The Geological Risk in the Historic Centers

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Abstract. The objective of the present study concerned the determination of the geological risk of the historical center. Risk assessment is a complex issue that aims to assess different aspects of disaster damage. Traditionally, risk analysis is based on a series of historical and site data to verify the probability that an event occurs in a certain place with a certain intensity at a certain time (Orlando et al. 2005a, b). The main limitation of this method is the complexity of the mathematical models necessary to represent reality and therefore it is not always possible to make realistic assumptions about possible future scenarios. Furthermore, the interest is concentrated only on disaster scenarios deriving from a type of geological risk: either floods, or seismicity, etc.

Therefore, a new approach is needed that takes into account all aspects of geological risk as a product of danger and vulnerability, and that will serve to define the response capacity of a territorial disaster system.

A weighted combination of vulnerability and danger has finally allowed to determine the geological risk, whose planning applications urban planning and Civil Protection were examined in detail in the concluding chapters. The evaluation phase is carried out through the Analysis Hierarchy Process method.

The aim of the research is to test procedures of analysis and techniques of geological risk assessment that take into account the complexity of the geological system and the state of the building heritage.

In this work, completely independent of the vulnerability, we proceed to the definition of the danger as the sum of the geomorphological, hydraulic and seismic one.

The result is a mapping of the areas studied (information base) elaborated in a GIS environment consisting of "layers of information layers of danger" interpolated with "layers of information layers on the structural history of the building", descriptive of the state of the building heritage.

The approach is tested in a case study estimating all geological risks in the Municipality of Polignano a Mare (Puglia, Italy).

This contribution showed that the proposed method would allow the development of a methodology that ensures replicability applicable to the various centers in Puglia.

Keywords: Historical heritage · Geological risks · GIS

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1 Introduction

The historic centers of Puglia, represent a cultural and historical heritage, which are known, because well documented, the architectural characteristics and the settlement transformations that characterize them. Little or nothing is known about the security conditions of the historical building heritage. The lack of structural investigations, of data on building typologies and of their relationships with the geomorphological, stratigraphic, seismic and hydrogeological conditions on which the historical settlement insists, can lead to the degradation and insecurity of the citizens with the consequent slowing of the modern tourist evolution which is involving most of the historic centers of Puglia.

With this study, for first time, a qualitative-quantitative method is proposed for the evaluation of the risk conditions of the historical centers: the objective of this study was to identify a scientific method able to identify and evaluate the degree of geological risk of the historical centers, by virtue of the conditions, of danger and of the state of vulnerability, of the buildings that make up the historical nucleus.

The objective of the present study concerned the determination of the geological risk of the historical center of the City of Polignano a Mare (Fig. 1).

This objective was pursued by evaluating two parameters deliberately independent of each other: the vulnerability and the dangerousness of the area under study.

This represents the strong point of the experimental path elaborated as it allows the applicability of the method to different types of scenarios simply replacing, if needed, the variables that contribute to their determination.

The territory in question is bounded towards the sea by a high coast with banks, with elevations between 10 m and 25 m.

The coast is articulated by an uninterrupted series of indentations and ledges, to places with small rocks a short distance from the shore. The stretches of ripa with greater difference in height are characterized by the presence of caves and caves most often placed at sea level.

From a morphogenetic point of view, the cliff is a current form resulting mainly from the demolition of the sea and the collapses, presumably of higher Pleistocene age.

The geological structure of the old town of Polignano a mare is very simple: it is characterized by outcropping rocks consisting of calcareniticlithotypes, often fractured and otherwise resistant to mechanical erosion that rest in unconformity on stratified, karst and fractured carbonate rocks of the Cretaceous (Fig. 2).



Fig. 1. Location of the city of Polignano a Mare



Fig. 2. The unconformity between calcarenitic lithotypes (Pleistocene) and stratified, karst and fractured carbonate rocks of the Cretaceous

2 Methodology

The research is oriented to the definition of a valid method for risk assessment, elaborated through the joint analysis of the architectural and structural characteristics of the built (construction methods, materials etc.) and of the geological dangerousness conditions of the territory considering for example the areas floods, those in landslide and the presence of underground cavities.

It is necessary to establish in which way and to what extent these aspects influence and are influenced by a hypothetical catastrophic event in order to be able to reassure the systemic vulnerability and consequently the damages resulting from a catastrophic event.

Traditionally, ever since a definition of risk was proposed by the UNDRO in 1979, according to which risk is the result of the product of hazard, vulnerability and exposure scores. Therefore, by submitting a model of the receiving system to the expected stress, the possible scenarios are defined and the material damages that follow are identified. The use of these models is certainly useful for the construction of risk scenarios, but it presents at least a double order of problems: the complexity of implementing mathematical models capable of representing phenomenal reality; the impossibility of considering some aspects related to the scenarios produced by catastrophic events.

The emergence of a systemic notion of reality, the discovery of the interrelations that link living beings to each other and to their habitat, have made the notion of the isolability of the single elements of study waver (Menoni 1996).

The joint processing of data relating to the study of danger and vulnerability, through the composition of matrices, defines a scale of risk values (output), to which correspond detailed maps indicative of the degree of safety compared with the degree of vulnerability building (exposure factor and ability to respond to the calamitous event). In the first instance, these assessments will contribute to defining the priority safety measures.

The evaluation phase is carried out through the Analysis Hierarchy Process method (Giangrande 2001), which allows to determine the benefits/costs ratio of a project when it is not possible to evaluate the advantages and disadvantages that would derive from its realization in purely monetary terms (Saaty 1988, 1990; Figueira et al. 2005).

The multi-criteria analysis lends itself to our study as it represents a technique capable of simultaneously taking into account a multiplicity of aspects specific to the problem being faced, both qualitative and quantitative, bringing out the different points of view of the actors involved. It allows, therefore, to determine the relationship between the geological risk and the resilience of an area of historical value, when it is not possible to determine the degree of security with only sector information, i.e. relative to the sole danger or vulnerability only.

The evaluation process first of all involves the construction of a dominance hierarchy, a reticular structure articulated on one or more levels representative of the objectives. The first level contains the general objective of the evaluation (geological risk). Each primary level could be subdivided into lower levels identifying more specific objectives (seismic risk, hydrogeological risk, volcanic risk etc.). The actions to be evaluated (danger and vulnerability) are located at the base of the hierarchy and are directly linked to the more specific objectives (terminal objectives). A hierarchy, in addition to the objectives and actions, may contain other elements of the decision-making process: among these, the actors of the process (the exposure based on the degree of use, the use of the property, etc.) must be included.

The result is a mapping of the areas studied (information base) elaborated in a GIS environment consisting of "layers of information layers of danger" interpolated with "layers of information layers on the structural history of the building", descriptive of the building status of the historical centers.

3 Results and Discussion

Polignano a Mare is a town in the metropolitan city of Bari in Puglia with a resident population as of 1 January 2016 of 18˙023 inhabitants (Istat data).

Located on the Adriatic side of the Murgian plateau, in an intermediate position between the plain of Bari (to NO) and that of Fasano (SE), the Polignano's territory occupies an area of just over 65 km^2 characterized by an almost triangular shape that leads to border with the territories of Mola di Bari, Conversano, CastellanaGrotte and Monopoli.

Its population increases up to 5 times during the summer period as it has a strong tourist value.

The coastline develops in a NO-SE direction of about 16 km: proceeding from north to south, after a couple of kilometers of low coast, the coast continues with a crag stretch whose height varies between 5 m and 10 m, interspersed with narrow and long coves, more or less wide coves and natural caves. The crag reaches heights close to 24 m at the inhabited area (Fig. 3).



Fig. 3. The cliff of Polignano a Mare

This town was chosen as a case study as the strong tourist value attracts many visitors and therefore lends itself very effectively to the need for a risk assessment, to which the users of the historic center may be exposed.

The historic center of Polignano a Mare has occupied an offshoot of the coast characterized by a cliff between the Monachile Lama, the Bastion of Santo Stefano and the GrottaPalazzese. It has a perimeter that can be estimated around 750 m linear and an area of approximately 32,500 m^2.

All the buildings have been identified by combining the buildings in aggregate and distinguishing them with a progressive number (Fig. 4). For each merger a form has been compiled which defined the construction methods, the structural conditions as well as the use and functionality. All the data contained in the forms have been merged thanks to the use of the GIS to an information database.

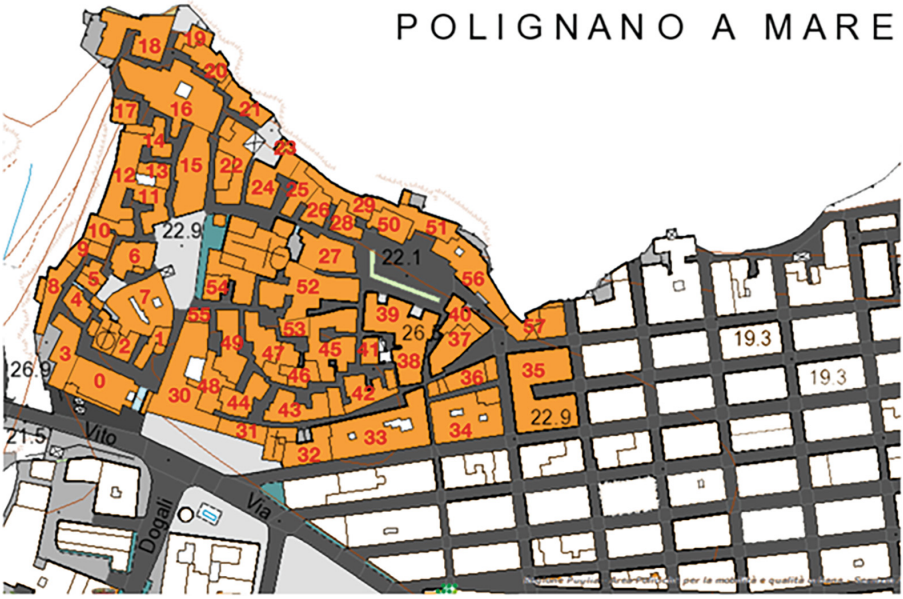


Fig. 4. In red identification and numbering of the buildings considered (Color figure online)

In this work the vulnerability is indicated, as the intrinsic capacity of a given element (building or aggregate buildings) to suffer damage due to a significant event, whose entities appear to be a function of the intensity of the phenomenon itself.

Therefore, in order to determine the vulnerability, an analysis of the state of the building heritage (buildings for the vast majority of masonry structures) was necessary, accompanied by an assessment of the exposure, or of the set of relations that are established between the building and the user.

After having carried out the analysis of the state of the building heritage falling within the historical center of Polignano a Mare and after evaluating the exposure of the elements it is possible to combine the two aspects in order to obtain an overall assessment of the vulnerability.

Combining the three classes used to define the state of the buildings with the three exposure classes, nine vulnerability classes are obtained (Fig. 5). The vulnerability map is shown in Fig. 6.

The geomorphological danger of the municipality of Polignano a Mare is the presence of a cliff that characterizes a coastline with a strong regressive tendency (due to erosion) along which we observe the spread of sea caves (Fig. 7).

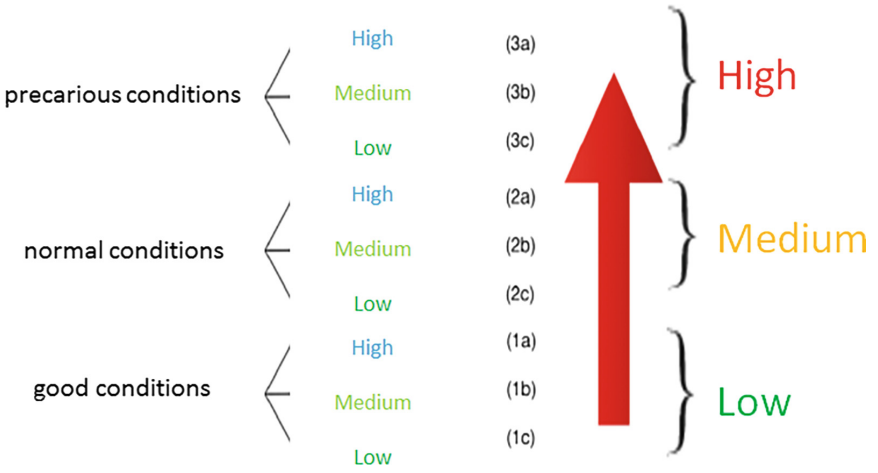


Fig. 5. The nine classes obtained for vulnerability

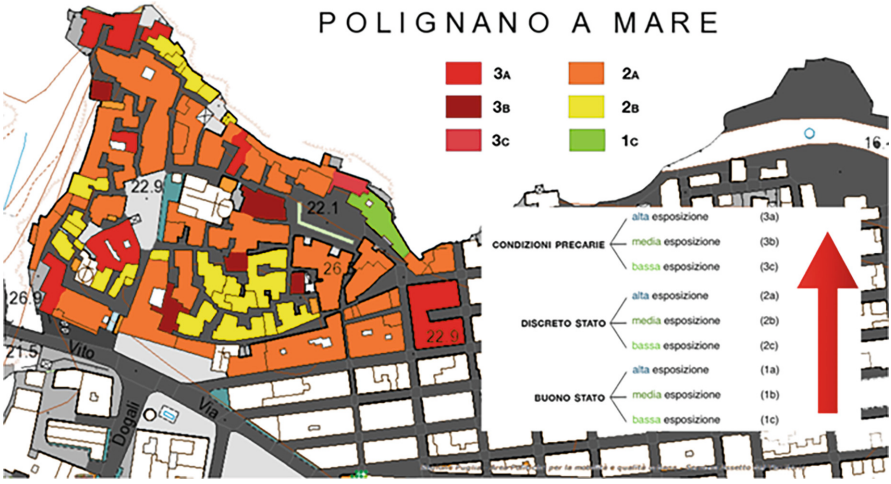


Fig. 6. Vulnerability map

Hazards have been defined depending on the distance from the caves and from the coast. In addition, the perimeter of the areas of hydraulic hazard taken from the hydrogeological planning plan of the district authority of Southern Italy is indicated (Fig. 8).

Belonging to the 4th seismic zone (very low seismicity) and the absence of obvious significant variations in the local seismic response did not lead to further distinctions of a specific nature.

The combination of the 3 hazard classes with the 3 vulnerability classes initially generated 9 risk classes.



Fig. 7. The cliff coast with the widespread presence of sea caves

One of the choices characterizing the experimental path concerned the definition of a hierarchy for the 9 classes: having chosen to assign the same "dignity" to both vulnerability and danger, the following hierarchical scale was obtained, in turn reorganized into 3 different degrees of risk.

To define the danger of each building in the area using the QGIS software, the building was located within the digital map (Fig. 10).

We can talk about geological risk when in a certain area there are dangerous conditions and these interfere with situations of overt vulnerability.

More generally, it can therefore be argued that the geological risk is the set of situations affecting people and assets deriving from the action of slope dynamics, water courses, avalanches and all those processes that, in a real way or potential, they can destabilize the conditions of territorial balance.

From the experimental point of view, the geological risk characterization is fundamentally based on the construction of a matrix able to combine vulnerability analysis with danger analysis.

The combination of the 3 danger classes with the 3 vulnerability classes initially generated 9 risk classes.

One of the choices characterizing the experimental path concerned the definition of a hierarchy for the 9 classes: having chosen to assign the same "dignity" to both vulnerability and danger, the following hierarchical scale was obtained, in turn reorganized into 3 different degrees of risk (Fig. 11).



Fig. 8. In blue the perimeter of the areas of hydraulic hazard (Color figure online)



Fig. 9. The last event of flooding in Polignano a Mare

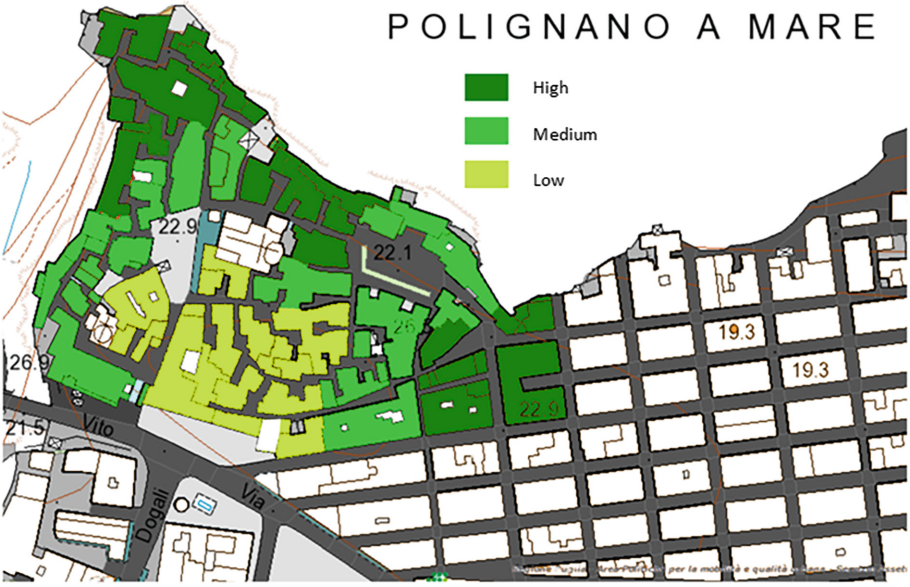


Fig. 10. Dangerousness map

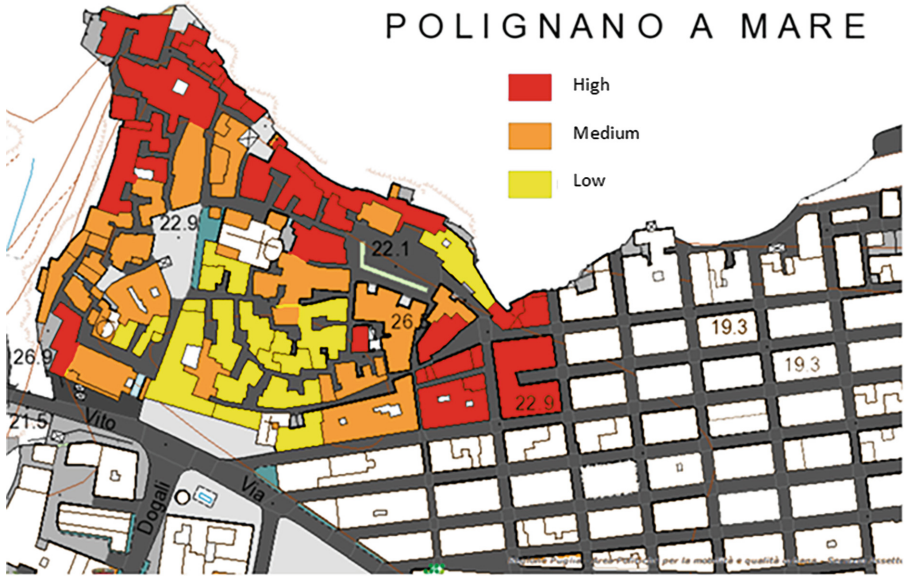


Fig. 11. Risk map

4 Conclusion and Results

The objective of this study was to determine the geological risk of the historic. the case study considered is the historic center of Polignano a Mare (Puglia, Italy).

This objective was pursued by evaluating two parameters deliberately made independent of each other: the vulnerability and danger of the area under study.

The result obtained is a mapping of the areas studied (information base) elaborated in a GIS environment consisting of "layers of information layers of the hazard" interpolated with "layers of information layers on the structural history of the building", describing the state of the buildings' Heritage of the Centers historians.

Furthermore, with regard to the same scenario, the method can be easily improved by replacing and/or implementing the analysis with new variables that are more influential than those already considered.

In the light of the results obtained it is possible to observe how the method is reliable, since the distribution of the risk classes in the area examined represents the actually more plausible one, taking into account both the complexity of the hazards and the vulnerability.

It is necessary to specify that the map obtained does not indicate imminent dangers or risks of collapse but provides a view of the sensitivities. The public administration has at its disposal a tool that allows identifying the priorities in mitigation actions.

An application is aimed at civil protection: it is possible to identify the most sensitive points and therefore the most effective escape routes and waiting areas, shelter and gathering rescuers.

This contribution has shown that the proposed method would allow to develop a methodology that ensures a replicability applicable to the different centers of Puglia.

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