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Reducing seismic risk by understanding its cultural roots: Inference from an Italian case history

Francesco Stoppa*, **Chiara Berti**

Department of Psychology, Humanities and Territory, University "G. d'Annunzio", Chieti, Italy;
*Corresponding Author: fstoppa@unich.it

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ABSTRACT

The paper discusses how to approach the problem of the social mitigation of seismic risk, in order to reduce damage and grief consequent to earthquakes. An alert protocol, intended as a working hypothesis, is proposed based on the experience gained from analysis of the behaviour and social response to the threat before and after the great disaster of the L'Aquila earthquake on 6th April 2009. Authors propose a protocol addressing four levels of increasing alert based on signs of earthquake preparation and social concerns. In this sense, it works as an intensity scale and does not strictly relate to earthquake size (magnitude) or seismic hazard. The proposed alert protocol provides sensible measures for reducing vulnerability, which is the only factor that can be more or less efficiently controlled, based on structural and behavioural adjustments. Factors indicating the difficult relationship between politicians, scientific community and citizens are considered: 1) a serious gap between researchers and citizens; 2) measures adopted by local administrators and the National Civil Protection Service not agreed by the population; 3) misunderstanding originated from a lack of clarity of communication about scientific terminology; and 4) the lack of an alert procedure protocol. In the current situation, all these problems are crucial and contribute to the unpreparedness to face a seismic event, and thus greatly increase the risk. The adoption and implementation of an alert procedure protocol requires a preliminary assessment of the context and should be adapted to the local sensibility and culture. The application of a protocol may reduce the contrasts between preventive measures and individual responsibilities, making mitigation measures more feasible and socially acceptable. In this paper, risk evaluation is not strictly related to probabilistic or deterministic predictions. In fact, this is a result of a project that comes from the general analysis of risk and is not intended to give an alternative hazard estimate method. This paper proposes an alert protocol addressing four levels of increasing alert based on signs of earthquake generating preparation and social concerns. Finally, there is a suggestion on how to gradually communicate the threat and get citizens involved in the risk mitigation process.

Keywords: Seismic Risk; Risk Mitigation; Alert Communication; Social Representations; 2009 L'Aquila Earthquake

1. INTRODUCTION

Despite the availability of a significant number of risk reduction measures, implementing seismic risk mitigation is a major challenge in most earthquake-prone countries. By integrating different theoretical frameworks and methodologies, ranging from earths sciences to social sciences, this paper is intended to increase risk awareness and efficiency of mitigation measures. It would also form a discussion base among 1) scientists involved in social activism; and 2) public and private institutions dealing with general risk mitigation communication and actions. Italy is a country characterized by high victim/building collapse/magnitude ratios which have claimed at least 200,000 fatal victims and enormous economic loss in the last 150 years. In the same period there were 35 seismic disasters and another 86 earthquakes only a little less destructive. Italy is a high-risk country, being densely populated and having high seismicity (**Figures 1(a)-(c)**) [1]. The highest-hazard areas are across the lesser populated Apennine chain, from Liguria to Calabria, however some important cities are included in the maximum-hazard area, such as Rieti, L'Aquila, Isernia, Campobasso, Potenza, Cosenza, Reggio Calabria. Sicily is a very seismic area where Messina and Catania were destroyed several time and Palermo also suffered some destruction. The Southern Alps have also a high seismicity. Along the Adriatic coast, Rimini, Ancona and Foggia have experienced several severe shocks. Naples province is very critical, having the highest population density and additional presence of active volcanoes. By examining the population density, presence of important cities, historically destructive epicentres and hazard map, it is possible to get an idea about the associated risk (**Figures 1(a)-(c)**). Most of the earthquake standards adopted in the highly seismic Borbone's Kingdom were cancelled by the government of the Royal House of Savoy, who had limited experience of earthquakes. Consequently, Italy to his unit did not have a seismic legislation. In the last century, the progress of advances in the awareness of potential dangers to the implementation of preventive measures was too small and slow, and the occurrence of an "unexpected" destructive earthquake changing the previous rules was the norm. In fact, roles have been changed mostly after destructive earthquakes (**Table 1**). Note the long gap during the economic collapse due to World War I and the 1929 crisis. During the 50s and 60s, the Italian economic boom with rapid and mostly uncontrollable reconstruction in the post-World War II period produced millions of new buildings not specifically designed to resist earthquakes. It is apparent that engineering measures were insufficient, and mitigation measures were carried out without providing social, cultural and political awareness of seismic risk. Sufficient mitigation factors were often ignored because of their economic cost and loss of immediate profit. So we believe that earthquake risk mitigation has to pass through social politics and the cultural preparation of the population. For this reason it is important to prepare individuals and institutions for pre- and post-earthquake scenarios. Earthquake disaster losses can be minimized with the implementation of appropriate risk mitigation decisions. Promoting and enhancing citizens', communities' and administrators' decisions to adopt earthquake risk preparedness measures is essential in order to reduce fatalities, damage to property and infrastructure, and economic and social disruption in a seismic disaster [2]. In this paper we suggest a working protocol of progressive degrees of alert. Establishing a standard protocol with more objective and impersonal mitigation choices will immediately result in a general benefit by reducing conflicts between administrators, scientists, politicians and citizens. This procedure would efficiently inform the population about hazard, and would avoid panic and indirect loss of income and lives.

2. THE ABRUZZI CASE HISTORY

The city of Aquila suffered extensive damage during the 2009 earthquake [3-5] (**Figure 2**). Considering the moderate magnitude (Ml = 5.8, Mw = 6.2), and even taking into account the local amplification effect, the number of 309 fatal victims, with a large peak for the 20 - 24-year range, and 1500 injured (10% severely injured) is very relevant [6]. Fifty-five university students died, and according to survivors many had felt reassured, interpreting the foreshocks as positive energy discharges, as communicated by a spokesman for the Protezione Civile. Many others had guaranteed that the collapsed buildings were "solid" and "strong". Most of the victims were as a result of the total collapse of seven multi-storey concrete-reinforced buildings in via Campo di Fossa 21 n 6 and 6/B, via Cola dell'Amatrice 17, via G. d'Annunzio 24, Via L. Sturzo 3, via Generale F. Rossi 22, via Poggio S. Maria 8 and via XX settembre 79, plus the partial collapse of the university college in the same road. L'Aquila historical seismicity is also very relevant, with foreshock sequences so noticeable that they were recorded by ancient historians before several destructive shocks occurred over 700 years [7,8]. Thus, the high fatal toll may be considered unexpected bearing in mind the long foreshock sequence, the night time of the earthquake and the sparse population distribution. Most of the victims were in the L'Aquila with 199 deaths, followed by Onna village with 40 deaths and Villa Sant'Angelo with 17 deaths. In another 15 localities, 1 to 8 deaths occurred. Most of the recent multi-storey concrete-reinforced buildings underwent critical damage and were right on the point of collapse (**Figure 2**). Because the earthquake struck at night there were no significant casualties due to fallen architectural elements on the roads, which would have produced many more casualties in daylight hours (**Figure 2**). In addition, public buildings, schools and university structures suffered major damage and collapse. This would have implied a much higher casualty rate if the earthquake had hit during daylight. The modern L'Aquila city was built in a very disorderly way, mostly without special precautions against earthquake; therefore, although the evaluation of seismic hazard has remained unchanged overtime, the risk was greatly increased. L'Aquila territory was downgraded after 2003 (Ordinanza n. 3274) to the second category, clearly in contrast with the surrounding communities and its location in the high-hazard area (**Figures 3**). It was thought that previous reassuring messages from the National Civil Protection Service, in order to avoid panic, were issued without the support of an efficient risk assessment and efficient mitigation measures. Appeals for calm, dissemination of information regarding the small possibility of strong shocks and the invitation to stay

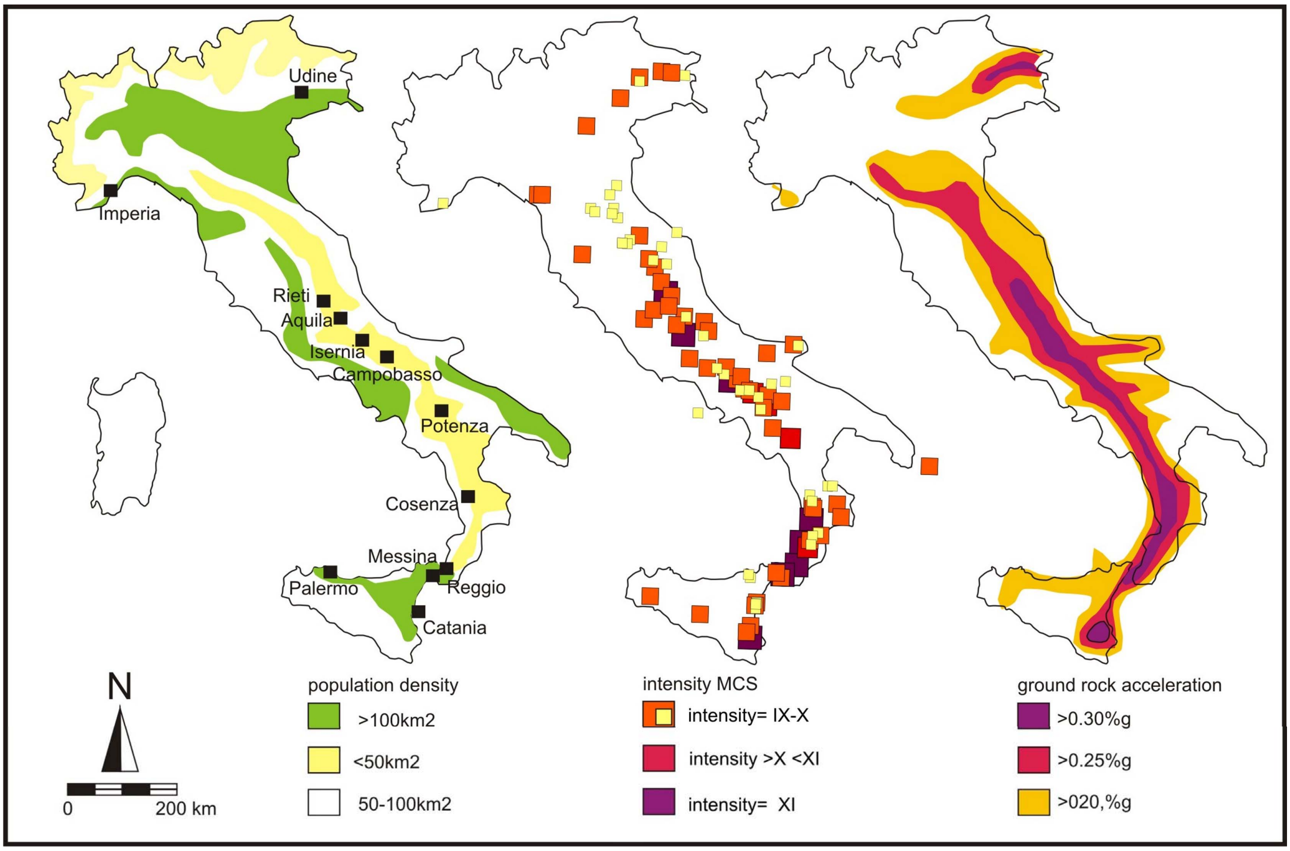

Figure 1. Simple risk assessment comparing population density (left), destructive historical earthquakes (centre) and hazard map expressed in terms of expected hard-rock ground acceleration (10% in 50 years) [1].

indoors induced many not to leave their houses when some strong shocks occurred a couple of hours before the main one on 3.32 am, 6th of April 2009. This may be considered a substantial modification of the cultural habit "to run in an open area" when a significant shake was felt by the Abruzzi population. This change in ancestral behaviour is interesting but needs to be put in the framework of the local cultural and psychological substrate related to natural phenomena interpretation [9].

3. EARTHQUAKE COMMUNICATION IN ITALY

This problem is germane to scientists who have to communicate the uncertain occurrence probability of a destructive earthquake to the national or local authorities [10]. This process is very difficult. Scientists are focused on hazard. However, disaster reduction is the main object of the communication and not only the description of the hazard itself, which remains largely a scientific datum not usually accounted for by most people, including administrative, political and military bodies. For a vulnerable population and/or goods exposed to geological hazards such as earthquakes, volcanic eruptions and flooding, it is very important to receive correct information as addressed in the recommendation of the Committee on Disaster Research in the Social Sciences. Information based on verifiable facts is thought to be proportional to the evolution of the event and, gradually given, should be consistent, clear and understandable. It has to be designed to match the technological, cultural and even emotional level of the population. It is intended to capture people's awareness, as a possible, about prevention measures without disorientating public opinion and the media. The goal is to enable the public to accept a negative event without under- or overestimating it, in the most effective way to mitigate risk [11]. It must be able to attract attention without generating irrational panic. With regard to the issue of communication around an earthquake, some basic concepts are as not simple as generally thought, and many professional geologists are not clear about the difference between some terms and contribute themselves to generating misunderstandings. Below, are presented and discussed some of the most diffuse lexical ambiguity in communication on the earthquake.

3.1. Intensity and Magnitude

Often there is confusion about the two ways of evalua-

Table 1. Laws and techniques introduced in Italy after strong earthquakes.

earthquake	acts and decrees
● 08 Sept. 1905, Calabria, Mw 7.1, 609 fatal victims	1907: Royal Decree. First rule on concrete-reinforced buildings. Security is considered as a matter of social interest, the buildings had to be accompanied by structural calculations. The safety of the structures is assumed guaranteed if certain rules are observed without prior verification. The structural components must resist to established levels of tension. Structural calculations are introduced to demonstrate the achievement of security in compliance with the allowable stresses of materials. The verification of the materials after the execution of the works is introduced.
● 28 Dec. 1908, Reggio and Messina, Calabria-Sicily, Mw 7.2, 95,000 fatal victims	
● 13 Jen. 1915, Marsica-Abruzzo, Mw 7.0, 30,000 fatal victims	1939: Royal Decree n.2229. Regulations for the execution of simple and reinforced-concrete buildings, testing of materials, introduction of official laboratories, civil engineers as an organ of control. Improves the other previous rules.
● 23 Jul. 1930, Irpinia-Campania, 6.7, 1,425 fatal victims	
● 15 Jan. 1968, Belice valley-Sicily, Mw 6.1, 370 fatal victims	1971: Technical standards on reinforced concrete, pre-compressed concrete and steel buildings. Construction has to be made on the basis of a project. Static testing becomes mandatory, civil engineering projects have to be deposited before the work.
● 06 Feb. 1971, TUSCANIA-Latium, Mw 4.90, 31 fatal victims	
● 14 Jun. 1972, Ancona-Marche, Mw 5.40, no direct victims	1974. Measures for buildings with particular regard to the seismic zones. The rules contain no more prescriptions to follow but they refer to future decrees to be issued in a year.
● 06 May 1976, Friuli, Mw 6.4, 989 fatal victims	
● 23 Nov. 1980, Irpinia-Basilicata, Mw 6.9, 2,914 fatal victims	1996: Ministerial Decree 16/01/1996 Technical Standards for buildings in seismic zones. They regulate all buildings whose safety may be of interest topublic safety. Buildings in: concrete, ordinary and reinforced masonry, mixed structures, panel structures, wooden structures, any alteration action on existing buildings.
● 26 Sept. 1997, Colfiorito-Umbria Mw 6.05, 11 fatal victims	2003 (Ordinance No. 3274). New land classification in 4 seismic zones based on maximum ground acceleration (solid rock). Zone 1 = 0.35 g, zone 2 = 0.25 g, zone 3 = 0.15 g, zone 4 = 0.05 g (non-seismic).
● 31 Oct. 2002 San Giuliano-Molise, Mw 5.8, 28 fatal victims	14/09/2005: Technical standards for construction. (In fact used only for public works) SAFETY ORDER 14/09/2005. Security is always evaluated in probabilistic terms. Concept of use life, period of time in which the structure, subject to routine maintenance, should be used for its intended purpose.
● 06 Apr. 2009, Aquila-Abruzzo, Mw 6.2, 307 fatal victims	14/01/2008: New technical standards for construction in force from 05/03/2008 to 30/06/2010 extended to 01/07/2009 for anticipated seismic event. Define the principles for the design, construction and testing of construction with regard to performance requirements in terms of mechanical strength and stability, even in case of fire, and durability. All new building category and materials. 05/02/2009 Explanatory Circular No. 617 defines local seismic hazard- and seism-resistant characteristics of the buildings. Nominal life of the building has to be declared. About pre-existing buildings (Art. 8 DM 14/01/2008), requires construction history and details, geometry, uniformity and quality of materials used, load, and should be subject to verification of the resistance to environmental action, construction errors, change of use, and the potential to achieve the level of safety by alterations. Improvements are structural safety measure applications, and many others.

ting an earthquake: intensity and magnitude. Also, the different intensity and magnitude scales are confusing for the public. Intensity is evaluated by increasing degrees of the Mercalli-Cancani-Sieberg Scale (MCS, 1930) or similar scales (*i.e.* Rossi-Forel, Medvedev-Sponheuer-Karnik, Shindo and Liedu). Intensity scales describe the average effects on people, environment and buildings in a given geographical locality. Intensity depends on ground-shaking motion and generally decreases with distance from the epicentre, but it also depends on effects due to local geological features, the materials used in buildings, the quality of those materials, and building design. Magnitude is a semi-quantitative measure of the energy or size of the earthquake at the source. The magnitude remains the same regardless of the distance from the epicentre but can be estimated in various ways. The Richter magnitude (Ml) is based on the maximum amplitude recorded by a Wood-Anderson seismograph, located within a conventional distance from the epicentre [12]. Each 10-fold increase in the amplitude of seismic waves with a frequency of about 1 Hz corresponds to an increase of one unit of magnitude. On the other hand, the moment magnitude (Mw) is related to the earthquake rupture (fault area, fault dislocation) and the elastic shear modulus of the rocks in the source region. Each increase of one order of magnitude implies an increase in energy of about 30 times greater. This makes the total amount of energy released by foreshocks and aftershocks negligible compared to a high-magnitude (>6.5) main event in which most of the energy is released. In Italy, the epicentral damage threshold is considered to be M 5.5, but even lower M has caused loss of numerous human lives and

Figure 2. Damage in concrete-reinforced buildings at L'Aquila, 2009 Earthquake (photo F. Stoppa).

extensive damage, *i.e.* the Tuscania earthquakes of 1971, Mw 4.9 (**Table 1**).

3.2. Hazard and Risk

The deterministic methods (Deterministic Seismic Hazard Analysis acr. DSHA) calculate the values of ground motions expected as a result of an earthquake of reference, usually the largest earthquake magnitude of all the considered faults/sources in the region, which supersedes all the smaller magnitudes and is most impactful for the site/area for all the time established for the area surrounding the site investigation. A deterministic approach is not actually used in Italy or in many countries today, for various reasons, even though it is the traditional method still used in California [13,14]. The probabilistic approach (Probabilistic Seismic Hazard Analysis, acr. PSHA) tries to approximate ground shaking produced by various earthquake sources. The assumptions are that earthquakes occur randomly in time, that the likelihood of occurrence within a given area is the same at every point, and that combining magnitudes by mathematical integration is physically meaningful for defining hazard. On the whole, PSHA focuses on how often a chosen threshold earthquake will occur, while DSHA focuses on how large the next credible earthquake will be, but not when it will occur. Risk is a concept that links the hazard (translated in Italian as *pericolosità*) to the value as well as the vulnerability of property and human lives exposed to that hazard. Of the three parameters that contribute substantially to the risk, we can take action only on vulnerability because we cannot efficiently decrease the value exposed and we certainly cannot change the hazard implicit in the geological nature of an area. Notably, a low hazard in a vulnerable populated area can correspond to a big risk. When an earthquake occurs, the consequence is that structures (buildings, bridges, industrial plants, dams etc.) are subjected to shaking and may be damaged or collapse. If they are designed or reinforced to withstand that force, the structure will perform well and so structural vulnerability can be reduced [15]. However, ground failure by liquefaction or deformation cannot be eliminated and is a serious problem for new residential and trade areas built on alluvial soils (e.g. the case of Emilia Earthquake of 2012). Thus, it is equally important to know which structures may experience failure because they are not specially reinforced or have other vulnerabilities. In fact, risk is never zero in populated areas. If structural vulnerability cannot be reduced efficiently, then it is important to inform the population about the possible occurrence of an earthquake.

3.3. Prediction and Prevision

The prediction of an earthquake is the act of announcing in advance the place, date and time of occurrence of a future event. In the Italian language, this term (*predizione*) is tied to the inspirations of a supernatural phenolmenon or clairvoyance. In many cases a prediction is linked to a prophecy. However, due to the influence of the English term "prediction", the word is now ambiguously used to indicate a forecast based on scientific calculations which in Italian should be called "prevision", i.e. *previsioni meteorologiche* = "weather forecasts" and not *predizioni meteorologiche*. The prediction of earthquakes is based on a series of assessments related to 1) the seismic history of the area; 2) its geological structure (probabilistic prediction); 3) specific distributions of energy released; 4) the number of events; 5) their position in the seismic-genetic structure (deterministic prediction); and 6) the presence of seismic precursors. Predictions suffer a lot of limitations and approximation depends on purpose and subjectivity, and varies with type of research, application, experience and judgment. Points 1 and 2, historical information is often lacunose; many active seism-genetic structures are hidden underground or undetected before they became active. Points 3, 4 and 5, the Gutenberg-Richter equation, could be built on inadequate data: the geometry and size of a fault could be unknown. Point 6, the significance of specific precursors, such as radon and other gases, and electromagnetic phenomena is heavily under debate or has not

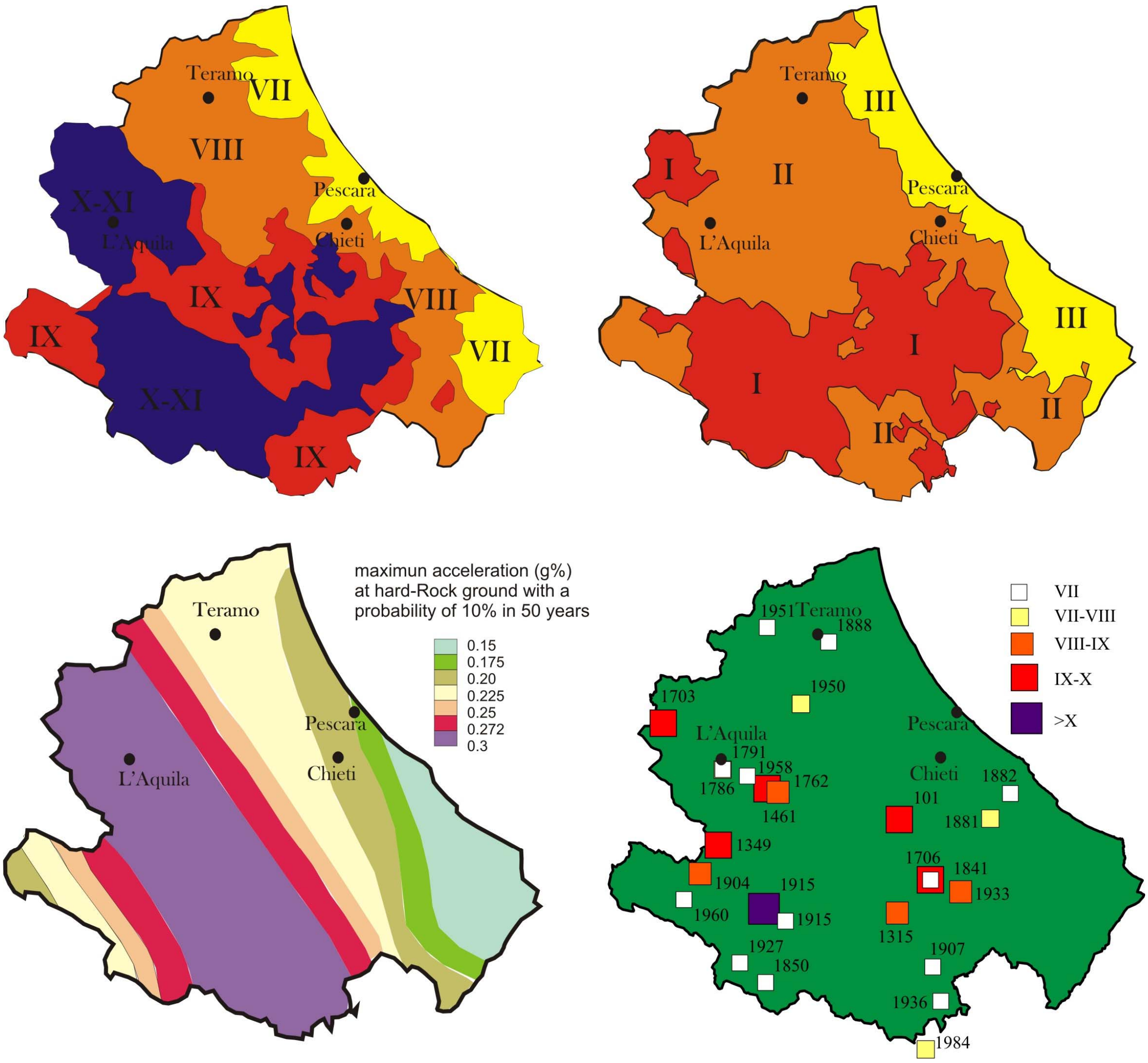

Figure 3. Maximum intensity felt during historical earthquakes in Abruzzi in terms of MCS scale (top left), classification of Abruzzi in terms of seismic category (top right), hazard distribution in terms of hard-rock ground acceleration expressed in g% expected in 50 years with 10% probability (bottom left), epicentres of historical earthquakes above the damage threshold (bottom right) [1].

been well studied by the scientific community, and its adoption may generate some confusion at this point due to inaccuracy, uncertainty and variation.

3.4. Alert and Alarm

We basically have to realise and make clear that alarm is a sudden loud announcement intended to attract attention to an event that is unlikely to occur and for which there is not a clear estimation of its risk. The Italian Penal Code, Article 658, says that "Anyone who announces disasters, accidents or non-existent dangers, raises the alarm with the authorities, or with institutions or persons exercising a public service, shall be punished by imprisonment up to six months or a fine of between 10 to 516€".

An alert is based on gradual objective information about threat, and its function is to increase the awareness of citizens and institutions to allow them to put in place measures proportional to the alert degree so as to decrease the risk in the long and short term. Unfortunately, in a society not culturally prepared to accept natural hazards, many people confuse the benefits of alert with paralyzing scaremongering. In this regard, it would be good to clarify the different meanings of the two words which are commonly used not in a proper way.

3.5. Risk Management

For a simple understanding of the factors that constitute risk it is worth recalling the fable of the "Three Little

Pigs"—a simple example that can be used for people at large and children first. In this fable, the wolf is the hazard, the construction materials of the piglets' houses and their behaviour are the vulnerability, and the endangered value is the homes and the lives of the piglets. Many ideas can be considered for risk reduction, but a substantial reduction is always linked to vulnerability. The wolf's desire to eat the piglets is unchangeably implicit in its nature; the houses already exist and the piglets' behaviour can only be modified when they know about their houses' weakness. In fact, the piglets run to and shut themselves in the brick house, which is able to withstand the mighty breath of the wolf, and thus they survive without any other damage beyond losing their straw and wooden houses. An acceptable price. There are some cases in which action can be taken, though controversial, the hazard. A case history could be the attempt to divert lava flows issued by the Etna volcano in Sicily. The long-lasting eruption in 1983 occurred with the emission of 100 million cubic metres of lava, destroying the Etna cable car and sports facilities. The eruption appeared to be quite unpredictable, with many lava tunnels and the emergence of lava flowing downstream, which brought fear to the outskirt towns of Ragalna, Belpasso and Nicolosi. This attempt generated much controversy and disagreement among scientists. After previous failed attempts to block the lava by dropping large concrete Friesian horses from helicopters into 'pit falls' of the lava tunnels, dozens and dozens of stoves to allow the explosive charges to enter the lava flow banks were applied with considerable difficulty given the high temperatures that managed to ruin the drill bits. The flow was partially diverted but the eruption ceased shortly after anyway. The cost of the operation was about 30 billion Italian lire. The lives of many military personnel were put in serious jeopardy. The endangered value was much lower than the 30 billion spent, and the scientific meaning of the lava detour was much less than the lives of the Explosive Ordnance Disposal personnel and the helicopters that were severely endangered during operations. Many felt this was an unacceptable price. Beyond this, it seems conceptually wrong to try to act on the hazard since the risk was not significantly reduced, while the money spent could have been used to decrease the systemic vulnerability of the area by possibly relocating some home properties at a higher level.

4. PSYCOLOGICAL ASPECTS OF RISK MITIGATION

4.1. Theoretical Model about Attitudes and Behaviours

Much of the planning and preparation for earthquake mitigation is done by seismologists, geologists, engineers, architects and public officials. Once the threat of an earthquake is established, these experts must try to obtain broader community support for programmes and projects. In this context, each choice may represent a compromise (compared to the maximum technically possible standard of seismic mitigation), considering both the constraints and supports of the context in which the decision-making process occurs. Public support for any new policy is critical; therefore, examination of citizens' attitudes toward earthquake risk reduction actions in the context of their perception of the earthquake risk should assist policymakers in obtaining public support and designing an effective risk management and information programme [16]. It has long been recognized that it is psychological elements which guide people's responses to a particular hazard rather than the estimates provided by experts. For this reason, knowledge of the psychological mechanism of risk perception and the factors contributing to the generally low level of earthquake preparedness that have been found among residents living in regions that experience high levels of earthquake activity [17-19] may help those who design and target preparedness interventions. The literature on risk perception and communication suggests that there are a number of reasons why health warnings are often not heeded or acted upon by the public [20]. These include message features (ambiguity of risk information or the actions needed to overcome risk), poor communicator abilities, personal characteristics of the audience (prior experiences, personality traits, cognitive biases, attitudes toward personal vulnerability, distrust of authorities), and social influences through the media and informal social networks [20-22]. In particular, [23,24] has consistently demonstrated that there are many factors that influence the perception of risk—among them, the salience of risk issues, the information provided by the mass media and the way in which they are presented. These factors, and whether a risk is perceived to be involuntary, potentially catastrophic or uncontrolled, are more important determinants of public response than the risk estimates provided by experts. Psychological research has also indicated the particular importance of approach in risk perception. If, in some cases, heuristics can simplify the mental operations, sometimes they can lead to systematic errors with serious implications for risk assessment and decision making. The systematic errors in the assessment of risk are often accompanied by a lack of willingness of individuals to question their own judgements. The interpretative paradigm in the psychology of risk perception allows, for those who plan general strategies for preventive intervention, some of the factors that regulate the response to psychological risk factors and the decision to implement preventive measures to be known. The way people perceive the risk of an earthquake influences their preparation for the event. In general, the probability of adopting preventive behaviour depends on both the perception of the probability that a given event will occur and an assessment of the severity of the event. According to the Health Belief Model [25], the probability that a person will adopt preventive measures depends on the perception of vulnerability and the severity of the threat, so the subject could have a realistic perception of a threat, but underestimate the personal risk. In the Theory of Planned Behaviour [26], a person's readiness to behave in a given way depends on attitude toward the behaviour, subjective norms and the perceived behavioural control. It refers to people's perceptions of their ability to perform a given behaviour. In general, all these models emphasize the role of attitudes and beliefs in determining behaviour. Control beliefs have to do with the perceived presence of factors that may facilitate or impede manner of behaviour. The issue of control seems to be crucial for understanding behaviours in the face of risks. For example, [27,28] proposed that individuals experiencing an external threat are likely to take action to reduce the threat, but only if they see the event as controllable. If the threat is seen as uncontrollable, people are more likely to resort to other means of coping, including cognitive avoidance and denial. Extrapolating this view to earthquake preparation, several researchers have found that people who live in earthquake-prone areas tend to deny and minimize the seriousness of earthquake risk when they believe that little can be done to mitigate the danger [26]. Even if unrealistic optimism could be positively adaptive, producing positive mental health effects [29], the denial of danger can lead people to ignore risks and not to adopt measures for risk mitigation [30]. In line with these empirical evidences and theoretical models, the risk communication field has gradually changed and moved from expecting that providing the public with clear information about risk was all that was needed for action to occur, to a recognition that adoption requires greater attention to these personal and social factors [31]. There has been an acknowledgement that telling people about health and environmental dangers is not likely to lead to risk-reducing behaviours without attention to social influences and the reasons why people are motivated to ignore or minimize threatening messages.

4.2. Improving Social Trust and Public Support for Earthquake Mitigation Model about Attitudes and Behaviour

Theoretical models and research on perception and social representation of risk thus indicate the need for an approach that combines direct and objective assessment of risk factors by incorporating the psycho-social processes in judging hazard and all the factors that influence the formation of behavioural intentions. In contrast, an approach focused only on objective hazard factors is inadequate when the phenomena involve human decisions. Despite the importance of the contribution of research on psychological mechanisms of risk, according to [32] it is important not to reify the concept of risk perception as an explanatory construct in a way that does not take into account other factors which should be incorporated into theoretical models used to explain public responses, such as ethical concerns, trust and distrust (in science, scientific institutions, risk regulators and information providers) and perceptions of social exclusion from risk management processes. Public trust in science and scientific institutions has not only declined in Italy since the 1950s [32]. This cultural shift in public attitudes towards science and technology has its roots in safety and risk: people question the extent and the impact on the natural world order and express a preference for societal decisions which favour risk aversion. According to [31], this is "partly due to increased economic affluence and educational level allowing people to develop the confidence to question the appropriateness of scientific development, and to demand increased democratization of scientific processes" (p. 569). With regard to public support and engagement in earthquake risk mitigation, trust in institutions and information sources may be as important as risk communication in determining public responses. Consideration of the extent to which a source is trusted or distrusted is very important if people's attitudes are not yet crystallized, as this information may influence the direction of attitude change. Source effects are likely to be more important for environmental hazards, where people perceive that they have very little personal control over exposure to the hazard. Increasing transparency in risk management processes, and the need to improve public trust, is likely to increase public participation in risk management itself [16]. Reference [33] specified some criteria for benchmarking the effectiveness of public participation exercises, which fall into two categories: acceptance criteria (related to public acceptance of a procedure) and process criteria (related to the effective construction and implementation of a procedure). Acceptance criteria include the criterion of representativeness, which addresses the need for participants to be representative of the broader public, rather than some groups the criterion of independence which addresses the need for unbiased management of the participation process the criterion of early involvement which refers to the stage at which the public should be involved in policy matters the criterion influence which implies that the output should have a genuine impact on policy and the criterion of transparency which implies that the wider public can see what is going on and how decisions are being made. Process criteria refer to resource accessibility, task definition, structured decision making and cost-effectiveness. Operationalizing these criteria will ensure the evaluation of a procedure and compare the effectiveness of different procedures at different times and in different situations. There are evidences that increased efforts to involve the public in the risk management process are likely to be the best way to address issues associated with perceptions of social exclusion and to obtain public support for earthquake mitigation programs [32]. What has been learned from public health campaigns is that while media campaigns often influence the topics that receive attention in group discussions, how people actually behave depends more on informal social influence and interpersonal factors than on the content of media messages. Panel data collected in I991 as part of the University of Southern California Longitudinal Study of Generations (LSOG) were used to predict reported preparation activities prior to and in response to the 1994 Northridge, California, earthquake. With regard to earthquake preparation activity, the results highlight that actual preparation practices depend more on interpersonal factors, such as the frequency with which earthquake preparation is encouraged or discouraged by network members [34]. While media messages are important sources of information about what needs to be done, organizing informal networks for action follow-ups has been found to be an important step in promoting and reinforcing adoption of new behaviours. That lesson was learned in a number of health campaigns [35-37] and applies as well to earthquake preparation. A community should familiarize themselves with the adoption of a protocol. The adoption should also be based on a participatory process aimed at developing disaster-resistant community and inspired by the principles set out in Section 4.2

5. SCENARIO OF ALERT DEGREES

The choice of actions to be taken by authorities during a pre-earthquake emergency, as well as deciding when to begin the emergency itself, must be guided by an objective process related to the study of an agreed-upon protocol for action and communication phases. The scenario of alert degrees cannot derive directly from authoritative seismic classification of the administrative territory which is influenced by political and economic bias vs. research project (**Figure 3**). The national seismic hazard map (**Figure 1(c)**) is relatively intractable, and often more maps for different applications are needed. It is standardized on hard rock with a maximum peak ground acceleration (PGA) of only 0.3 g for Zone 1 and thus must be adjusted for engineering and local seismic response. Map developers are not responsible if an earthquake exceeds predicted parameters and, most importantly, emphasize how often or when an earthquake may occur instead of how big the earthquake will be. Large earthquakes may occur in the absence of notable precursors, even if this is very unlikely [38,39]. Due to the variability of preparation signs of an impending earthquake, geological as well as seismological models have often been proven to be inadequate and a principle of caution must always be adopted. This cognitive action takes the form of active and democratic participation of all socio-economic and cultural components by communication, decision making and organization so as to mitigate the risk by reducing vulnerability. The economic cost of prevention is relevant but the benefits are immense in the case of damaging/destructive/catastrophic earthquakes. Political leaders or decision makers have to be convinced that what seems to be an improbable event may occur at any moment, producing a devastating/catastrophic effect. The population has to be prepared to consider anti-seismic measures and the application of protocols as a social priority. It is thought that a scientific committee has to issue hazard evaluation, however probabilistic methods adopted in Italy do not consider rapid variation of precursors though too problematic to define/identify. If the national commission or local regional scientific committee has to express its opinions, this should be done in real time. Constantly following the event recordings will make it possible to pass from one level of an alert to another. This seems unlikely and some "impersonal" automatism is needed. In this paper, we illustrate some possible measures designed for risk mitigation through gradual evaluation of preparing for a potential earthquake in four alert stages. Progressive passage from one level of alert to another, up to the main event, is established and represented by the colours green, yellow, orange and red (**Tables 2-5**). Note that the importance of measures taken from the green level to the red decreases as a function of the time available to achieve them. The progression may not be regular in some cases and passing to a higher level is not indicative of definite progression to the next one. It is also possible to come back from red alert to green alert and vice versa. The costs in terms of loss of income are inversely proportional to the colour scale in cases of non-earthquake. So it is valuable because only red measures will produce a relevant loss of income in the case of non-earthquake. The factors uses in preparing this protocol could be considered somewhat empirical and superficial if related solely to hazard. However, at the scale of risk considered here, they are very efficient if applied correctly. They have to be adapted to the local situation, taking into account the general lines expressed in Section 4. We are aware that most people will consider this protocol simplistic but it is intended to stimulate discussion about its necessity and, hopefully, it could be improved in the near future about attitudes and behaviours**.**

Table 2. Green (no alert).

	Conditions (one or more)
a.	● Area already classified as seismic by historical, geological or whatever else evidence of past relevant seismicity. ● Probabilistically earthquakes expected in the medium- and long-term period (10 - 50 years). ● Area in a defined seismic box. ● Maximum earthquake and risk scenario known.
b.	● Specific studies indicate that probabilistic approach could be optimistic. ● Local geology implies relevant site effect of amplification. ● There are facts which suggest increased risk, for example other natural or anthropic hazards have been detected. ● Some specific vulnerability has been detected.
	What to do (public)
a.	● Structures have to be adapted to current local hazard category and/or to withstand current codified peak ground acceleration, etc. ● Supplementary measures have to be taken according to the seismic microzonation (site effect). ● Structures and infrastructure (bridges, embankments, tunnels, etc.) have to be checked and reinforced. ● The use of geologically hazardous areas (landslides, faults, escarpments, liquefiable soils, etc.) for 'human occupancy' structures has to be prohibited. ● A clear zone around dangerous industry and dams has to be established. ● "Critical" buildings: hospitals and public offices, schools and colleges, sports facilities and recreational places, cinemas and theatres, hotels, etc have to be checked and improved for public safety. Some of these are planned to be suitably converted into refugee shelters. ● Scholars and employees in schools, museums and other public buildings, commercial centres and major industries should be given training. ● Clear instruction on how to behave and response to an emergency has to be disseminated. ● Monumental heritage has to be reinforced. ● Suspended and heavy elements have to be secured in offices and public buildings (e.g. museums, churches). ● New installation of dangerous critical facilities like nuclear power plants, chemical plants and oil industry etc be prohibited, ● Public announcement should not necessarily be issued.
b.	● The procedure indicated in green "a" has to be made more efficient and rapid. ● More restrictive use of particularly vulnerable areas has to be established. ● A specific communication has to be designed to stimulate citizens to take supplementary measures to those in "a". ● The specific formation of civil defence structure and of volunteers has to be intensified.
	What to do (private)
a. = b.	● Learn what the precursors of an earthquake are and what the seismic history of the place where you live is. ● Learn how to behave and act before, during and after an earthquake. ● Check 1) whether your home or office is earthquake-proof; 2) whether the structure can withstand earthquake impact without collapsing *i.e.* the maximum stress expected in that place; 3) if it has structural weaknesses or failures; and 4) if it is equipped with safety equipments. ● Check whether the foundation soil is solid (solid rock) or inconsistent (loose soil soaked in water). ● See whether you may be exposed to landslides and any kind of floods triggered by earthquake such as, dam failure, river dam breakage, and lake and sea tsunamis. ● Whether the building is in an area at risk of landslide or flood, is founded on liquefiable soils and is not earthquake-proof, consider seriously moving to a higher level or safer area. ● Do social activism and participate in first aid and other safety training.

5.1. Green (No Alert)

Conditions used to assess the green level (**Table 2**) are largely based on general geology and seismicity (paleoseismology, permanent fault displacement, earthquake recurrence, earthquake probability, calculated ground motion acceleration) of an area used to construct earthquake hazard maps. Problems may arise from incomplete numbers and type of active faults, their dip, width and slip rate which may still not be completely available at this level. Action to undertake is different but relates to engineering and land use associated with risk evaluation, aimed at reducing future damage and at general public safety. In preparing critical structures (bridges, schools, hospitals etc.) it is necessary to incorporate site response and design spectrum shape/level as a function of maximum credible earthquake magnitude. As a conservative criterion, the geographical distribution of the alert should be related to the peak acceleration produced by the nearest maximum credible earthquake and consideration of the local effect and seismic propagation.

5.2. Yellow (Alert Preparation)

Conditions used to assess the yellow level (**Table 3**) imply a revision and update of general information made available on the green level of the local seismicity and geology which incorporates new information and knowledge from ongoing local seismicity. Emerging new technology should be used to update local knowledge on Late Quaternary faults (active-dormant). Dip, width and type of these faults have to be thoroughly analysed and also deep-seated or blind faults may be discovered or hypothesized. Refine magnitude estimates using regional empirical fault parameter-magnitude relationships. Use both empirical data and simulated ground motion esti-

Table 3. Yellow (alert preparation).

	Conditions (one or more)
a. b.	● High probability of earthquakes in 5 - 10 years, micro-seismicity in the box. ● Discontinuous seismic swarms lasting months or years. ● Any indication of precursors "a". ● New data about increased hazard or risk with respect to "a".
	What to do (public)
(a = b)	● Efficiency of response to evacuation plans has to be checked frequently. ● Emergency phone numbers of principals, volunteers, associations etc. have to be disseminated. ● Emergency training has to be intensified. ● Ad hoc area access and evacuation ways have to be established and permanently indicated by signs, a quick information system and alternative ways (via mobile phones, permanent or mobile loudspeakers, mails, radio and televisions). ● Future tent location areas have to be equipped and refurbished. ● Suitable facilities for shelters, vital and food supplies etc. have to be identified. ● Contingency plans have to be displayed in large public facilities. ● Communicate the status of pre-warning: "It is likely that over a period of several months or years a stronger earthquake shock may occur; let us organize according to the protocols previously distributed."
	What to do (private)
(a = b)	● Study and share a common plan with your family, adapt it to different situations, home, school, work, day/night. ● Establish a safer place to stay during an earthquake, an escape route, a meeting point near your home or another place in which to converge automatically if family members are separated. ● Check that the workplace and school emergency services are efficient and carry out regular and effective training. ● Make social activism because the authorities draw up contingency plans and means of warning and civil protection.

Table 4. Orange (pre-alert).

	Conditions (one or more)
a. b.	● Frequent discrete swarms of low-magnitude events, some are felt, plus some felt shocks (M between 3 and 4) in the seismic box for weeks or days, the population is alarmed. ● Any escalation in suspected precursors "a", including stronger M shakes, or new data about increased hazard or risk with respect to "a". The presence of some other suspected precursor is significant and the alert degree should pass to level b, and should not be reduced even if precursors diminish for a short period. What to do (public).
	What to do (public)
a = b	● Public buildings which are unsafe for providing alternative locations (schools, etc.) have to be evacuated. ● The level of reservoirs has to be within safe limits. ● Activities involving the arrival from outside of sporting events, conventions, fairs, elections, etc. have to be suspended or delayed. ● Efficiency and safety measures have to be tested for water, gas pipelines, power lines, overpasses, etc. ● First aid and water/food supply have to be accumulated in safe and accessible sites. ● Communicate that: "It is possible that within some weeks or months a strong shock or very strong earthquake may occur; let us organize according to the protocols previously distributed."
	What to do (private)
	● Secure the premises where you stay or work and devote particular care to the place where your children play or study. ● Sleep in a safer area of the house. ● Look around to find heavy and/or sharp objects that might fall on you or explode or cause fire or flooding, such as furniture, ornaments, lamps, mirrors, appliances, water heaters, boilers, tanks, etc. Remove them from the area where you sleep or stay and fix them firmly, including pipes and electrical wiring. ● Switch off gas and electricity installations if not in use. ● Learn to communicate via emergency phone numbers by only giving necessary information without clogging the lines with unnecessary comments.

mates for continuity and confidence in practice. When in doubt, stay on the conservative side and avoid over analyses. Maximum credible earthquake should be used as a starting source model for ground motion simulations. New specific attenuation curves have to be prepared. Action to undertake relates to evaluation of usefulness and effectiveness of the structural resistance of crucial facilities. Most of the actions adopted in the yellow alert level are germane to land and social governance and are mostly long-term bias measures.

GIS technology can be used to program management of an emergency both before and after the earthquake. Complementary tasks are assigned equally to the public sector and private citizens. There is considerable time to carry out the measures that should be provided for yellow level while it is uncertain.

5.3. Orange (Pre-Alert)

Conditions used to assess orange alert (**Table 4**) imply an increase in the seismic activity and presence of other precursors. Additionally, "a" and "b" subcategories could be introduced. In fact, "b" factors and/or precursors can

Table 5. Red (alert).

	Conditions (one or more)
	● Some widely felt shocks (M ≥ 4) in a week, rapid increase in seismic energy release in the box, significant increase in seismicity rate r (events/day), clustering of foci and decrease/change in b-value [40]. ● Seismic pause. ● The possible presence of other precursors: radon and/or geophysical and geochemical anomalies and/or ground deformation and/or greenhouse gas and/or turbidity and changes in the level of water in the wells. These phenomena may or may not be present; if present they are very significant, if not present they do not decrease the alarm degree.
	What to do (public)
"a = b"	● The state of alert has to go to full level. ● Shows and markets have to move to open-air locations or completely safe buildings. ● Gatherings indoors (churches, theatres, stadiums, sports arenas, etc.) have to be avoided. ● Schools have to be closed, hazardous industrial activities close or reduce activity. ● Support staff has to be alerted. ● A network of emergency communications has to be established. ● Procedures of public emergency have to be established. ● Shelters have to be prepared. ● Communicate that: "It is possible that in a few days time a ruinous or disastrous earthquake shock may occur; let us organize according to the protocols previously distributed."
	What to do (private)
	● Prepare an emergency box and keep it in a safe and accessible place, for example your car parked away from falling objects: it must contain not only basic necessities such as blankets, canned food, water, medicines, money, first aid, flashlights, but also a crowbar, large shears, a fire extinguisher, a pickaxe, gloves and emergency signals, etc. ● In case of a strong shake, be vigilant and careful, do not scream, huddle under protection (table, bed, etc.) near you if you cannot reach a safer place. Outside be extremely cautious about falling masonry. Identify sources of danger. ● Wait until the shock has ceased and carefully exit to open space, paying attention to elements that can collapse, such as walls, balcony, cables and gas leaks. ● Do not use or approach elevators and watch out for floors and stairs that have collapsed especially in the dark. ● Do not try to turn on lights or open flames. Protect your mouth and nose with a cloth to avoid inhaling dust. ● Help those in trouble and calm those who are panicking.

be present or not present, can be recorded or not recorded, being less predictable, and passage to "b" is not required to go to the next level.

Problem is the uncertainty about whether a near destructive earthquake may occur or not.

Action to undertake relates to evaluation of usefulness and effectiveness of social protection measures including emergency management, insurance and evacuation. The population is consistently instructed about how to behave.

5.4. Red (Alert)

Conditions used to assess red alert (**Table 5**) imply increased specific preparation signals [40] and change of physical parameters and presence of other precursors. Their study is worthwhile with a proportional effort from the scientific community, even if it has been noted that long-term prevention is more effective.

Problem in communication is due to previous insufficient information. The size of evacuation and numbers of refugees are a measure of lack of previous mitigation action. Action to undertake relates to evacuation from unsafe structures and inhibition of any activity that could increase the vulnerability. Special safety is adopted. The population should know that any infringement in taken at its own risk.

6. CONCLUSION

The L'Aquila earthquake of 6 April 2009, and its disastrous consequences, has stimulated many minds to a review process of forecasting methods and assessment of risk in Italy and elsewhere. It is now clear that in many civilized countries prevention measures are applied only to a fraction of what can be done, as many old structures cannot be successfully converted to anti-seismic structures and land modification costs are too high and economically and culturally unrealistic. This fact suggests that only proper preparation and communication based on sound forecasting methods can be used to mitigate the risk through the reduction of social vulnerability. The analysis of the Italian situation, extendable to many other countries, allows us to state that the success of risk mitigation measures is not directly related to hazard evaluation. However, a merely probabilistic approach may be too optimistic, and some deterministic tightening is necessary to adapt to high-hazard analysis of the systemic vulnerability of Italian cities. Hazard evaluation methods and anti-seismic norms seem inappropriate to the situation of Italian buildings since many concrete-reinforced buildings totally collapsed during the earthquake of moderate magnitude at L'Aquila, claiming an extremely high number of fatalities. Social vulnerability mitigation and disaster-resilient communities depend very much on interpretation of communication issued, based not only on hazard and risk assessment but also on common sense and, even, on irrational behaviour produced by social representation. A too optimistic communication issued to avoid panic as well as repeated unnecessary alarms increase vulnerability. Even if necessary, it is not enough to try to influence risk perceptions through a proper communication alone; increasing public trust in the risk management process is crucial if effective policy about risk management should be developed. Independently from the seismic classification of the territory, an alert protocol should be adopted and conservative communication should be issued if an evolution of increased seismicity of the area is seen or even only feared. An efficient protocol has to fill the gap between scientific data and people's psychological and cultural sensibility and interpretation. Appropriate communication associated with the use of a protocol has the task of stimulating beneficial progressive alert, allowing people to take additional personal safety measures

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