

Thinking about resilient cities: studying Italian earthquakes

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Cities are complex systems that result from the interaction between several factors: urban, socioeconomic and policy strategy overlap factors. These elements interact continuously with one another, which makes governance notably complex, particularly in the case of risk management. This paper focuses on the resilience of cities, with recent Italian earthquakes as case studies. The resilience of cities should undeniably play a fundamental role in seismic risk mitigation and government. The authors highlight that seismic vulnerability (e.g. buildings and lifelines, etc.) seems to be a fundamental topic in resilience. Nevertheless, to investigate the resilience of cities, the problem is strongly multidisciplinary and non-linear. However, to improve earthquake resilience in national, regional or single urban territories, the incorporation of engineering/science (physical), social/economic (behavioural) and institutional dimension (multilevel territorial government) resilience should be considered. Considering that the best strategies cannot be identified to support decision makers, the authors of this paper are working on possible applications of different multicriteria decision-making methods. Only after implementing a new multidisciplinary, multicriteria and multilevel framework to improve resilience will it be possible to define a quantitative evaluation of resilience. Seismic risk management may be considered an optimal conjunction between scientific research and decision making.

1. Introduction

In the past few years, several studies have been conducted. Cutter *et al.* (2013) emphasised the role of resilience on national politics and the importance of creating a culture of resilience. It was correctly and clearly observed that the resilience of a community should be based on an integrated approach. Moreover, Cutter *et al.* (2008) presented a model to design and compare different methods to assess the disaster resilience of a community. Significant efforts are in progress to understand, investigate, improve and define the methods and the framework to improve community resilience (Ainuddin and Routray, 2012; Miles and Chang, 2006; Olwig, 2012; Zobel, 2011). Furthermore, some interesting definitions have been introduced to obtain a better understanding of resilience, recovery time and the disaster-resilient community (Cimellaro *et al.*, 2010; Zobel, 2011). As a result, different procedures have been developed, and different analytical tools have been considered. Nevertheless, it must be noted that these works are often related to single objects (e.g. one building), critical facilities, service networks (e.g. hospital and lifelines) and businesses (Rose and Krausmann, 2013) and so on. The proposed resilience functions can capture the effect of the disaster on single types of treated objects (e.g. a network), but they cannot be

applied to cities. However, Chang and Shinozuka (2004) made some interesting observations. The resilience of a community was linked to the performance level standard divided into its technical, organisational, social and economic aspects.

In fact, in Italy and other Mediterranean earthquake-prone countries, the effects of earthquakes have shown the notably low resilience of the cities involved. To study the effect of natural disasters on cities, the initial state of the system is important, with particular reference to its socioeconomic conditions and the structural and infrastructure aspects.

In recent Italian earthquakes, the damage suffered by buildings (both private and public) has been the main source of losses, and consequently the whole system, in general yields no resilience. In the long term, the return to normal conditions has been achieved only with considerable economic investment. If these resources had been used in mitigation, the policies would have produced significant economic growth and avoided many casualties. With this viewpoint, the scientific community have had many doubts in the recent past about the ability of Italian scientists to contribute significantly to real risk mitigation before an earthquake occurs. The present paper describes

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several recent Italian earthquakes, the current state of earthquake preparedness in Italy, and how it negatively affects community resilience. It also discusses how community resilience in the face of earthquakes and other hazards could be improved and suggests a framework for implementing these improvements.

The message of the paper is that prior mitigation saves money with respect to the cost of recovery from damage. This concept was firmly established in many papers published in the last four decades and is firmly imprinted in researchers' minds. Nevertheless, the simple analysis of recent Italian earthquakes (that are reported in the paper) shows clearly that this concept has never been applied in the past 40 years.

In fact, although the advantages of multidisciplinary studies on seismic risk have been recognised for decades, real seismic risk mitigation policies remain an academic topic while their implementation is still largely unrealised.

2. Which resilience?

In recent years, resilience has become a usual term in the field of risk management. Nonetheless, the concept of resilience is actually scarcely ever applied. The concept of seismic resilience also considers the social dimension. According to Bruneau *et al.* (2003), community seismic resilience is defined as the ability of social units to mitigate hazards, contain the effects of disasters when they occur, and perform recovery activities so as to minimise social disruption and mitigate the effects of future earthquakes. Generally, this goal has been realised by working emergency responses and strategies, which involve many institutions and organisations, particularly those that are related to the essential functions for community wellbeing, such as acute care hospitals. In Italy, the relationship between the resilient city, the government and the planning tools is currently not clear.

The authors believe that the resilience of a community (such as the capacity to adapt to new and negative conditions) should be analysed and evaluated into three classic main aspects: that is, a prepare–respond–recover approach

- The relationship between the resilient city and the government and planning tools, based on the improvement of the structural and infrastructural capacities of the system to withstand the event.
- The capacity of the civil protection system to respond to natural events and bring immediate help – besides bringing relief to the people affected, it is possible to limit the losses; for example, it is possible to help the wounded and restricted people, and secure the goods, facilities, services and so on to accelerate the return to normality.
- The economic capacity to intervene with adequate resources to ensure a fast return to normality.

The first aspect is related to a pro-active approach and it may also be considered the fundamental question in improving the resilience capacity of a community in advance of seismic events. The second and third points follow a reactive approach.

Regarding the Italian situation, some critical issues have been reported by Tilio *et al.* (2012). In recent years, seismic emergency and risk management have almost entirely been entrusted to civil protection at different levels of government of the territory. In fact, each town that has an emergency plan (considering only the seismic risk standpoint) must adopt a possible seismic scenario and the subsequent actions to manage the emergency. Nonetheless, in the past few decades emergency plans have not considered the possibility of intervening to mitigate risk before a seismic event occurs, and spatial planning laws generally have not considered seismic risk as a crucial element that influences the development strategies and policies. Moreover, in peacetime, particularly during the prevision phase, once the seismic loss scenario is defined, the following elements should have been identified: (a) prevention, (i.e. mitigation strategies in order to determine the acceptable vulnerability levels), (b) emergency phases, which refer to the expected seismic scenario, and (c) post-emergency phase and re-establishment of normality.

In general points a and b are often underestimated.

One of the most important aspects concerns how to define and apply the mitigation strategies (point a, above). The minimum set of elements has been identified with reference to three phases of risk management. Considering the prevision and prevention (referring to peacetime), emergency and post-emergency phases, the minimum set can be sketched as the nesting of three subsets. In recent years, several studies have been performed to examine seismic risk (Chiauzzi *et al.*, 2012; Dolce *et al.*, 2006; Masi *et al.*, 2013; Puglia *et al.*, 2012), and many interesting applications have been proposed to the decision makers.

However, it is important to observe that these studies generally have not improved the resilience of cities. In fact, they have often not been adopted by public administrations in urban planning.

While significant improvement has been made regarding emergency management (point b, above), much less effort has been taken to mitigate the seismic risk considering the seismic vulnerability of buildings. Some interesting activities have been undertaken regarding public building stock (starting from OPCM 3274, 2003). However, with particular reference to private buildings and monumental/historical heritage sites, assessment and retrofitting activities are not sufficiently

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widespread to mitigate the seismic risk. There are a number of technical reasons for this and they will be discussed in the following section.

Considering the Italian situation, it can be affirmed that a resilient city has never been used as a tool in risk mitigation. Thus, it appears important to investigate the actual resilience of cities. To improve the resilience of cities, the authors are working on simplified processes and tools available to policy makers, scientists, professional engineers and geologists. To achieve this goal, resilience must be considered as a fundamental phase in pre-disaster preparation activities following a pro-active approach.

3. Lessons from recent Italian earthquakes

In the past 30 years, earthquakes that have occurred in Italy have dramatically shown that a resilient city (in the actual and scientific sense) was never used as a tool in risk mitigation and development strategies, and the policies have not considered an orientated prevention approach.

In the following section, there is first, a brief summary of the contributions of some seismologists on mitigation is provided. Then, the deficiencies in the past decades are highlighted. Nevertheless, the authors are aware that many studies are in progress to determine new hazard maps using innovative models.

3.1 Seismological viewpoint

From the viewpoint of seismological studies, the backbone of the Italian historical earthquake catalogue (Rovida *et al.*, 2011), which is derived from several studies and minor improvements, originated from the study of Baratta (1901). Thus, at least since the beginning of the twentieth century, no large earthquake in Italy should have come as a surprise. Limiting this analysis to the events that have occurred since the mid 1970s, the authors have obtained a notably dismaying picture of the contribution that seismologists provided to risk reduction before the event occurred and the correct intervention after its occurrence.

Regarding risk reduction, in the time window from 1908 to 1984, seismic-prone areas have been recognised as such only after a large event has occurred, which implies that following cases such as Messina in 1908, Avezzano in 1915, Mugello and Amiata in 1919, Garfagnana in 1920, Irpinia and Ancona in 1930, Cansiglio in 1936, northern Puglia in 1948, Carnia in 1959 and Belice in 1968, increasingly, more areas were considered to be seismic. Thus, in those areas, some special building code was enforced. In 1984, after the huge (in terms of victims and losses) 1976 Friuli and 1980 Irpinia earthquakes, 2965 municipalities, approximately 30% of the total number of municipalities, were finally recognised as seismic-prone areas. They were subdivided into three 'categories', and the first

category was the most dangerous, where stricter construction codes were enforced. Unfortunately, the first category remained reserved for areas where a large event had occurred after 1908.

During 1997 to 1998 a sequence of several rather large events took place in a wide area in central Italy, namely in the Umbria and Marche regions. At the time, the new seismic categories were in place and the sequence actually took place in an area that was classified in the second category. The observed intensity was for the first time in line with what could have been expected, but this success in forecasting might have been casual.

The following relevant event, in 2002 in Molise (south-eastern Italy), was not as successful. Even though new probabilistic seismic studies founded and validated by the National Department of Civil Protection (BIBLIO) were showing that the area could have been involved in events of this size, the Italian legislation had not been updated.

Finally, as a consequence of the 2002 Molise earthquake, the national government enforced a new law, OPCM 3274 (2003), based on the above-cited studies, in which the entire Italian territory was subdivided into four zones, with the first zone being the most dangerous. It was the best approach until that time, although areas such as south-eastern Sicily remained in the second zone despite the occurrence of the largest known Italian earthquake in 1693 with a moment magnitude (M_w) of 7.4 and a Mercalli–Cancani–Sieberg (MCS) scale reading of XI.

Even though it appeared that the legislation was finally in line with scientific studies, the effects of the 2009 Aquila earthquake ($M_w=6.3$) were also underestimated (Masi *et al.*, 2011). The municipality of L'Aquila was in fact placed in the second zone, although the 1461 and 1702 events (both with a MCS reading of about X) had occurred there.

Not only did OPCM 3274 (2003) consider the area a level of medium seismicity, but also the research project INGV-DPC-S1 (Montaldo *et al.*, 2007), which provided the seismic hazard maps of the Italian territory presented in the current Italian codes (NTC08, 2008; OPCM 3519, 2006), still considered it to be a medium seismicity.

However, in the period after the new hazard map was issued and before the 2009 earthquake, some articles based on different approaches all suggested that the seismic hazard at L'Aquila could have been underestimated (e.g. Pace *et al.*, 2006).

The last event examined is the 2012 Po Plain earthquake. Before it occurred, nobody believed that the Po Plain was a seismic area. In 2004, it was included in the third zone mostly because of the risk of the Apenninic earthquakes. As previously stated, nobody was worried about this area, although

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Baratta (1901) reported an event in 1570 in the nearby city of Ferrara. According to him, the seismic sequence had lasted for several years. Similar to the 1570 sequence, the 2012 sequence occurred along a well-known (to geologists) buried thrust belt.

Hence, earthquake knowledge has not been very useful in reducing and mitigating the seismic risk and increasing resilience in Italy in the past 40 years.

3.2 Effects of earthquakes on cities

In this section, any considerations about particular cases are reported to highlight the resilience of cities. The damage suffered by buildings (private and public) seems to be the main source of earthquake losses. This aspect is highlighted on the basis of the past earthquakes. So the seismic resistance of buildings is a fundamental factor in the resilience of cities. Some striking examples are considered.

In the past 40 years, Italian earthquakes have shown that the capacity of a town to return to a state of equilibrium is notably low. This statement can also be made in relation to relatively small damaging earthquakes (the majority are $M_w = <6.5$). In fact, in Italy, these earthquakes have caused large numbers of losses and fatalities. Some striking examples are considered. Moreover, considering the historical seismic events, there appears an evident link between the social memory and little or no resilience.

The first case to be analysed is that of the 1980 Irpinia earthquake. It was a $M_w = 6.9$ event, which means that it was by far the largest of all the events examined. Most of the affected area was either classified as not seismic or as mildly seismic. As a consequence, many buildings (mostly masonry buildings) were designed only for gravity loads. The damage was huge (about 2000 casualties) and reconstruction sometimes led to the complete relocation of some towns.

The first example to be considered is Conza della Campania (south-western Italy). This was the ancient town of the Hirpini and was founded in approximately 200 BC. The town was almost completely destroyed by the 1980 Irpinia earthquake and was rebuilt in the nearby valley. The historic centre became a ghost town (a tourist attraction from the early 2000s). It must be highlighted that during the previous years (1951–1980), Conza della Campania was affected by depopulation and the number of inhabitants was significantly reduced (by more than 50%, ISTAT). The relocalisation was therefore decided on also as a means to improve the socioeconomic conditions of the population.

The same fate has affected Romagnano a Monte (Figure 1). Its origins date back to the Middle Ages, when a castle was built in approximately the year 1000 AD. It was located on the



Figure 1. View of Romagnano a Monte (2012)

enchanted top of a rocky spur. Being the smallest village on the borderline of Cilento, it was not well linked to the neighbouring towns. Romagnano a Monte village was also affected with a significant reduction of inhabitants (by approximately 40%, ISTAT (2011)) during the twentieth century as a result of socioeconomic problems. In the 1980 Irpinia earthquake, the village was widely damaged ($MCS = VIII-IX$, Rovida *et al.*, 2011) but was not destroyed like the other towns (Figure 2). A few months after the 1980 Irpinia earthquake, on the basis of high damage levels and mostly existing socioeconomic problems, the historic centre was forsaken. The village has been rebuilt a few kilometres away in subsequent years. The old village has also become a tourist attraction.

Conversely, in other cases a different approach has been adopted. At a short distance from Romagnano a Monte,



Figure 2. Romagnano a Monte: typical masonry and light and thrusting roof

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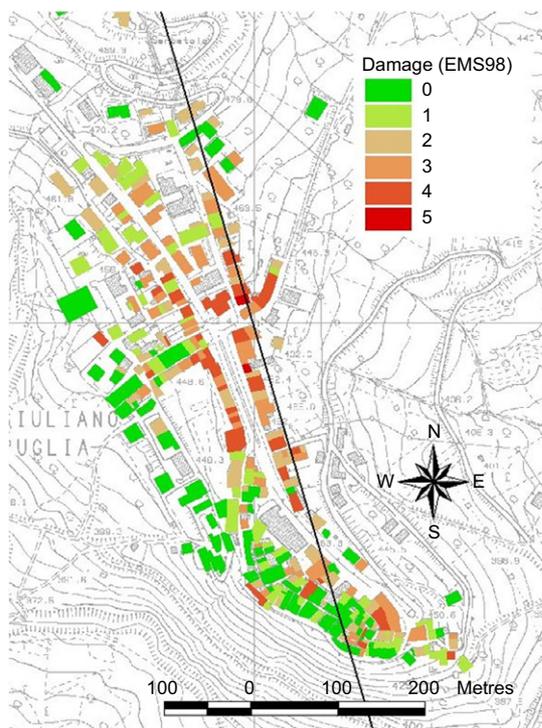


Figure 3. San Giuliano di Puglia: damage distribution: EMS98, the European Macroseismic Scale

Balvano is another small town (Basilicata, southern Italy) in the epicentral area. During the 1980 Irpinia earthquake, the collapse of the main church caused 77 fatalities (including 66 children), and the town became a symbol of the earthquake. Balvano was also affected by the same socioeconomic problems with a consequent significant reduction of inhabitants (approximately 40%, ISTAT (2011)) during the twentieth century. Moreover, the 1980 earthquake destroyed the town, but unlike the above cases, it has been rebuilt and seismically retrofitted.

A similar case to Balvano is documented following the 2002 Molise earthquake. The damage survey shows that there was an anomalous concentration of damage in a zone of the small town of San Giuliano di Puglia (Mucciarelli *et al.*, 2003; Puglia *et al.*, 2012). In the historic centre of San Giuliano di Puglia, the observed damage was essentially ascribed to the vulnerability of the buildings. In other parts of the town, serious structural deficiencies were surveyed, which contributed to explaining the greater surveyed damage. Moreover, the role of site amplifications appeared to be significant (Figures 3 and 4). Although the earthquake can be considered a moderate magnitude event, San Giuliano di Puglia is considered a significant exception because the earthquake caused the primary school to collapse, killing 27 children and one teacher. Thus, considerable resources have been used (considering the low



Figure 4. San Giuliano di Puglia: collapsed and demolished buildings in main street

magnitude) for comprehensive studies (Puglia *et al.*, 2012) and an extensive rebuild.

After the earthquake of 6 April 2009, (Masi *et al.*, 2011) the everyday life of the people and the welfare of the entire community have been modified (or destroyed). A significant number of businesses that operated in the centre of town were moved to the suburbs, whereas many business closures occurred (approximately 25%), and the number of closures also increased as a result of recession. It is also noteworthy that most of these people have been relocated in new temporary suburbs. After 3 years, approximately 60% of the rubble from the collapsed buildings had to be removed. Now (after 5 years), L'Aquila, the capital town of the administrative region, remains unusable. Is it becoming a ghost town?

This overview shows that both reconstruction and relocation have often been unsuccessful.

From a landscape viewpoint, the ghost towns (i.e. Romagnano a Monte and Conza della Campania) are unique and fascinating. The historic villages have endured unknown natural hazards for many centuries; nonetheless, they do not show any resilience in the modern age.

Conversely, when a reconstruction strategy has been selected, the pre-earthquake conditions have not been attained again.

The point of the above descriptions is therefore the failed reconstruction projects. In the literature, several functional models are reported. Some interesting studies are presented in recent literature (Özerdem and Rufini, 2013), even though the topics are treated with a different technical approach to this

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paper. Some of these are interesting but they do not apply to Italy.

Thus, it is clear that post-earthquake strategies have been defined as political strategies, without any in-depth analysis in terms of reconstruction models. In fact, the majority of earthquake-stricken areas of the last century have never fully recovered, because reconstruction processes have always taken so long that any existing model would not really work. For the above reasons, functional models of reconstruction processes are not addressed in this paper.

3.3 Resilience of cities

Considering the cases discussed above, there are no resilient cities. In Italy, significant progress has been made in the past decade regarding emergency management. On the contrary, much less work has been done to mitigate the seismic risk. In fact, the capacity to return to a state of equilibrium after recent earthquakes depends on the political choices and the significantly involved economic resources. In all cases, the demographic decrease usually continued even after seismic events. Moreover, the recovery time has always been notably long.

The role of the seismic vulnerability of buildings on the resilience of cities is the fundamental critical aspect. However, the seismic vulnerability depends only on the political strategies in the management of post-earthquake emergencies. This statement is also valid for relatively small earthquakes (e.g. Molise with $M_w = 5.8$).

The 2012 Po Plain event must be considered a small earthquake and it has caused a huge number of losses and casualties. The post-earthquake response initially appeared a significant exception due to the population reactivity and the economic wellbeing of the region. Moreover, it seemed that the financial flow would be readily available and adequate. The reality, however, is somewhat different. The reconstruction process is still slow and much economic activity has been moved to nearby areas, under market pressure.

This earthquake has highlighted some problems of interest to the topics in this paper. The problems and the typical damage of several diffused historical masonry typologies such as towers, churches and palaces (also used as dwellings) are not different from those surveyed in other recent Italian earthquakes on masonry buildings that were either not retrofitted or designed to resist only gravity loads. In the case of historical masonry structures, both palaces and churches, local damage mechanisms often occur (e.g. out-of-plane overturning, Figure 5).

After the 2012 Po Plain earthquake, particularly interesting aspects related to mixed reinforced concrete (RC) masonry buildings (notably widespread in the area) and RC buildings

(also of recent design and construction) have been surveyed. For the first typology, these characteristics have caused extremely negative behaviours that are not acceptable even for buildings that are designed for only gravity loads (Figure 6).

In the recently built areas, more recent RC–masonry buildings showed a higher damage level than the neighbouring buildings (Figure 7). Figure 8 shows that many buildings suffered a near-collapse damage level. Apparently, this damage distribution resembled the typical distribution due to the site effects. The inadequate behaviour occurred due to the design (only for gravity loads) and the faulty construction (Figure 8). Moreover, similar behaviour has been observed in many recent (after 2000) RC buildings, as reported in Figure 9, which shows a total collapse.

Based on the above considerations, it is important to note that the 2012 Po Plain earthquake has also highlighted the strong influence of building vulnerability on seismic risk, but the region appeared to have a good resilience in terms of reaction on a short time scale. However, after 24 months, most of the retrofitting and rebuilding activities remain in progress or in the starting phase; therefore, also in this case, the reconstruction process seems unsatisfactory.

In this work, resilience and vulnerability are considered to be strongly linked concepts. A high vulnerability of the building stock can be considered predominant to determine resilience. On the contrary, the authors believe that the vulnerability should be embedded in the resilience as a multidisciplinary process to risk mitigation.

To analyse the recovery capacity of an entire community is complex and requires more hard work than the capability of a single critical facility. Thus, simplified models (Cornell and Krawinkler, 2000; Whitman *et al.*, 1997) do not appear to be available or applicable. Cimellaro *et al.* (2010) noted that these models neglected the complexity of the recovery processes. In this paper, the reported cases show that the recovery time is much longer than the amount that the existing models provide. Assuming an acceptable recovery time (proportional to the seismic intensity), the above system appears to have an approximately zero effective resilience.

A simple quantitative measurement of the loss of resilience in a community (e.g. Bruneau *et al.*, 2003) is thus not possible. Several improvements of this formulation have been proposed. For example, an interesting approach is reported in Cimellaro *et al.* (2010). Significant improvements have been made to define the loss function.

Using these procedures, excellent results can be obtained concerning single networks (structures, infrastructures and

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Figure 5. Typical damage mechanisms (out-of-plane overturning) of church façades: (a) Emilia earthquake; (b) L'Aquila earthquake



Figure 6. 2012 Emilia earthquake: partial collapse of mixed RC-masonry buildings

lifelines etc.). In fact, to investigate the resilience of cities, the problem is strongly multidisciplinary and non-linear. In Zobel (2011), other significant improvements have been considered. In particular, the proposal incorporates both the multidimensionality and non-linearity of the problem and the preferences of the decision maker.

These Italian cases showed an unfortunate reality. The recovery capacity of communities is very different among different geographical regions in a very closely spaced community and for the same magnitude of earthquake. Moreover, maybe due to the high vulnerability of the buildings, resilience appears to be independent of the seismic intensity but directly dependent on the seismic vulnerability of the buildings, and is approximately zero. In fact, the recovery time must be measured in many years. In particular, in the cases reported, resilience seems to be mainly dependent on socioeconomic conditions and the key role of the political decision maker is evident. The proposed procedure by Zobel (2011) and Cimellaro *et al.* (2010) can be a useful tool and a starting point.

4. Discussions on increasing resilience

There are some recent scientific discussions about the capability to forecast earthquakes and their consequences (Wyss *et al.*, 2012) and the link between the country level of corruption and the consequences of earthquakes (Ambraseys and Bilham, 2011). Some considerations are reported in the previous section regarding earthquake knowledge in reducing or

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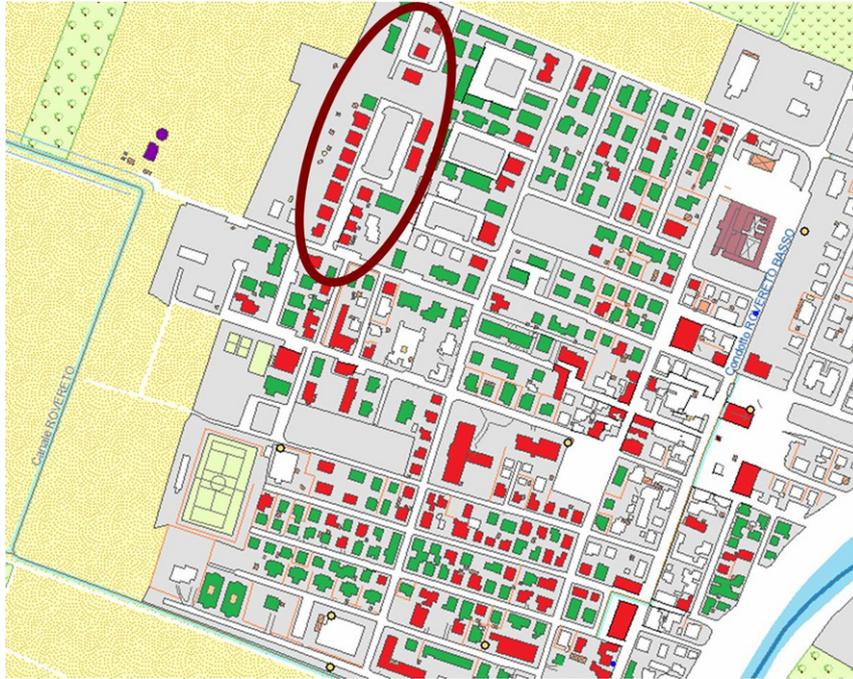


Figure 7. 2012 Emilia earthquake. Apparent effects on site in Rovereto sul Secchia (Modena, Italy). The circle represents recent RC-masonry buildings with higher damage level than the neighbouring buildings



Figure 8. 2012 Emilia earthquake: significant damage (near collapse) on recent mixed RC-masonry buildings

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Figure 9. 2012 Emilia earthquake: collapse of recent (post-2000) RC buildings

mitigating the seismic risk and increasing resilience. The corruption in building construction certainly plays a fundamental role in killing people during an earthquake. Corruption also plays an important role, particularly in developing countries, where many cities have been made into megacities in the past few decades in a fast and uncontrolled process.

Both problems are only a part of many other factors that cause fatalities and injuries in earthquakes. The improvement in disaster resilience should be a fundamental national issue (Cutter *et al.*, 2013). However, to improve earthquake resilience

in national, regional or single urban territories, the incorporation of engineering/science (physical), social/economic (behavioural) and institutional dimension (multilevel territorial government) resilience should be considered. Resilience encompasses both pre-disaster preparation activities and post-disaster responses. In these processes, policy makers, scientists, engineers and emergency managers must play a key role. From the previously discussed cases, it is evident that the resilience of cities was too often affected by only political strategies that are inadequate, always post-event and with long periods.

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Although the advantages of multidisciplinary studies on seismic risk have been recognised for decades, real seismic risk mitigation policies remain an academic topic while their implementation is still largely unrealised.

There are a number of technical reasons for this, such as the absence of standards, paucity of vulnerability data and standard institutional, regulatory and legal practices that do not pursue the least initial cost of mitigation policies as the goals of decision makers. There are, however, more social implications. In particular there is the failure of the scientific community to transfer knowledge to the decision level, or to state it in another form and the failure of the political class to understand that better preparation and the implementation of mitigation policies would greatly improve the system response.

First, the socioeconomic conditions in an earthquake zone appear to influence resilience significantly, but other important problems may also be considered

- education and information of the people about seismic risk management
- lack of procedures for management strategies and intervention on a wide territorial scale
- incorrect or no enforced application of the building codes
- incorrect application or lack of appropriate, fast and economically sustainable retrofitting techniques
- inappropriate siting of buildings (e.g. Mucciarelli *et al.*, 2011).

Therefore, a direct correlation between a single cause and the number of deaths and losses caused by building collapses in earthquakes can be implausible if not misleading. Following these uncorrected approaches, seismic risk mitigation may be incorrect because it is based on unapplied or partial procedures. Moreover, considering the diffusion and economic resources in seismic risk and seismic mitigation studies, it can be stated that this generation of researchers has unprecedented responsibility to exercise their skills to modify the trend of fatalities and losses.

Much work has been performed, and a significant problem may be the transformation of the results of studies (a non-exhaustive list is Bernardini and Lagomarsino, 2008; Binda *et al.*, 2010, 2011; Borzi *et al.*, 2012; Braga *et al.*, 2011; Chiauzzi *et al.*, 2012; Lagomarsino and Resemini, 2009; Masi and Vona, 2012) into simple and optimised rules for practical planning (support to the decision maker) and design. Simple, fast, available and economic retrofitting strategies should be determined and integrated into mitigation policies for non-seismic buildings. Thus, it is also possible to increase the resilience of cities in a short time after earthquakes (e.g. as reported in the following discussion).

The authors believe that different tools should be defined, based on the objective of the actual usage. In seismic risk mitigation policies, these tools (e.g. fragility curves) should be determined considering the repair/retrofitting costs. Several approaches have been developed based on numerical analyses (e.g. Borzi *et al.*, 2012; Masi and Vona, 2012; Vona, 2014) to study the vulnerability and the possible retrofitting.

Some differences must be highlighted between masonry buildings and RC buildings regarding appropriate, fast and economically sustainable retrofitting techniques.

In Italy, as in many similar countries worldwide (particularly, other Mediterranean earthquake-prone countries), a particular reference should be devoted to monumental, historical buildings and palaces (which are also used as dwellings). In fact, when the resilience concept is discussed, economic and production activities and cultural heritage are considered with relative importance depending on the specific characteristics of the town considered.

However, in past earthquakes, significant casualties have occurred due to monumental and historical buildings (in particular churches). Moreover, in many countries (e.g. Italy, Greece, Spain and Turkey), the damage or loss of cultural heritage could cost some percentage points of the gross domestic product if both economic and cultural values are considered (which is invaluable). In fact, if a cultural heritage site is well known, preserved and protected, it is an excellent source of income and can significantly induce development in many areas.

These buildings play an important role in past seismic events. They have shown that the actual vulnerability of historical sites is generally higher than that of more recent neighbourhoods. Moreover, they have more retrofitting problems. In fact, the requirements of historical environments are often related to social and economic changes. Historical buildings that no longer serve their original functions must sometimes be re-used. The decision to re-use historical buildings is a difficult problem, but should be addressed by decision makers with consideration of the natural hazards. An appropriate mitigation strategy that also considers a suitable re-use can result in a sustainable preservation of historical assets and greater safety. Thus, the respectful conversion of structures for new uses based on economic and social needs ensures the authenticity of the structure and the historical environment. Primarily, the assessment and retrofitting of the structure requires knowledge of traditional materials and construction techniques. Then, an evaluation of the seismic vulnerability of monumental and historical buildings is a critical task to plan seismic risk mitigation.

Different investigation procedures and strategies have been applied at different levels of complexity of monuments and

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historical buildings. Several approaches have been developed based on vulnerability curves, vulnerability classes and local damage mechanisms (Lagomarsino and Resemini, 2009). Many applications to the safety of cities and villages have been provided. Moreover, interesting implementation of safety measures has been determined (Bernardini and Lagomarsino, 2008; Binda *et al.*, 2010, 2011; Lagomarsino and Resemini, 2009).

In recent years, much information has been collected about earthquake damage and masonry quality. It is well established that building vulnerability should be evaluated considering in-plane and out-of-plane mechanisms (Lagomarsino and Resemini, 2009). Thus, a considerable amount of information is available and has been collected and well arranged in previously produced guide lines.

Figure 10(a) shows an example of retrofitting of a church tower in emergency conditions. This is an economic and expeditious retrofit for a bell tower. If these typologies of retrofit are widely performed in ordinary conditions, a great deal of damage to people, things and monuments/historic buildings (Figure 10(b)) can be avoided.

Similarly, RC buildings should be given adequate design and construction provisions for the next-generation seismic codes. For example, with no structural elements, after recent earthquakes, severe damage to masonry infills and partitions is found in many old and recently completed RC buildings, which caused heavy socioeconomic consequences, including human casualties, loss of building functionality (particularly important in the case of strategic constructions) and unusable buildings (Braga *et al.*, 2011; Di Cesare *et al.* 2014). Non-structural damage has more frequently been analysed both in out-of-plane and in-plane failures. Some measures to improve the behaviour of the infilled RC structures are reported (e.g. Braga *et al.*, 2011; Ricci *et al.*, 2011).

Similarly, the evaluation of the fundamental period of RC buildings is crucial in seismic risk mitigation. Several studies have been performed to estimate the fundamental period variation considering different levels of damage (Di Cesare *et al.*, 2014; Ditommaso *et al.*, 2013). Moreover, some simplified methods have been proposed to evaluate the damage to RC buildings (e.g. Ponzo *et al.*, 2010), which began from the most significant data that were recorded on the top of the building. These methodologies can be applied to provide fast and economically suitable retrofitting strategies. Moreover, considering the constructive and technological aspects, which may modify the structural response, these procedures can be reported in line guides.

Finally, to improve the resilience of cities, strategic buildings play a significant role. Due to the expected social role and

performance during seismic events and emergencies, management retrofit strategies are typical problems for public administration and public decision makers. The strategies adopted have often been devoid of objective criteria. Due to the number of buildings that require seismic retrofitting and the reduced economic availability, engineers must prepare interventions that represent the best solution to avoid waste.

It is difficult to select the best strategies. In general, several and greatly different aspects must be considered. Considering that the best strategies cannot be identified to support the decision makers, the authors of this study are working on possible applications of different multicriteria decision-making (MCDM) methods. These methods are commonly used in most fields (scientific, economic and industrial) and interesting applications are possible to improve resilience (Vona and Murgante, 2014).

Thus, synergistic works on the pro-active approach to improve the resilience of cities must be based on joining scientific research and modern procedures in the decision-making process. Complex models should be adopted considering the complexity of the recovery processes.

Although in Italy there are some very fine scientists (e.g. earthquake engineers, geologists, urban planners, economists) their studies have been widely ignored in urban planning, building codes, determining lack or poor vulnerability and hazard data, and standards (institutional, regulatory and legal practices).

The study of the resilience of cities needs a strong and complex multidisciplinary approach. As a consequence, the development and application of true mitigation policies are expected.

In this paper, some interesting cases of reconstruction (Romagnano and Conza, L'Aquila, Emilia region) have been analysed. In particular they have highlighted some ongoing issues

- the resilience of cities is very low or completely lacking
- in several cases (Romagnano and Conza), the reconstruction process has completely failed in its goal
- the fundamental role of resilience in future strategies and policies for urban planning is evident
- a significant role is played by monumental and historical buildings due to their economic and cultural values. Unfortunately their seismic vulnerability is extremely high, but if preserved and protected they could be an excellent source of income and could significantly induce development in neighbouring areas.

Thanks to the new codes and standards, new buildings will be considerably more resilient; however, the large, invaluable

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Figure 10. Fast retrofitting of a church tower: (a) in emergency conditions; and (b) brittle behaviour of a similar church tower without strengthening

historic heritage needs development of new tools to mitigate the associated seismic risk significantly. This will, moreover, be favoured by future urban planning based on resilience concepts.

To improve the pro-active resilience of cities, simplified processes and tools are needed for policy makers, scientists, professional engineers and geologists. To achieve this goal resilience must be considered a fundamental phase in pre-disaster preparedness activities.

A framework has been proposed (Figure 11). Seismic risk management may be considered an optimal conjunction between scientific research and decision making.

In the last few years assessment of the seismic capacity of buildings (Vona, 2014) and consequent possible retrofitting have become fundamental topics in earthquake engineering. In particular, the selection of retrofitting strategies has been carried out by several authors (i.e. Caterino *et al.*, 2008). The choice of criteria for the selection of intervention strategies for the seismic retrofitting of buildings is in fact one of the key issues for the reduction of seismic risk on a large territorial scale.

This issue is certainly of greatest interest for the wide stock of residential and strategic buildings. Obviously, the best choice should be determined on the specific features of the single structure and on its seismic deficiencies obtained from the

assessment procedure. In this way, different methods and alternative approaches regarding single buildings could be investigated and the consequent application will lead to the optimum strategy.

On a wide territorial scale the approach must be different. The location of economic sources plays a fundamental socio-economic role.

In particular, strategic buildings are expected to have high performance during and after seismic emergencies. In past years, decision making and the selection of different

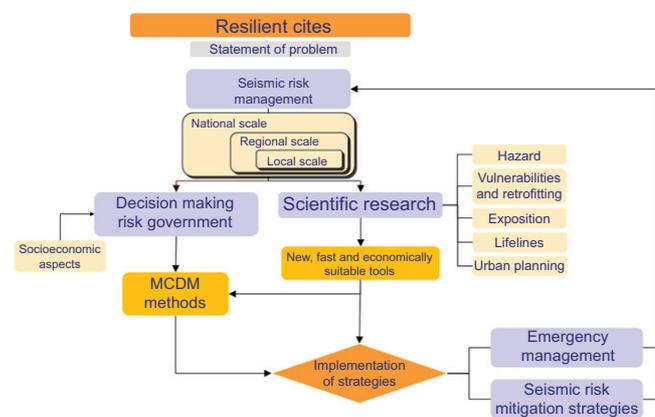


Figure 11. Framework to obtain resilient cities

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strategies were often devoid of rational criteria. Due to both the huge number of strategic buildings requiring interventions and the limited economic availability, a first step is needed to determine the priority of interventions on a wide territorial scale.

MCDM methods seem to be the ideal tools for proper planning. They allow the use of several objective parameters in political choices.

On this basis the core proposal of this paper (Figure 11) is focused on the improvement of resilience through MCDM methods. An example of this approach can be seen in Vona and Murgante (2014), where it has been applied to strategic buildings. More specifically in this work, it is proposed as an optimal procedure to schedule intervention in strategic buildings on a wide territorial (regional) scale in peacetime.

The same approach should be applied to other typologies of buildings (residential, and industrial complexes, etc.).

In this way, it will be possible to develop multicriteria curves of time–risk that are able to guarantee an effective increase in and control of resilience. Moreover, a backward evaluation process of the effectiveness of strategies may be implemented to determine new or more correct procedures.

Only after implementing a new multidisciplinary and multilevel framework to reduce resilience will it be possible to determine a quantitative evaluation of the resilience of cities. Therefore, it can be viewed as an overlapping of different resilience values of the various subsystems in cities.

5. Conclusions

The resilience of cities should undeniably play a fundamental role in seismic risk mitigation and government.

In this paper several examples show that in Italy there is currently no resilience.

This poses two questions

- Who decides the resilience of cities and how?
- How is possible to increase resilience to overcome the above problems?

In Italy, civil protection is required to manage the prevention and protection activities, but its role sometimes replaces those of municipalities and local administrations. In fact, regions and municipalities determine urban plans. The administrative practice, however, often does not consider the natural risks in the territory. With considerable evidence, efficient regulatory policies and frameworks should be created to overcome the

lack of planning capacity, the lack of systematic learning from past events and the lack of commitment from territorial governments to integrate seismic risk into broader development programmes. Furthermore, much effort should be devoted to insufficient public awareness about the appropriate action to take before an earthquake and the application of building codes.

From the above discussion, it is clear that post-earthquake strategies have been determined in political strategies based on no rational criteria. On the contrary, the main strategy should be focused to improve the seismic behaviour of as many buildings as possible (based on MCDM methods).

The main conclusions of the present work highlight the need to develop the following elements

- simple, fast, readily available and economically sustainable retrofitting strategies
- administrative process simplification, considering the constraints regarding the cultural heritage
- retrofitting strategies and definitions of simple and optimised rules for planning, and design based on scientific results
- definition of rational criteria for risk-mitigation policies
- allocation of resources based on the optimised life cycles of the structures and MCDM methods. A new management model for planning strategies and their rapid implementation at the local government level must be provided.

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