

Changing from the Emergency Plan to the Resilience Plan: A Novel Approach to Civil Protection and Urban Planning

Marco Vona(✉)

School of Engineering, University of Basilicata, 85100 Potenza, Italy
marco.vona@unibas.it

Abstract. Seismic risk study and consequent mitigation strategies have become always more important. In modern communities are complex communities; therefore, there are complex processes based on strongly different topics: urban planning, socio-economic dynamics, the need to preserve cultural heritage, safety, and natural hazard effects. In last years, a significant change in point of view seems necessary. In particular, the seismic risk mitigation (and more generally, the natural risks mitigation) must become one of the main topic in urban planning and governance of communities. it is to be highlighted that in past earthquekas higher consequences and losses have been generally caused in the medium and long term by the low or lack of resilience of the communities. However, in recent years, the concrete application of the concept of the resilience have taken on a key role in seismic risk studies. In particular, the resilience assessment of the housing stock, both qualitatively and quantitatively can be considered the core of the problem. In this study, based on the concept of resilience a change in urban planning and emergency management tools is defined. A case study is considered to show a first application. The improvement of the resilience of the investigated town is defined on several strategies and then it is quantified.

Keywords: Seismic risk mitigation · Residential building stock · Seismic losses · Resilient quantitative approach · Civil protection · Resilience plan

1 Introduction

Currently, the unique way to reduce the natural disasters' effects are the mitigation and prevention strategies. They are based on the resilience's concept and it is expected to be the most common approach for future developments. The decision makers' activities should be based on the operational tools and the population should be encouraged to apply these tools. The development of resilient communities must be considered the main goal of risk prevention and mitigation programs.

In several studies, the concept of resilience has been integrated with classic risk analysis statements [1–4]. The recovery process must be defined in quantitative ways, as a convolution of several functions. In the recovery process, social, economic, and public support are essential to guarantee an immediate response and acceptable levels of service in a reasonable time.

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Four fundamental properties are generally considered in the resilience analysis.

1. Robustness: reduced loss of functionality.
2. Redundancy: the ability of a system to create alternatives.
3. Rapidity: the ability achieve goals in a timely manner.
4. Resourcefulness: the ability to use resources to achieve the selected goals.

Based on these principles, several methods have been developed in recent years to quantify the resilience to disastrous phenomena. Community resilience must include normal mitigation procedures and emergency management activities. More specifically, a community is considered resilient if it has:

– low probability of damage;
– low consequences due to damage;
– low recovery times.

Conceptually, resilience should be considered as the global effects of mitigation measures in "peace time" and quality of management in emergency times. Nevertheless, the real improvement of the community resilience must be based on mitigation measures in peace time. Quality, quantity, and effects of management in emergency times must be considered as the consequence of the mitigation measures. Emergency procedures, tools, and materials are defined (or should be defined) based on mitigation measures.

In this study, a proposal is reported for new urban planning and civil protection tools based on resilience. The resilience of the community is clearly quantified. The proposal is based on a de-aggregation process of the resilience of the community and its sub-sections. Emergency management are not considered but they should be defined in subsequent step.

2 Resilience Tools

Currently, the relationship between civil protection goals and resilience concepts is increasingly used. An example of real application is implementation in the state of California, in particular in the cities of Los Angeles and San Francisco. Resilience has been considered as the core of the mitigation strategies [5]. Several actions and some provision are defined for existing buildings, structures and infrastructures [6, 7].

Unfortunately, these cases can be considered as virtuous exceptions. Nevertheless a significant number of studies and consequent applications be found in the literature, a few applications have been performed, often related to single objects, such as critical facilities and service networks (hospitals, lifelines).

Actually, in Italy and other Mediterranean earthquake-prone countries, the resilience is strongly related to their socioeconomic, structural, and infrastructural conditions, and further need to protect and preserve the cultural heritage.

The recent earthquakes have highlighted the high level of economic and social losses. The community showed a strong decline, reaching an unacceptable standard of life or leading the community to extinction [8]. For this reason, proactive strategies must be considered for modifying and improving the resilience performance of communities.

In past earthquake, the Italian buildings stock (both public and private) exhibited a considerable fragility due to the structural types and their interaction. On the other side, public and private resources are often few and not sufficient to retrofit of these buildings. However, the government strategies can play a key role based on specific subsidies and incentives, insurance and retrofit obligation, declassification for building use, and so on [9].

In this way, the beneficial effects of the real application of the concepts of resilience should be clearly highlighted. Consequently, the resilience concepts must be the guide line in the activities of mitigation of seismic risk. These concepts should be clearly included in the current civil protection procedures. Thus, the emergency plan should become the resilience plan of community.

The civil protection activities resilience-based approach should be a strategy based on the planning of public and private seismic vulnerability reduction according to urban planning, following:

- reduction of the seismic damage, losses.
- Reduction of the recovery time.
- Reduction of the downtime.
- Use of less financial resources.

The core of the proposal is the resilience index [10], based on a combination of resilience for building types in specific areas (at the urban scale):

$$R_{\text{index}}(\text{I}) = \sum_{area=1}^{n} \left\{ W_{\text{area}} \cdot \left(1 - \sum_{type=1}^{m} \frac{E\left[T_{\text{RB}} | C_{r,r|I}\right]}{T_{\text{LC}}} E\left[C_{r,r} | d_{l,type|\text{I}}\right] P\left[d_l = d_{l,type} | \text{I}\right] \right) \right\} \tag{1}$$

where the weight factor W_{area} is considered to define the relative importance of a single area of the community rather than the others. The evaluation is based on a seismic scenario; thus, the expected ratio is defined. The considered resilience model links the functionality losses directly to the seismic vulnerability of buildings. Finally, the building recovery time T_{RB} and the control time T_{LC} are needed, and they are defined based on the level of damage, difficulty in work activities, and available economic resources.

Based on available data, it is possible define the optimal way to analyses and evaluation. In a wide territorial scale and historical centre, damage probability matrix (DPM [11]) can be used to vulnerability characterization. The repair cost (RC) and repair time functions are derived from the damage level. The building recovery time are derived by the level of damage to a building, difficulty in work activities, available economic resource. Operatively, the seismic resilience is based on the following steps:

- Selection of the seismic scenario event.
- Evaluation of seismic vulnerability (based on a well-validated model).
- Analysis of the damage scenario.
- Evaluation of losses, restoration time, and resilience index.

Based on this approach, emergency plans become the community resilience plans containing prevision, tools to forecast losses, and strategies for prevention in a practical way.

The community's resilience function is defined as reported in Fig. 1. It is based on three different parts:

1. partial and rapid return to partial functionality in the short term (a few days)
2. pseudo-horizontal phase (planning and implantation of preliminary activities for the reconstruction process)
3. increase in functionality due to the progressive repair works.

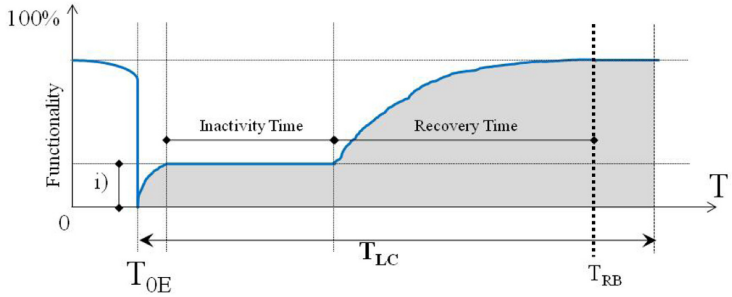


Fig. 1. Resilience-based flowchart of the adopted methodology [9].

3 The Case Study

A first practical application of the proposal is reported in this study. As a case study, the town of Miglionico (a little town in the south of Italy) is considered. It can be considered a typical mountain historical centre in Italy. The mitigation needs must coexist and overlap with the conservation requirements of historic buildings. It is located in a medium to low seismicity zone where a significantly high vulnerability (due to the lack of mitigation strategies). The investigated town has been divided into two main residential zones: the historical centre and the new zone. An earthquake scenario event is considered (Fig. 2).

The vulnerability of the buildings is investigated and their seismic damage is evaluated. In this study, damage probability matrices (DPMs) are used [11]. This approach can be considered as an optimal solution to study the seismic performances of the considered existing masonry buildings. Consequently, some typical retrofit strategies are considered regarding the retrofit goals and repair costs.

EMS-98 intensity is used as seismic input in the DPMs to obtain the damage scenario of the residential buildings under study. This approach is based on four vulnerability classes, ranging from high (class A) to low vulnerability (class D). The building stock is defined by an in-situ survey and after the typological survey [12], the seismic vulnerability evaluation carried [11].



Fig. 2. View of the Miglionico village.

The buildings are generally organised in aggregates. This is a typical urban configuration of the historical centres. The most widespread materials and structural configuration are investigated based on detailed information and interior inspections. Their structural characteristics are considered as: thickness of the masonry walls, connections between orthogonal masonry walls, and connections between masonry walls and slabs. The in-situ survey is coherent to the most commonly used survey form, based on the typological part of the survey form for usability and damage (AeDES). Structural characteristics are reported in GIS (Geograpical Information System). In Fig. 3, the results of the in-situ survey is reported. Based on the survey, six homogenous zones have been defined: four homogenous zones in the historical centre and other two zones outside the historical centre.

The high, medium, medium-low, and low vulnerabilities (vulnerability classes A, B, C, and D, respectively) are considered. The low vulnerability (class D) is assigned for the structures built or retrofitted according to the seismic classification after 1980 with modern seismic code. In Fig. 4, the vulnerability distributions are reported.

To achieve the goal of this study, one damage scenario for the entire building stock is defined. About the selected seismic intensity, the historical data show a clear lack of information until ‘800. Consequently, another event (I_{EMS98} = VIII) is selected with higher intensity. It is represent the higher return period event. Obviously, more accurate hazard analyses can be performed but they are outside the scope of this study.

Based on the building vulnerability and selected earthquake event, the estimation of the building damage is obtained. As a consequence, the losses can be estimated based on the resilience concepts. The resilience is evaluated for the building stock. In particular, the resilience’s curve has been defined for each of the six areas.

The robustness is evaluated as the residual functionality (non-damaged buildings). The recovery time is the main issue for decision-making in the retrofitting strategies. It is clearly dependent on the building types and their expected damage, socioeconomic and political conditions, and financial resources. The recovery time is assessed based on the data available from the L’Aquila earthquake (2009) and the subsequent

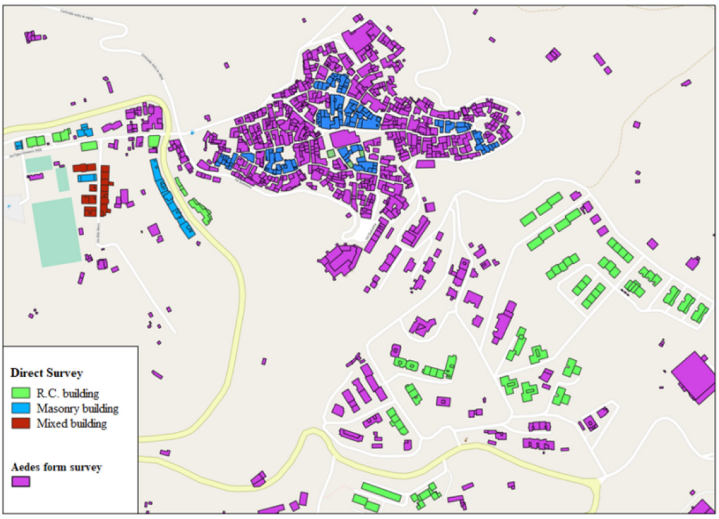


Fig. 3. In situ direct survey.

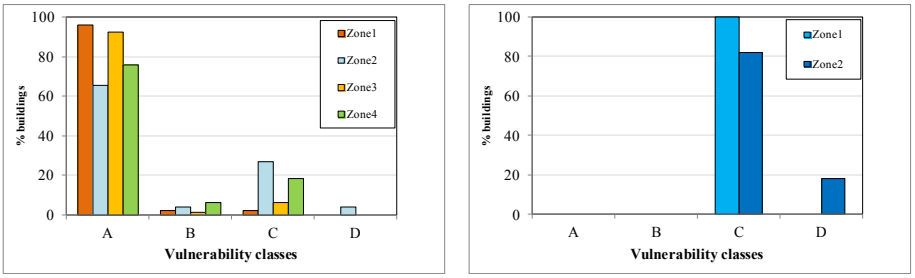


Fig. 4. Statistical distributions of the vulnerability Classes in Miglionico town.

reconstruction process [13, 14]. The available data on the progress of the reconstruction process are used to define the step functions in the current state. Rapidity is based on repair operations and their costs.

For the considered case study, the repair costs (using the price list for the Basilicata Region) have been defined considered the repair costs related to evaluated damage levels. A global repair cost has assigned and then normalized to a rebuilding cost of 1100 €/m^2. Based on the evaluated damage levels, the cost ratio $C_{r,r}$ is evaluated, which ranges between 0 and 1.

Based on the past post-earthquake data, time intervals are estimated. The inactivity time is evaluated as 21 months for the four areas of the historic centre and 9 months for the two expansion zones. The trend of the functionality curve first considers the recovery of buildings with a low damage level and then considers the recovery of buildings with higher damage levels. The considered control time is T_{LC} = 18 years.

Based on a similar approach, the recovery time is evaluated based on the required time to restore a particular damage level. In particular, the cost and time models are validated following the same procedure used in a previous study [10], i.e., based on the repair cost function and there pair time function derived from the available reconstruction process data. The set of repair work activities are evaluated in accordance with the most widespread repair and strengthening techniques [13, 14]. In Fig. 5, the obtained resilience curves are reported.

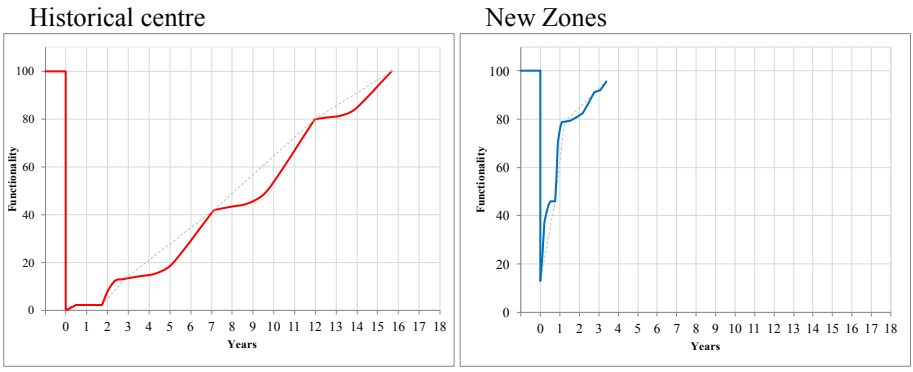


Fig. 5. Resilience performances for the historical centre and new zones.

4 Resilience-Based Mitigation Strategies

Based on resilience's concept, different mitigation strategies are defined for the investigated case study. Each strategy is able to increase resilience to varying degrees. Consequently, the key to optimal selection is a quantitative evaluation of the resilience. The basic principle to define an effective strategy to enhance the resilience is derived from the target performances for buildings after the retrofit program. To define an operative resilience plan, the resilience-based strategy is developed considering the retrofit goal (performance target).

Three different goals for seismic retrofit are considered, based on the Italian law, which is based on tax deductions for interventions. The tax deduction is linked to the seismic upgrade, based on the following improvement of the class of risk:

- 70–75% for 1 class of risk;
- 80–85% for 2 or more classes.

Independently on the type of seismic retrofit, a shift to a lower vulnerability class from the current one is considered. The class of risk is directly linked to the vulnerability class and the functionality curve is defined following the previous showed procedure. In this case a direct proportionality relationship is considered between the functionality reduction and inactivity time.

In the first strategy, one shift of vulnerability class (1-V) is considered; two shifts of the vulnerability class (2-V) and on total upgrade (TU) are considered respectively for the second and third strategy. From new vulnerability classes, news seismic scenarios are derived (I_{EMS98} = VIII). Consequently, new resilience curves are obtained (Fig. 6).

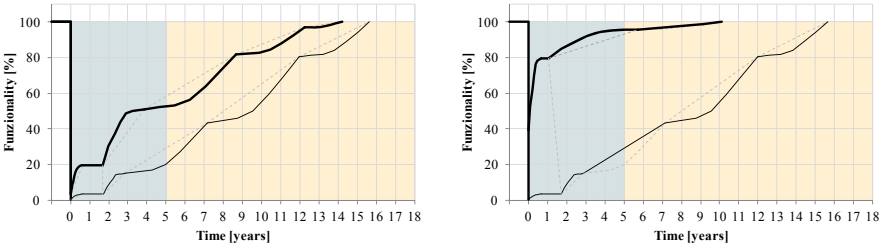


Fig. 6. One shift of vulnerability class (1-V) on the left and total upgrade (TU) on the right: resilience curves for Historical center.

Moreover, after 18 years, a community cannot be considered resilient. Consequently, different control time value (5 years) is considered and significant different RI values are obtained. In Fig. 7, the results and comparison of the current state (CS) and the considered mitigation strategies are reported.

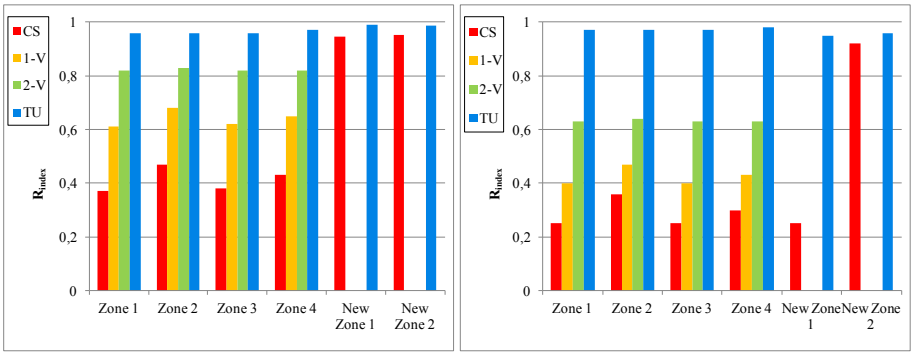


Fig. 7. IEMS98 = VIII: Effects of different seismic mitigation strategies: resilience index for T_{LC} = 18 years (left) and T_{LC} = 5 years (right).

5 Conclusion

In this study, a novel approach to civil protection and urban planning is defined. The proposal is a resilience-based approach which the concepts of resilience and their quantification are considered to direct impact on urban regulations and planning. Several interesting seismic risk reduction strategies are defined and the operational tools are determined. Although the study is based on simple data and not very accurate

information, the results highlighted a significant enhanced of the resilience of the community.

The study can be considered a work in progress and the next steps can be summarized as:

- more accurate approaches for each step of the proposed methodology as new and specific, accurate, or simplified procedures for fragility curves, seismic hazard analysis, seismic risk evaluation [15], and so on;
- effective cost – benefit evaluation of mitigation measures as indirect cost, loss of functionality costs, social costs, etc.;
- more accurate evaluation of resilience considering a multidisciplinary approaches [16];
- increase the resilience based several mitigation activities and measure to be taken in peace time (see for example [17, 18]).

The proposal should be considered as an improvement of the new Civil Italian Protection code [19], which currently neglects operational approaches based on the resilience concepts. This study proposes a new approach, which replaces the existing civil protection plan with a resilience community plan. The concept of changing from emergency plan to resilience plan should be considered as a natural evolution of emergency plan.

Several development and improvement can be defined considering more accurate tools. For example, fragility and vulnerability function can be considered for buildings, based on analytical models and accurate methodologies [20, 21]. These methodologies should be defined in uniform way for each building types, particularly in a wide territorial scale and on historical centres.

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