Resilience Against Earthquakes: Some Practical Suggestions for Planners and Managers

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ABSTRACT

This paper offers a working definition of resilience and associated concepts, including vulnerability to earthquakes, coping, capacity and redundancy. It concludes that resilience must be set in motion and maintained by a collective effort that involves all stakeholders and people who are at risk. The paper offers ten suggestions for action in order to create a methodology for resilience against earthquakes. They are as follows. Tell people what to do in an earthquake. Develop urban search and rescue capacity on site. Reduce non-structural as well as structural hazards. Plan flexibly and make emergency planning a process, not an end. Create networks that can improve the exchange of knowledge, information and training. Encourage governance by involving different stakeholders in earthquake disaster risk reduction. Make good practice proliferate and adapt it to local circumstances. Ensure that programmes of disaster risk reduction are sustainable in the long term. Before the next major seismic event occurs, create a strategy for recovering from it. Create a culture of resilience against earthquakes, in which the problem is widely understood and taken seriously by people who are at risk or are in positions of authority.

Keywords:
Earthquakes;
Resilience; Disasters;
Injury prevention;
Damage reduction

1. Introduction

1.1. On the Definition of Terms

The term resilience, or resiliency, had its origins in developments about a century ago in the field of mechanics and materials testing [1]. A resilient material has enough rigidity to resist an applied force and also sufficient flexibility to absorb part of the stress. The concept was taken up in the 1960s by ecologists [2] and later by psychologists [3]. In the 2000s, it began to be widely applied to the field of disaster risk reduction (*DRR*). By analogy with mechanics, a resilient society is one that is simultaneously able to resist the impact of disasters (i.e. avoid a certain amount of harm and damage) and absorb it by adapting to the hazard [4].

Resilience in *DRR* interacts with the concepts of coping, capacity and capability [5]. A society that is resilient to hazards has developed its ability to cope with them. This involves both direct prior preparedness and setting aside resources against future losses (i.e. capacity). Formally, the latter can be achieved by insurance (the maintenance of a pool of money to reimburse people who suffer loss) and by creating redundancy, the provision of duplicate resources, services and procedures [6]. As redundancy is expensive, and because it can tie up resources that are seldom used, it is not usually one of the favoured options, but when a major event takes place it can become a very precious safeguard.

The sum of resilience, coping and capacity is the inverse of vulnerability [7]. In the present context, this refers to the propensity of human socio-economic systems to suffer harm as a result of major hazards. Vulnerability is the dominant component of risk and both are difficult to measure because they are innate phenomena. Like friction, vulnerability is only mobilised when a hazard strikes. By the time it is recognised and can be investigated, it has already become impact, its post hoc form. In disaster research, there is a developing consensus that the protection of lives and livelihoods (i.e. gainful employment) is the key to reducing vulnerability and increasing resilience [8]. It has also become apparent that vulnerability is composed of many factors, as summarised in Figure (1). The components interact and influence each other.

2. The "What?" and "How?" of Resilience

The axiom that "resilience is needed against earthquakes" requires qualification in order to ensure that it does not lead to an indiscriminate approach. Priorities need to be established so that resources are not wasted. In general terms, these should be to reduce loss of life, care for the injured, limit damage and provide conditions for rapid and effective recovery, including the timely provision of shelter to people who have lost their homes. Given the propensity of earthquakes to cause mass fatalities [9], the largest emphasis should be given to effective (including cost-effective) measures to reduce loss of life. In this context, resilience must be created and maintained by collective effort. All members of society are stakeholders, and all should be involved in the process of making conditions safer. This requires mechanisms of consultation and social inclusion, which thus contribute to the process of governance, government by active consensus [10].

As building collapse is widely known to be the principal cause of death and injury in earthquakes, it follows logically that one of the greatest strategic priorities should be to make buildings less susceptible to catastrophic damage by enforcing good building codes, retrofitting pre-code buildings and banning unsafe development [11]. Note, however, that non-structural damage within and around buildings is an important secondary source of injury [12].

Specialised search and rescue are likely to be in short supply during a major seismic event. However, little is known about the impact of this on rates of survival in collapsed buildings, except that it is potentially high [13]. Moreover, little is known about the impact of immediate response by untrained, unequipped people, who are often the only ones on

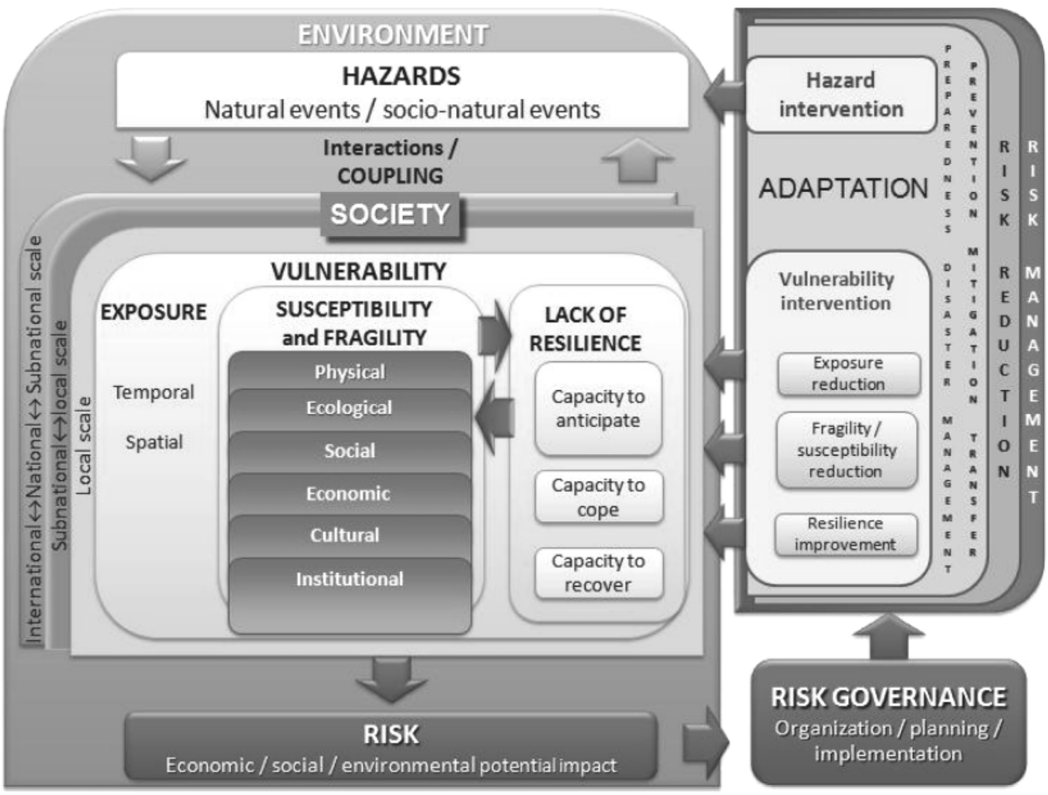

Figure 1. An explanatory classification of vulnerability to hazards and disasters. Source: MOVE Project, www.move-fp7.eu.

site when rescue is needed. Evidence from the Mexico City earthquake of 1985 suggests that amateur rescue in collapsed buildings can be highly dangerous [14], unless it is complemented by training and the provision of safety equipment.

Resilience means a safe environment, but if it cannot be achieved in any reasonable future time period, people should at least be encouraged to learn self-protective modes of behaviour.

3. A Strategy to Encourage Self-Protective Behaviour in Earthquakes

If buildings cannot be made safe enough to withstand earthquakes, can occupant behaviour be modified in such a way as to minimise the risks of being crushed or entrapped when a disaster occurs? Unfortunately, despite decades of research on the epidemiology of earthquakes, there is still a lack of knowledge of types of injury in relation to patterns of building collapse and occupant behaviour, and thus of risk factors in particular situations [e.g. 15]. Nevertheless, it would be useful to develop a methodology that will form the basis of a strategy to react better to earthquakes when they occur.

The first step is to know the level of seismic risk and what it is capable of doing. This involves predicting magnitudes, recurrence intervals, maximum accelerations of the ground and other variables that influence the performance of buildings and structures. It also involves developing an understanding of the seismic performance of typical buildings in the local area. In many architectural environments, this may be relatively easy to achieve at a basic level. For instance, the L'Aquila earthquake of 6 April 2009 in central Italy led to characteristic patterns of damage to vernacular housing that involved only two main types of building: one in stone masonry and one in reinforced concrete [16]. An example of how lack of stiffness in a frame structure leads to a concentration on mid-floor damage is given in Figure (2).

The second step is to create scenarios of impact and damage and relate them to patterns of human activity and occupancy of buildings and built environments that are at risk from seismic events. There are essentially five levels of risk to people, in relation to seismic damage levels.

1. Damage level: [1] minimum damage to walls, fitments and furniture.
   Personal risk level: prudent behaviour will minimise risks.
2. Damage level: [2] significant damage to structures, cladding and fitments.
   Personal risk level: significant risk of injury but not of death.
3. Damage level: [3] general damage and collapse

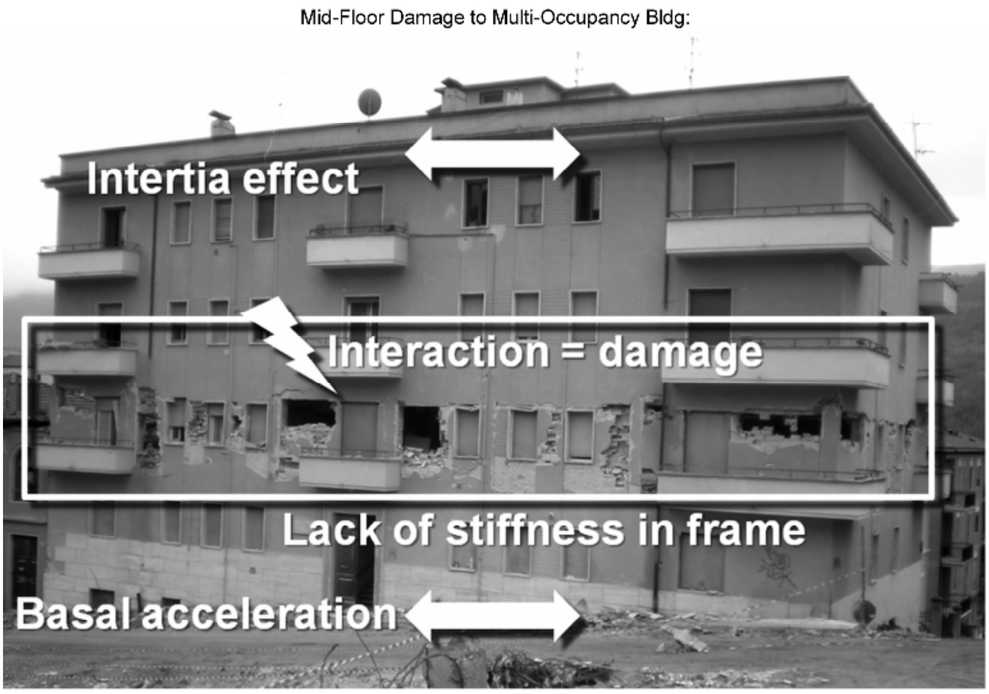

Figure 2. Characteristic pattern of damage in a multiple-storey condominium building affected by the L'Aquila, central Italy earthquake of 6 April 2009..

of architectural elements.

Personal risk level: significant risk of injury but relatively low risk of death.

4. Damage level: [4] serious damage or partial collapse of building.

   Personal risk level: strong risk of injury and significant risk of death.

5. Damage level: [5] collapse of more than 50% of the structure.

   Personal risk level: limited and mainly unpredictable probability of survival.

Whereas little can be done to save people caught in the total collapse of a structure, the previous four levels involve degrees of criticality in which behaviour will influence the probability of being injured (levels 1-4) or killed (levels 3-4).

The procedure for enhancing self-protected behaviour is thus as follows. First ascertain the characteristic patterns of seismic damage and transform them into simple models that are applicable to significant proportions of buildings in a given urban area. This will help explain how people are put at risk. It is helpful if such buildings can be mapped for emergency planning purposes so as to show where the greatest vulnerabilities lie. It is also useful if the level of vulnerability to damage can be ascertained for each building by structural engineers. This is seismic microzonation.

Secondly, survival strategies need to be worked out. These should be communicated to residents and building users, who should be encouraged to plan for an emergency situation. The survival strategy could consist of the following parts.

1. Identify the safest part of the house with regard to the following risks:
   - Fall of tiles or collapse of the entire roof;
   - Instability of the façade and cornices;
   - Potential collapse of the stairs during egress;
   - Detachment of beams and risk that they will batter down the building;
   - Use of heterogeneous materials giving rise to a complex seismic response.
2. Avoid risky behaviour;
3. Create an exit strategy:
   - Identify a safe place to reach near to the house;
   - Identify the most dangerous parts of the house and how to avoid them.
4. Create a mutual support network of friends, relatives and neighbours.
5. Collect and store useful equipment:
   - Train family members and test the reaction plan.

For example, in many cases façades that are badly anchored to the structure of the building can collapse, or at least elements of them can detach during the shaking and fall into the street. At the same time, stairways are often the least stable part of the building, especially if they are inadequately suspended from floors and load-bearing members. They may collapse during the tremors. Hence, it may be highly inappropriate to rush out into the street until the hazards of doing so have been properly assessed [17].

Ideally, a programme of resilience against earthquakes should accumulate information and expertise about possible damage and potential reactions of people caught in major seismic events. There is also some scope for pre-emptive planning of search and rescue, especially if it is known where, characteristically, people are most likely to be trapped when a certain kind of building collapses [18].

4. Ten Suggestions for Increasing Resilience to Earthquakes

The previous section offered a rather limited strategy for improving survival rates in earthquakes. This should be part of a much broader initiative to save lives, reduce damage and injuries and increase society's resilience in the face of the seismic threat. There follow ten suggestions about how to achieve this.

1) Tell people what to do during an earthquake. As noted in the previous section, the biggest risk tends to be when people are at home in vulnerable vernacular housing, especially at night when they are sleeping. There is a need for authoritative knowledge on the best self-protective behaviour, and for a methodology to assess risk in vernacular housing and other kinds of accommodation.
2) Develop urban search and rescue (*USAR*) capabilities on site. One of the great tragedies of major earthquakes is that *USAR* capacity often comes from thousands of kilometres away and does not arrive until 36-72 hours after the earthquake. Typically, between 1,200 and 2,300 rescuers from up to 50 different countries may converge on the disaster area in this way [19].

Instead, *USAR* capacity is needed immediately, and in all cases before 12 hours have elapsed. Hence, stockpiling of simple equipment (ladders, ropes, flashlights, loud-hailers, reflective garments, hard hats, first-aid medical supplies, etc.) in local neighbourhoods and training local people to constitute their own rescue groups can achieve much. However, people must be trained to avoid the risks associated with urban heavy rescue and to understand the nature of earthquake injuries and how they should be treated by basic life support (first-aid) procedures.

3) Reduce non-structural as well as structural risks. Many of these are internal to buildings, although some, like collapse of signage, are external. Many non-structural risks can easily be assessed and remedied, often by a small amount of work securing items to structural members with screws, bands and other anchors.
4) Plan flexibly. Planning should be a process not an end in itself: in fact, the planning process is often more useful than the product (the emergency plan), as it tends to identify and highlight problems that need to be solved. Plans should cover all risks and should allow for multiple and secondary hazards. They should use scenarios of impact, response and recovery, as this is the best way of investigating what is likely to occur in a major emergency. Scenarios are flexible investigations of possible alternative futures: rather than being a predictive device, the scenario is a means of understanding cause and effect relationships, and of ascertaining future needs.
5) Create networks. These need to be built at all scales, from international collaborations of experts to local and area networks of responders and residents. The presence of support networks helps keep the issue of seismic safety current and ensures that people do not feel alone. It helps disseminate information and promote learning and information sharing [20]. Networks may be efficient means of diffusing innovation to people who can benefit from it. They create a benign form of disaster subculture, which contributes to social solidarity.
6) Encourage governance. This can include promoting stakeholder involvement and personal disaster planning. Few people have their own disaster plans, or any idea as to what they and their families would need to do in a disaster situation. Yet, it need not be so. Governance for seismic risk reduction is both a national and a local matter, but as the local area is always the theatre of disaster impact and response, it is the main foundation of all governance devoted to resolving this issue. Moreover, one needs to understand and work with local culture, as this will facilitate the acceptance of new ideas and strategies.
7) Make good practice proliferate. The networks can be used to ensure that this happens. Although there is really no such thing as best practice, as circumstances differ from one place to another, good examples can be adapted to new areas, and research results need to be utilised.
8) Ensure programmes are sustainable. For this to happen, the programmes need to have full support from stakeholders in all branches of civil society. One recurrent problem is that while it is relatively easy to induce public administrators to authorise one-off payments (i.e. capital expenditure), they are less happy with recurrent spending (i.e. revenue expenditure). Nevertheless, this is necessary, as salaries have to be paid and programmes need to benefit from continuity of funding. Hence, disaster risk reduction needs to be considered as a fundamental everyday service, as essential as waste treatment and electricity supply, and as well funded.
9) Create a post-earthquake policy and strategy before the next major seismic event. Few public administrations have been innovative enough to plan for recovery before disaster, although the disaster researcher Harold Foster described some such examples of that as long ago as the 1970*s* [21]. Nevertheless, although the full details of what will be needed cannot be known before the event, the basic lineaments of recovery are likely to be clear in advance. There should thus be a plan for the provision of shelter, and a strategy for safeguarding livelihoods and thus promoting economic recovery.
10) Create a culture of resilience against earthquakes. This involves a social programme of information and discussion that brings resilience into the mainstream of daily life. People need to be induced to believe that although natural hazards do not strike every day, they are a constant threat

to lives and livelihoods and there is a common responsibility to face up to that threat. It helps to be able to answer the question "what is welfare?" [22]. The answer should probably be that it is the safeguarding of people who, through poverty, age or disability, are unable to look after themselves in some way. Welfare also means the ethical distribution of resources and the maintenance of minimum standards of living. The concept, and its morality and ethics, should not be distorted by disaster. Hence, it needs to be examined--fairly, critically and explicitly-- before disaster strikes.

5. Conclusion: Beyond Resilience

The discussion presented above suggests that there is much that can be done to reduce the risks of casualties and socio-economic effects of earthquakes, even if damage cannot substantially be abated. Society needs to be hardened, so that it resists the impact of disaster by devoting resources and organisation to that process. This is sometimes termed social capital building [23]. Thus, expertise, experience, know-how and resourcefulness need to be concentrated in the community and conserved and developed over time so that they can be handed on from one generation to the next. Programmes need to be sustainable in their own right and also need to interface with the more general problem of the sustainability of life. In fact, perhaps the biggest challenge of the future will be, not merely to make society resilient to disasters such as earthquakes, but also to make it resilient to less cataclysmic changes (in sea level, global climate, resource availability, and so on) that are none the less fundamental.

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