9578-5.

Van der Borst, M., Schoonakker, H. (2001). An overview of PSA importance measures. Reliability Engineering and Safety Systems, 72, 241-245 .

Azzaro, R., D'Amico, S., Rotondi, R., Tuvè, T., Zonno, G. (2013). Forecasting seismic scenarios on Etna volcano (Italy) through probabilistic intensity attenuation models: a Bayesian approach. Journal of Volcanology and Geothermal Research, 251, 149-157

Lagomarsino, S., Giovinazzi, S. (2006). Macroseismic and mechanical models for the vulnerability and damage assessment of current buildings. Bulletin of Earthquake Engineering, 4, 415-443.

Cherubini, A., Corazza, L., Di Pasquale, G., Dolce, M., Martinelli, A., Petrini, V. (1999). “Risultati del progetto LSU-1”, in “Censimento di vulnerabilità degli edifici pubblici, strategici e speciali nelle regioni Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia e Sicilia”. Graphic Press s.r.l., L’Aquila.- Cherubini 1999