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Special Issue 1.2021

The Emergency Plan for the use and management of the territory

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THE EMERGENCY PLAN FOR THE USE AND MANAGEMENT OF THE TERRITORY

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The cover image is a photo of the landslide that hit the municipality of Amalfi (Italy) in February 2021.

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Emergency and spatial planning towards cooperative approaches

Challenges and opportunities in the multi-risk area of Campi Flegrei

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Abstract
The dependency of risk scenarios on the dynamics of urban transformation clearly highlights the need of ensuring a closer cooperation between spatial and emergency planning processes. So far the relationships between the two processes have been rather limited, leading at most to the transposition of the emergency plans' indications in the spatial plans. Nevertheless, more cooperative approaches would be crucial to increase safety, resilience and sustainability of human settlements, above all when they are threatened by different hazard factors. In order to explore barriers and opportunities for a better cooperation between emergency and spatial planning processes, this contribution will focus on the Campi Flegrei in the Campania Region (Southern Italy): a densely populated area, hosting a significant historical, cultural, and natural heritage, and prone to volcanic, seismic and hydrogeological hazards. The case study area is also characterized by the coexistence of emergency and spatial planning tools acting on different geographical scales, developed by different actors and not always fully consistent each other. In detail, based on the analysis of the location and accessibility of emergency facilities, crucial to guarantee an effective response in the aftermath of hazardous events, we will here highlight both the main criticalities of the emergency plans recently carried out for the selected Municipalities and the difficulties and opportunities related to a better integration between spatial and emergency planning at municipal scale.

Keywords
Emergency planning; Spatial planning; Multi-risk areas.

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1. Emergency and spatial planning: what opportunities for a more effective cooperation?

The importance of carrying out in peacetime emergency plans capable of increasing the capacity to cope with the numerous critical issues arising in the aftermath of hazardous events – from the evacuation procedures to the first aid to the hit populations – has been stressed by numerous scholars over the last two decades (Perry and Lindell, 2003; Lindell and Perry, 2007; Alexander, 2015). The definition in advance of expected risk scenarios, involved stakeholders, intervention procedures as well required and available resources are now commonly interpreted as prerequisites for ensuring the timeliness and effectiveness of the emergency response (Lindell, 2013).

However, the effectiveness of the emergency management largely depends on the overall features of the complex process, which has in the emergency plan its main outcome, aimed at increasing the response capacity of communities and local institutions in the aftermath of the event (Menoni, 2013).

Among the key requirements of an effective emergency planning process, the dynamic features of the process itself and the flexibility of the planned actions must be mentioned. Since the primary goal of an emergency plan is to offer operational responses to the different risk scenarios that may occur in a given area, first of all the knowledge base, which risk scenarios are based on, has to be constantly updated: risk scenarios are, indeed, far beyond from being a static picture, since they constantly evolve due to the change both of the hazard features and of the characteristics of the potentially hit areas (Di Lodovico & Di Ludovico, 2018).

Furthermore, the foreseen measures should be flexible and adaptable in order to better cope both with the uncertainty, inevitably linked to the available risks knowledge, both with the likely occurrence of unexpected events or impacts (FEMA, 2010) that often result from complex chains of primary and secondary events and related impacts (Galderisi, 2020).

Besides, an emergency plan represents the outcome of a multi-actor process, based on the active involvement of a wide range of stakeholders: from the multiple actors in charge of different sectors of emergency management (decision makers at local, regional and national levels; managers of critical infrastructures, etc.) to the communities potentially affected by the different emergency measures. Thus, a further requirement of an effective emergency planning process is the capacity of identifying in advance the involved stakeholders, their specific responsibilities and tasks, the intervention procedures and cooperation mechanisms, the features of the communities potentially affected by a given hazard, such as the factors that might affect their response in emergency phase (age, disability, language barriers, etc.), and the potential needs arising from the different components of a community in the aftermath of the event. A direct engagement of local communities in the emergency planning process should allow not only to increase the sense of responsibility of community members, but also to build up a more in-depth knowledge of their heterogeneous background, experiences and expectations, revealing in many cases fragilities that are difficult to infer from the traditional statistical analyses of social fabric (FEMA, 2011).

According to the main features of an effective emergency planning process previously outlined, it seems appropriate to question whether and how this could benefit from a greater cooperation with spatial planning processes. To date, unfortunately, the relationships between emergency or civil protection plans – as currently defined by the 2018 Civil Protection Code – and spatial plans are generally limited to the transposition into the latter of the emergency areas established by the former (waiting areas, reception areas, storage areas) and to the use of data and information provided by spatial plans (when available) in order to identify the assets exposed to different hazards in the civil protection plans. However, some of the disasters that affected Italy in the last decade brought out the numerous criticalities arising from the fragmentation of competencies and plans in the field of risk management and spatial planning, pushing towards a more effective cooperation. A relevant example in this line is the multilevel collaboration among municipalities, provincial and regional authorities carried out in the Region Emilia Romagna. Following the 2012 earthquake, the Province of Modena took a leading role, ensuring an operational support to all the affected municipalities, guiding them in identifying the network of the strategic elements at the provincial scale and, in some cases, in integrating the results of the analyses carried out in the municipal spatial plans (Manicardi et al. 2014).

Hence, renewed approaches both to emergency planning – aimed at improving its consistency with the main requirements currently provided by scholars and institutional guidelines – and to spatial urban planning – aimed at ensuring a more effective integration of risk reduction issues in planning tools – could lead to new relationships, cooperative and synergistic, among these tools, facilitating meanwhile the development of integrated policies, capable of increasing sustainability and safety of human settlements to the various risk factors they are exposed to (Francini et al. 2018b).

The need of considering risk not as a 'sector' but as a crucial issue of the regular development policies and of promoting an integrated governance to better dealing with disasters are not new issues, since they have been stressed by scholars since the early 2000s (Christoplos et al., 2001; Djalante, 2012). Furthermore, the 2030 Agenda for Sustainable Development, and namely the goal 11 "Make cities and human settlements inclusive, safe, resilient and sustainable", clearly emphasizes the need of "adopting and implementing integrated policies and plans" to improve settlements' resilience to disasters, as well as of developing and implementing "in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels".

Moreover, it is worth noting that both the considered planning processes are confronted with "spatial" issues (Alexander, 2015), related to the singling out of intervention areas as well to the location in safe and equally accessible areas of facilities serving the community in peace or in crisis times.

Currently, most of the regional guidelines for emergency planning in Italy direct to the consultation of spatial plans for a precise identification of the exposed assets, while very few refer to the need for Geographical Information Systems (GIS) capable of collecting, processing and integrating data and information from heterogeneous sources able to support all the decision-making processes aimed at reducing risks, managing emergencies and improving citizens' awareness on the risk features of the territories they live in (Regione Puglia, 2019). Hence, the building up of shared and integrated GIS, capable of supporting both territorial and emergency planning could represent a relevant step towards a better cooperation. The risk scenarios outlined by the civil protection plans, based on detailed analyses at local scale of the different natural or man-made hazards, could represent an important information, far more detailed than those generally used and derived from the first level sectoral plans, for risk-informed urban planning processes. On the opposite, the detailed analysis of the heterogeneous features of the local context set up by the spatial plans could provide a more in-depth knowledge of the multiple dimensions of vulnerability – connected to spatial, functional, social, economic dynamics – crucial to a more effective emergency management. The post-event crisis often reveals, in fact, unexpected functional, social and systemic vulnerabilities that, if not adequately and timely addressed, may significantly increase secondary or indirect damage.

A further area of potential cooperation between the two planning processes relates to the choice of the most adequate areas and routes to be allocated to the civil protection needs. Currently, emergency areas and routes identified by civil protection plans are incorporated in spatial plans, which assign them compatible land uses, aimed at ensuring their adequate maintenance in peacetime. However, these areas and routes, which have to be identified and located according to specific requirements (morphological and dimensional characteristics, accessibility criteria, safety, underground services, etc.), could represent key elements of wider networks of public urban spaces – open spaces, green areas, urban facilities – and sustainable mobility paths. These networks, adequately designed and equipped also in terms of furnishings and signs, could be crucial both to increase quality and livability of settlements in peacetime and to improve their response in crisis times. Yet, such a possibility would require a shift from the traditional focus of civil protection plans on individual elements, functional to the emergency management, towards a multi-objective perspective addressed to redesign the whole urban system to better cope with the heterogeneous demands that a community poses, in peace and in crisis times.

Finally, the hoped-for transition of emergency planning processes, also required by the 2018 Civil Protection Code, from top-down processes to more inclusive and participatory processes, capable of ensuring a greater integration between expert and local knowledge as well as of envisioning solutions shared with local communities, could open up new opportunities for cooperation. The engagement of local communities in decision-making processes has represented, in fact, a priority for spatial planning since the late 1990s: in this field numerous methods and formats have been developed, which could be usefully translated and applied into emergency planning processes, so far largely interpreted as technical processes, mostly entrusted to experts.

Summing up, the enhancement of cooperative relationships between spatial and emergency planning processes could contribute to increasing the quality and effectiveness of both, laying the foundations for building up safer cities, in which development/regeneration choices might actively contribute both to risk reduction and to the design of networks of public spaces that, based on criteria of flexibility and redundancy, could answer multiple needs, including that one of ensuring a more effective and immediate response of urban systems in case of hazardous events.

2. Spatial and emergency planning in a multi-risk environment: the case study of Campi Flegrei

In respect to the previously discussed features of emergency plans and to the desirable synergies between emergency and spatial planning processes, we will focus here on the interactions between these processes in the Phlegraean Fields (Campi Flegrei) (Fig. 1): one of the most critical areas within the metropolitan area of Naples, due to its multi-hazard features combined with a high population density and a rich historical, archaeological and natural heritage. The area is a vast volcanic caldera (with a diameter of about 10 km), partly emerged and partly submerged, whose volcanic activity has been characterized by series of explosive eruptions occurred from vents scattered inside the caldera (Macedonio et al., 2012). The peculiarity of the Phlegraean Fields, compared to the volcanic areas characterized by a central volcanic system as the Vesuvius, is that in this case the area of possible opening of eruptive vents is very large, with significant consequences in terms of extension of the potentially affected territory.

The Decree of the President of the Council of Ministers, issued in 2016 and titled "Provisions for updating the emergency planning for volcanic risk of Phlegraean Fields", divided this area into two zones:

- a red zone, exposed to pyroclastic flows and including the whole municipalities of Monte di Procida, Bacoli, Pozzuoli and Quarto and part of the municipalities of Naples, Marano and Giugliano in Campania; this area currently hosts about 500,000 inhabitants;
- a yellow zone, exposed to pyroclastic fallout, which involves the remaining part of the municipal territory of Naples, except the eastern area of Ponticelli, and numerous municipalities located north of Naples (Marano, Mugnano, Calvizzano, Villaricca, Melito, Casavatore).

As mentioned above, the Phlegraean Fields represent a paradigmatic example of multi-risk area: in addition to the volcanic hazard, this area is prone to several hazard factors including earthquakes, floods and landslides. All the Municipalities fully included in the red zone show a maximum ground accelerations value ranging from 1.55 and 1.70[1]: thus, all of them are classified as seismic zone 2. These Municipalities are also characterized by high values of population density and host more than 300 buildings and sites of high architectural or archaeological value.

[1] Acceleration with probability of exceeding 10% in 50 years (ag). Further details on the seismic classification of the Italian territory are available at: http://www.protezionecivile.gov.it/attivita-rischi/rischio-sismico/attivita/classificazione-sismica [Accessed 1/12/2020]

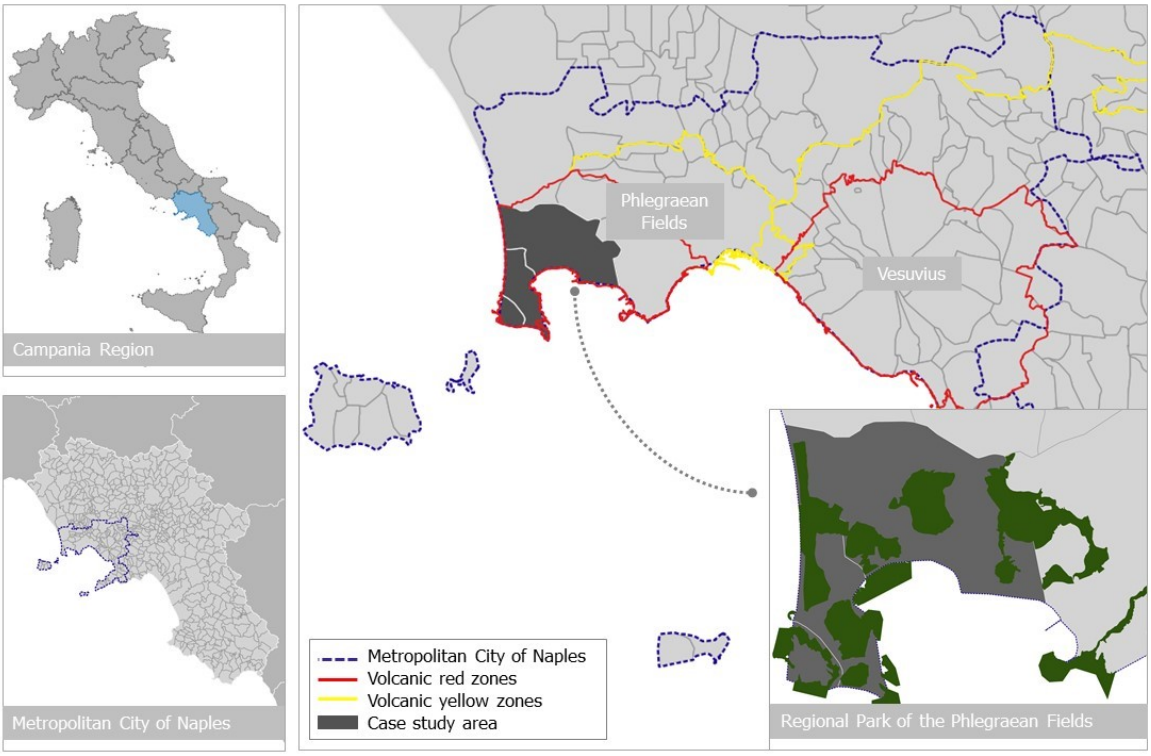


Fig.1 The case study area and its territorial context

Moreover, in the considered area about 65% of residential buildings were built before 1980: it is worth reminding that the first Law (the Law 64) providing a national seismic classification of the Italian territory as well as the first seismic building codes was issued in 1974. Furthermore, more than 6% of the population resides in areas characterized by high and very high landslide hazard levels (P3 and P4), while about 2% in areas characterized by medium or high hydraulic hazard levels (P2 and P3)[2].

The features of the case study area and the numerous hazard factors it is prone to would have required the implementation of measures aimed at reducing its exposure and vulnerability, especially through spatial plans capable of limiting building growth, at least in the areas at higher risk.

Unfortunately, spatial planning in the metropolitan area of Naples has been for long characterized by a significant inertia both on a territorial and on a municipal scale: for example, the Metropolitan Territorial Plan – which is the review of the previous Territorial Coordination Plan drawn up at Provincial scale even before the establishment of the Metropolitan city – is still waiting for a final approval, while in 2020 the Strategic Metropolitan Plan has been approved. This document, despite recognizing the multi-risk features of the metropolitan area, provides an articulation of the area in five homogeneous zones, which does not fully reflect the different risk features of the metropolitan territory, namely for the two large volcan areas of Vesuvius and Phlegraen Fields.

The spatial urban plans in six of the seven municipalities of the red zone are prior to the regional planning law issued in 2004, dating back in some cases even more than twenty years ago.

Only the municipality of Monte di Procida has approved a new spatial plan in 2020, while the municipalities of Bacoli and Quarto have carried out a preliminary plan in 2015 (Tab. 1).

Similarly to other cases, such as the Vesuvius and the Etna (Curci, 2020), also in the Phlegraean Fields, the limited attempts to counteract the building growth have been entrusted to the Landscape Plan of the Phlegraean Fields approved in 1996 and by now largely outdated, to the establishment of numerous protected

2 Data source: https://www.istat.it/it/mappa-rischi [Accessed 24/11/2020]

areas included in the Natura 2000 protected areas network and to the Regional Park of the Phlegraean Fields, established in 2003 and still lacking a specific plan.

Municipalities	Plan in force	Plan in progress
Bacoli	Spatial Plan 1976	Preliminary Plan 2015 (update 2017)
Giugliano	Spatial Plan 1985	-
Marano di Napoli	Spatial Plan 1987	-
Monte di Procida	Spatial Plan 2020	-
Napoli	Spatial Plan 2004	Preliminary Plan 2020
Pozzuoli	Spatial Plan 2002	-
Quarto	Spatial Plan 1994	Preliminary Plan 2015

Tab. 1 Spatial Plans in the municipalities of the red zone: updating status

However, despite the severe constraints provided since the end of the Nineties by landscape-environmental planning, in the time span 2006 and 2018 the extension of residential urban fabrics[3] has increased of about 2,8% in the red zone (Fig. 2).

The limited measures aimed at reducing or at least avoiding a further increase of the already significant exposure of the Phlegraean Fields and the lack of interventions to reduce its vulnerability in the face of the heterogeneous hazards that this area is exposed to, assign a difficult task to emergency planning. The latter is required, in fact, to outline measures able to cope with complex risk scenarios in a context where the high residential density is combined with a limited risk perception (Ricci, Barberi et al., 2013).

Very few actions have been so far put in place in order to improve local risk awareness: in particular, it is worth mentioning the information campaign "I do not risk", promoted by the Civil Protection in 2019, which included events specifically devoted to the volcanic risk in the Phlegraean Fields.

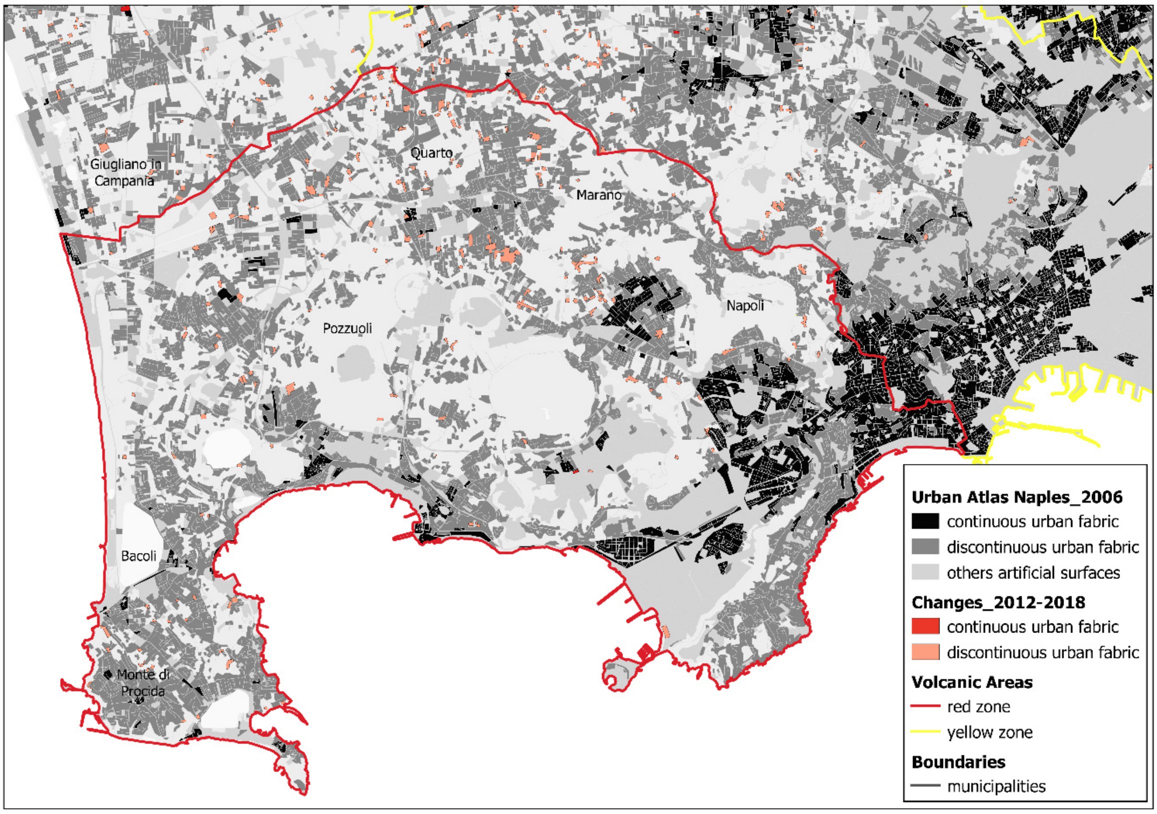


Fig.2 Changes in continuous and discontinuous urban fabric in the Phlegraean Fields between 2006 and 2018

[3] Continuous and discontinuous urban fabrics have been distinguished according to the classification provided by Urban Atlas. Further details are available at: https://land.copernicus.eu/local/urban-atlas [Accessed 1/12/2020]

In this complex area, emergency planning has been articulated in two levels:

- the Phlegraean Fields National Plan;
- the Municipal Civil Protection Plans.

The first one, aimed at increasing the response capacity in the face of the likely volcanic risk scenarios, is the result of a long process, started in 2001, which led to: the subdivision of the Phlegraean Fields into two areas – the red and the yellow one – in relation to the expected eruptive scenarios; the definition of the alert levels; the development of the Evacuation Plan for all the Municipalities included in the red zone, where the preventive evacuation is identified as the only measure to ensure the safety of the population. Moreover, the "Provisions for updating the emergency planning for the volcanic risk of the Phlegraean Fields", issued in 2016, identified the twinning scheme between the municipalities of the red zone and selected Italian regions. Finally, the Resolution of the Campania Region 547, issued in September 2018, definitely approved the Evacuation Plan. The latter, carried out by the Campania Region with the support of the Campana Mobility Infrastructure and Networks Agency (ACaMIR) and in collaboration with the concerned Municipalities, outlines the procedures aimed at ensuring an assisted evacuation, in 72 hours, of the entire population that, through a limited number of "gates" identified by the Plan, should be firstly transferred from the "waiting areas", identified by the Civil Protection Plan of each Municipality, to the "meeting areas", located outside the red zone, and then to the "first points reception" located in the twin regions (Fig. 3). In the yellow zone, essentially affected by pyroclastic fallout as well by ash accumulation phenomena, the definition of specific emergency measures is entrusted to the municipal civil protection plans: these measures should be flexible, due to the difficulty of precisely delimiting the area that will be actually affected by pyroclastic fallout, which strongly depend on winds' directions and on the severity of the eruption. As far as municipal civil protection plans are concerned, to date all the municipalities in the red zone, also thanks to the funds put in place by the Campania Region starting from 2014, have adopted a plan or have started, at least, the updating process (Tab.2). Among these plans, three out seven were drafted before the Guidelines for the preparation of the Municipal Emergency Plans[4] issued by the Campania Region (DGR 146 -27.05.2013). Moreover, five of them have been updated after the "Provisions for updating the emergency planning for the volcanic risk of the Phlegraean Fields" issued in 2016, in order to consider the most recent emergency areas defined by the National Plan. In brief, the emergency planning process undertaken for the Phlegraean Fields undoubtedly shows some elements of interest. Among them, the nature itself of the planning process: a multi-scale and multi-actor process that has been developed thanks to a close collaboration between different institutional levels (from national civil protection to individual municipalities). However, it also shows some significant weaknesses.

Municipalities	**Approval date**	**Funding 2014**	**Funding 2017**
Bacoli	2016 (volcanic update 2018)	YES	-
Giugliano	2017 (*being updated*)	YES	YES
Marano di Napoli	2013 (volcanic update 2018)	YES	-
Monte di Procida	2017 (volcanic update 2019)	YES	-
Napoli	2012 (seismic update 2019)	YES	YES
Pozzuoli	2016 (volcanic update 2020)	YES	YES
Quarto	2012 (volcanic update 2018)	YES	YES

Tab.2 Civil Protection Plans in the red zone's municipalities: updating status

4 It is worth noting that the Regional Guidelines, in accordance with Law 100/2012, referred to the Municipal Emergency Plans. It is only with the Civil Protection Code D. Lgs. 1/2018 that these tools have been defined as Municipal Civil Protection Plans.

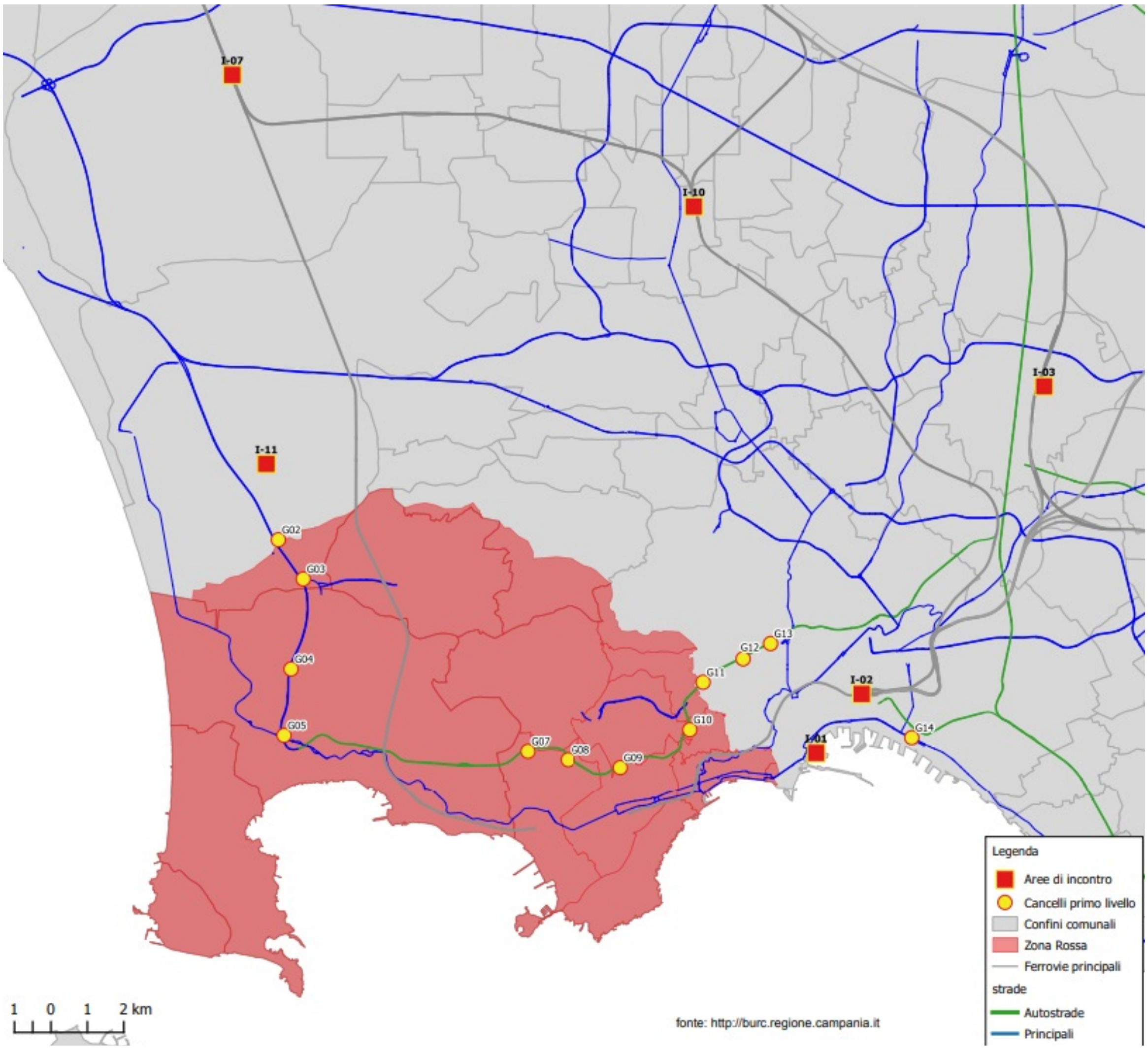


Fig.3 The evacuation gates (yellow), meeting areas (red) and main road networks (green and blue) identified by the National Plan in the red zone

First of all, while the emergency planning process at national/regional scale has been underway for about twenty years, with numerous updates, only some civil protection plans at municipal level have been recently approved and some of them are outdated compared to the regional guidelines for emergency planning, to the most recent regulatory innovations introduced by the Civil Protection Code, and to the most recent provisions of the National Emergency Plan for the Phlegraean Fields.

Still, despite the multi-actor nature of the emergency planning process, the involvement of local population is still limited and essentially attributable to the implementation of some information campaigns. This is a not a trivial issue, especially in an area that between the Seventies and Eighties of the last century witnessed a difficult and still largely debated experiences of "forced evacuation". We refer, in particular, to the precautionary measures due to the worsening of the bradyseism phenomenon, which led to the forced removal of the population from the Rione Terra and the historic center of Pozzuoli and to its permanent relocation into new neighborhoods placed at the outskirts of Pozzuoli. These interventions, carried out in the lack of an overall vision of the urban development due to the lack of a municipal masterplan, resulted into significant and long-term social and economic damage for the local population. In particular, the lack of updated spatial planning tools at different scales has led not only to the consequent lack of rules capable of reducing, or at least of not increasing, the exposure and vulnerability of this vast territory, but also to a difficulty in developing an effective cooperation between emergency and spatial planning processes.

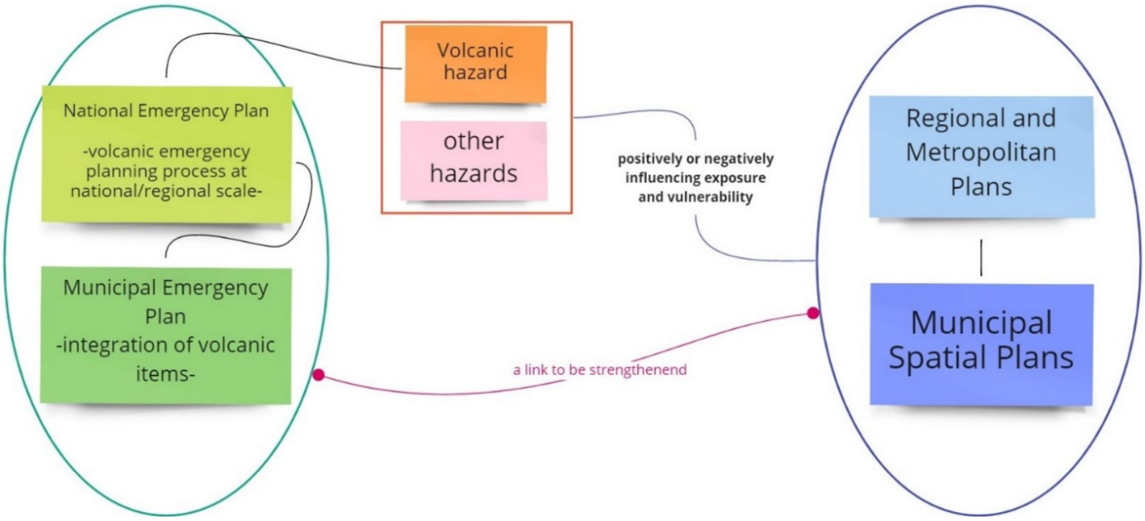


Fig.4 The complexity of a multi-scale and multi-actor decision-making process

To date, in fact, only the municipality of Monte di Procida has a spatial urban plan drawn up after the approval and the update of the civil protection plan.

Summing up, the peculiar context of the Phlegrean Fields clearly highlight the difficulties of building up a multi-scale and integrated decision-making processes. In this area, the complex issue of better cope with volcanic risk requires a close interaction among emergency plans at different geographical scales; moreover, emergency plans at municipal scale have to take into account the multiple hazards affecting this area as well as their likely chains. Finally, emergency planning would largely benefit from a closer integration with planning tools at different scales – so far essentially missing – capable of reducing exposure and vulnerability features of this area to the multiple hazard factors (Fig. 4).

3. How effective are emergency measures in the red zone? A focus on three Municipalities in the Red Zone

As previously highlighted, the lack of effective measures aimed at ensuring a preventive reduction of the multiple risks that the Phlegraean territory is prone to assigns a difficult task to emergency planning, called to set up measures able to face complex risk scenarios, in a territorial context characterized by a high concentration of population (to date the inhabitants of the red zone are about 500 thousand) and assets as well as by a road network not fully adequate to guarantee equal access to the emergency facilities and, above all, to the gates identified by the National Plan for the evacuation of the resident population in case of volcanic eruption.

In order to better understand the main criticalities of emergency planning in the Phlegraean area, a rough evaluation of the effectiveness of the main forecasts of current emergency planning tools has been carried out, with reference to three municipalities totally included in the red zone: Monte di Procida, Bacoli and Pozzuoli. All the three considered municipalities are affected by different hazards: in addition to the likely eruptive scenarios identified by the National Plan for the Phlegraean Fields, they are all classified as zone 2 in the regional seismic classification and characterized by large areas prone to hydraulic and landslide hazards. Finally, as mentioned above, only Monte di Procida has approved, in 2020, the spatial urban plan.

In detail, the attention is here focused on the strategic facilities for emergency management identified by both the National Plan for the Phlegraean Fields and the Civil Protection Plans of the Municipalities of Bacoli, Monte of Procida and Pozzuoli. Taking into account that emergency facilities are closely connected to each other as well to the other elements of the urban system, the following issues have been specifically examined:

- the "safe" location of the emergency facilities as well of the road infrastructure connecting them to the residential areas;

- the accessibility of the waiting areas identified by the Civil Protection Plans and of the evacuation gates identified by the National Plan from the residential areas;
- the redundancy of the roads ensuring both the access of rescuers to the residential areas and the evacuation of these areas in case of hazardous events.

The aforementioned steps have been carried out through a GIS-based analysis. The initial heterogeneous dataset, composed by different sources (Municipal Emergency Plans, National Evacuation Plan, Central Campania Regional Basin Authority, ISTAT census) has been organized in a set of layers and integrated with additional layers deriving from Open Street Maps (OSM) and the GIS of the Campania Region for the road network and from the Corine Land Cover and Urban Atlas for the characterization of urban areas (Fig. 5).

3.1 Is the location of emergency facilities and infrastructure safe?

With reference to the strategic buildings and infrastructures identified by the Municipal Emergency Plans, it is crucial to firstly examine the location of these elements, in respect to the hazard and vulnerability features of the area.

It should be reminded, in fact, that both of them should be located in safe areas: this implies that they should be located in areas which are not affected by any hazard and, especially in case of seismic events, they should be also located in areas not highly vulnerable to earthquake impacts. In the latter case, indeed, the collapse, even partial, of buildings overlooking the waiting areas or the roads connecting emergency buildings and areas with the residential areas could reduce the functionality of these elements, limiting their usability or accessibility.

Since both strategic areas and buildings, and road infrastructures are largely exposed to climate-related events (Markolf et al. 2019), their location has been examined in respect to both the distribution and levels of hydraulic and landslide hazards, as identified by the Central Campania Regional Basin Authority (Fig. 6), both the seismic vulnerability levels of the residential building stock (Fig. 7). As shown in figure 6 all the strategic facilities (strategic operation centers, municipal police offices, health facilities, ports and heliports, etc.) are located outside the areas prone to hydraulic and landslide hazards, except some waiting, reception and gathering areas, even though all of them are located in areas characterized by low levels (P1) of hydraulic or landslide hazards (Fig. 6).

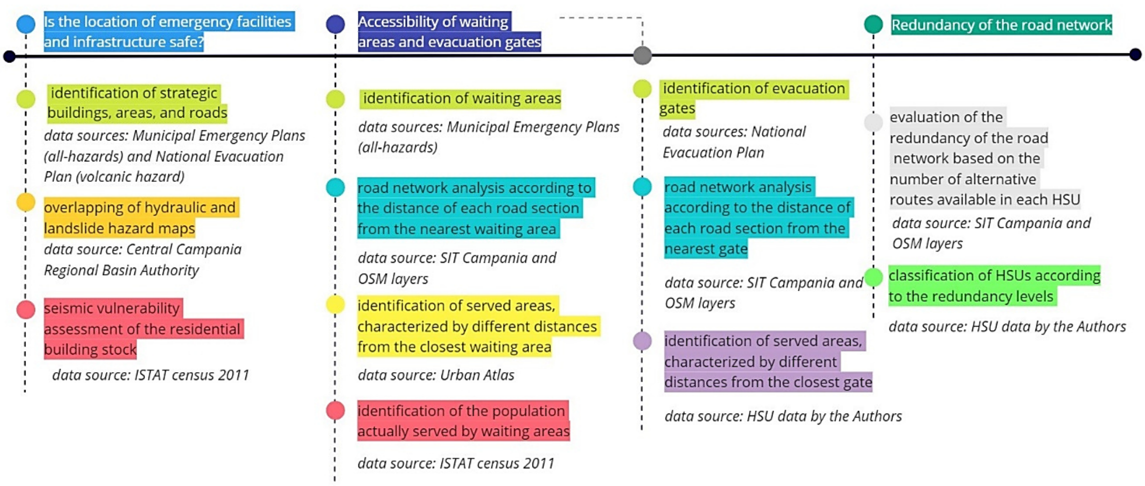


Fig.5 The methodological steps

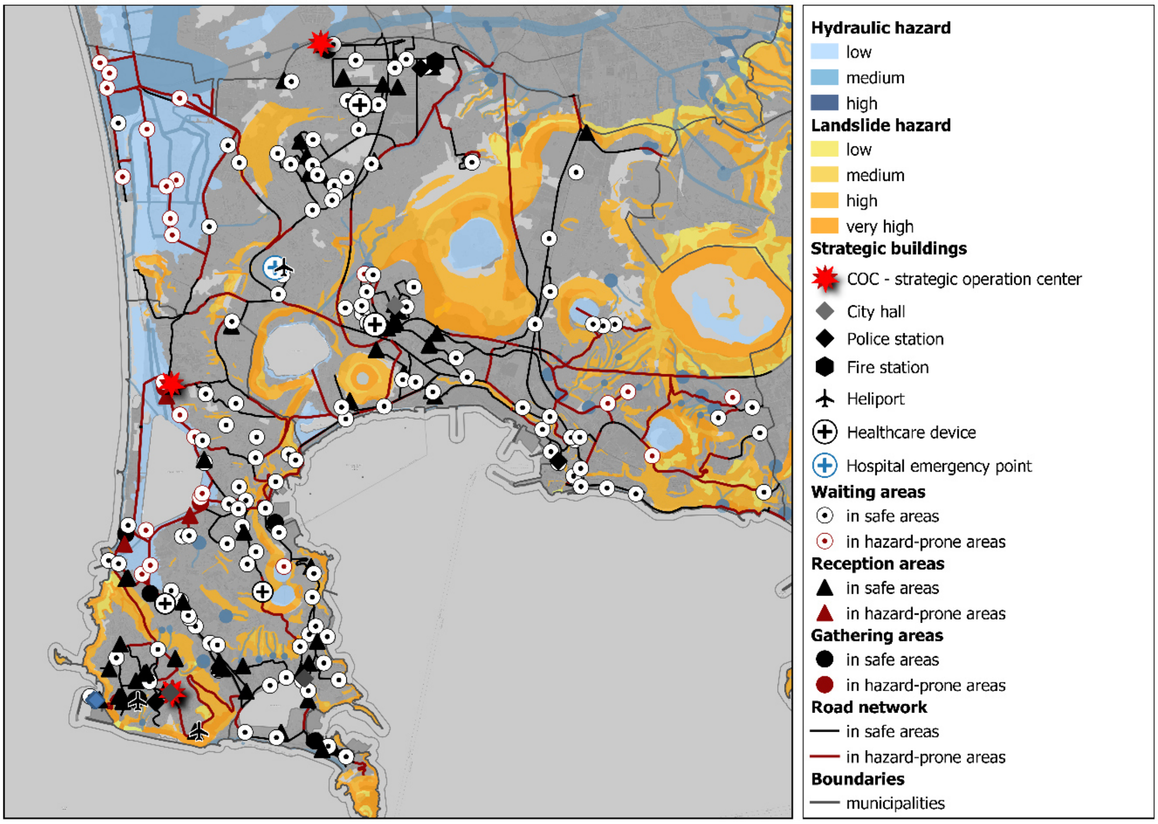


Fig.6 Location of emergency facilities and infrastructure and hydraulic and landslide hazard levels

Although for strategic facilities the prerequisite of a safe location can be considered almost totally satisfied, focusing on the emergency road network, this prerequisite is only partially satisfied: almost 50% of the road network crosses, indeed, areas prone to hydraulic or landslides hazard.

Another aspect that deserves attention is the location of strategic buildings, areas, and infrastructure in respect to the seismic vulnerability levels of the urban fabrics. To this aim, the whole territory of the three considered municipalities has been subdivided into homogeneous spatial units (HSUs), obtained through the overlapping of three basic layers: ISTAT census units, land uses (as defined by the Corine Land Cover) and hazard levels, namely hydraulic and landslide hazard levels, being the whole territory prone to seismic and volcanic hazard. Then, the seismic vulnerability of each HSU has been assessed, following the methodology proposed by the Technical Directives provided by the Tuscany Region[5] for carrying out geological, hydraulic and seismic surveys. Despite the numerous methods proposed for the assessment of the seismic vulnerability of the building stock, also based on census data (Cacace et al. 2018), the selected methodology allows obtaining a seismic vulnerability index through an expeditious procedure, based on parameters that can be easily measured through data provided by ISTAT census for the residential building stock (Bacci and Di Marco, 2019). In detail, the seismic vulnerability index for each HSU has been obtained through the following parameters:

- the period value (Vp);
- the building materials' value (Vb);
- the height value (Vh);
- the seismic classification index (Ic);
- the urban density index (Id);
- the construction type index (It).

[5] Annex A to the Regional Resolution 31, 20/01/2020. Available at: https://www.regione.toscana.it/documents/10180/24616464/Delibera_n.31_del_20-01-2020-Allegato-A.pdf/04f0fce0-61c8-fe48-dcc3-b90d1b818e89?t=1585748800829 [Accessed 3/12/2020]

The period value (Vp) represents the percentage of residential buildings built in each considered period, multiplied by a defined coefficient, with respect to the total number of residential buildings in each HSU. The value is calculated as follows:

$$Vp = \frac{100(E8+E9)+65(E10+E11)+35(E12+E13)+15(E14+E15+E16)}{100(E3)} \quad (1)$$

where the Ex values represent the data provided by ISTAT for the construction periods of the residential buildings and the numerical values represent the coefficients related to each construction period.

The value (Vb), which indicates the percentage of buildings in material other than reinforced concrete with respect to the total, is obtained as follows:

$$Vb = \frac{1-E6}{E3} \quad (2)$$

where E6 is the number of residential buildings made of reinforced concrete and E3 is the total number of residential buildings in each HSU.

The height value (Vh) represents the percentage of residential buildings with the same number of floors, multiplied by a coefficient, compared to the total of residential buildings and it is calculated as follows:

$$Vh = \frac{0.50(E18)+0.75(E19)+0.875(E20)}{E3} \quad (3)$$

where the Ex values represent the data provided by ISTAT[6] for the number of floors of residential buildings and the numerical values represent the coefficients, assigned in relation to the different numbers of floors.

The seismic classification index (Ic) is introduced by the adopted methodology to increase vulnerability values in those areas where, before 2003, the seismic class was lower than current one. For these areas, the Ic index is equal to 1. In the case study area, since all the selected municipalities were classified as seismic zone 2 also before the 2003, the Ic index is considered equal to 0.

The urban density index (Id) that, based on the adopted methodology can be defined according to the locality code assigned for each census unit by the ISTAT census equal to 0 for main and secondary urban settlement and for industrial areas and equal to -2 for isolated buildings, is here referred to the land uses classified by the Corine Land Cover: in detail, it is equal to 1 if the HSU is classified as urban area and equal to 0 in the other cases.

Similarly, the construction type index (It), which in the adopted methodology, according to the locality code assigned for each census unit by the ISTAT census, is defined equal to 1 for industrial areas in order to take into account the higher vulnerability of long-span buildings, is here posed equal to 1 in case of HSU classified as industrial by the Corine Land Cover and equal to 0 in other cases.

Summing up, each HSU has been classified according to the value assumed by the seismic vulnerability index obtained as follows:

$$Iv = \frac{Vp^2+Vb^2+Vh^2+Id^2+It^2}{Vp+Vb+Vh+Id+It} \quad (4)$$

where all the considered indexes vary between 0 (minimum vulnerability) and 1 (maximum vulnerability).

As shown in Fig.7, the seismic vulnerability analysis of the urban fabrics allows identifying a significant percentage of strategic facilities located in areas characterized by high levels of seismic vulnerability and a very high percentage, more than 65%, of road sections crossing highly vulnerable areas.

6 The description of the data provided by ISTAT for each census unit is available at: https://www.istat.it/it/archivio/104317 [Accessed 3/12/2020]

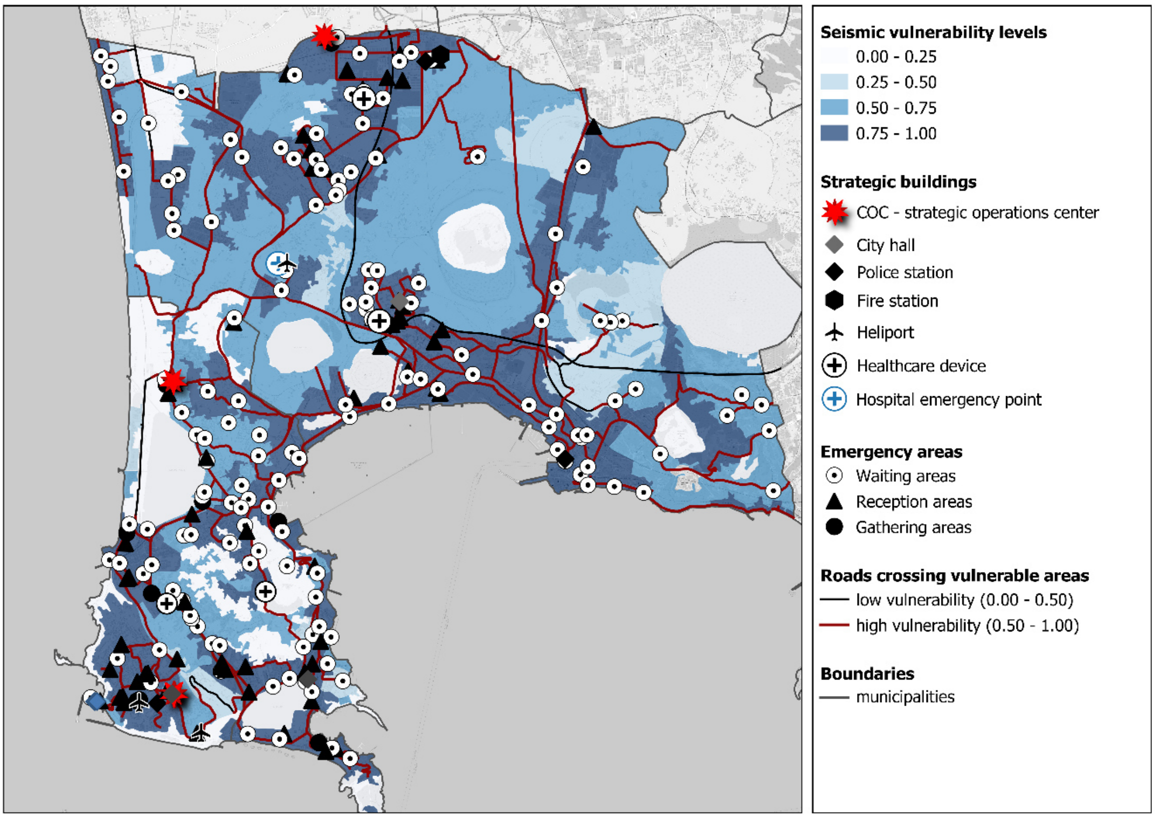


Fig.7 The location of emergency facilities and infrastructure in respect to the different levels of seismic vulnerability of the urban fabric

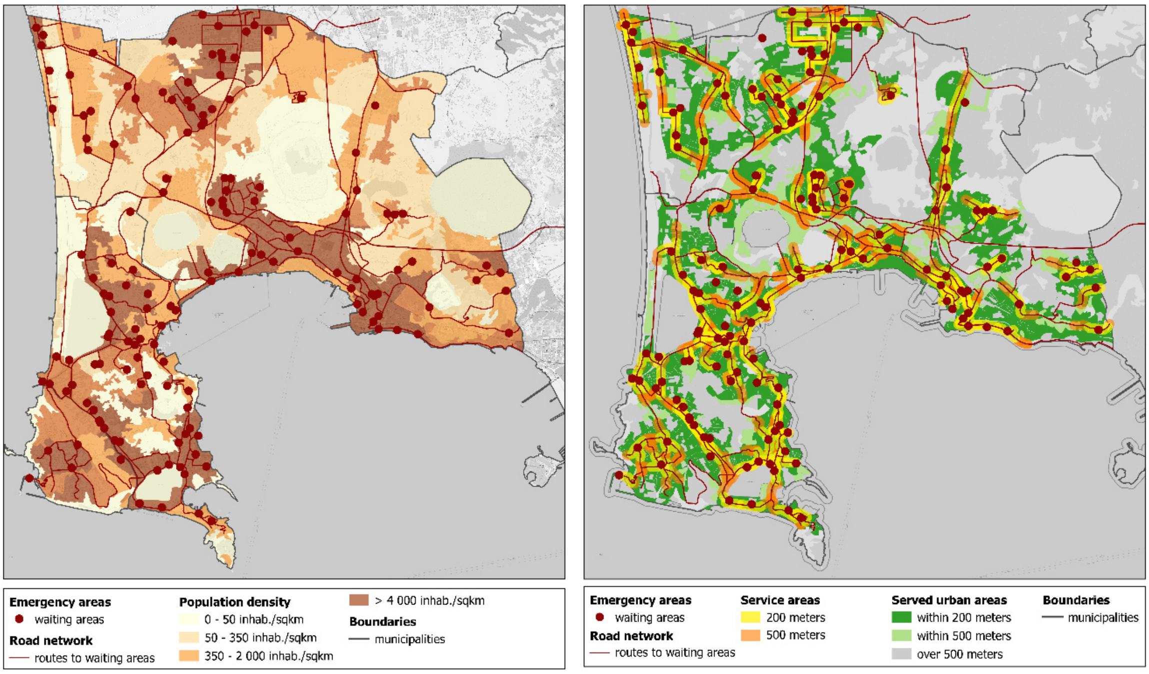
With reference to the effectiveness of emergency management, these analyses reveal significant criticalities both in terms of "safety" of the identified waiting areas, and in terms of effective accessibility of or from emergency facilities (Francini et al., 2018a).

3.2 Accessibility of waiting areas and evacuation gates

Another key point to evaluate the effectiveness of current emergency planning refers to the accessibility of both waiting areas, identified by the civil protection plans, and evacuation gates, identified by the Evacuation Plan.

With reference to the waiting areas, it is useful to remind that they represent the first meeting areas in case of hazardous events that, as mentioned above, have to be spread throughout the municipal territory: they should be located in safe areas and easily accessible through safe, and generally pedestrian, paths. Their size depends on the number of inhabitants and on the accommodation capacity of each area: they are generally used for a relatively short period of time, as they are intended to provide population with the first information on the event and the first aids, while waiting for the preparation of the larger reception and gathering areas.

In the selected case study areas, the civil protection plans currently in force identify 147 waiting areas: most of them are squares, public and private parking lots and open spaces placed along the road network (Fig. 8a). The accessibility of each waiting area has been firstly calculated along the roads. Hence, the road network has been divided into sections according to the distance of each road section from the nearest waiting area (service areas) (Fig.8b). Then, in order to assign a level of accessibility to each residential area and due to the number and spread of the waiting areas, the whole considered territory has been divided into units significantly smaller than the HSUs previously considered.



(a) (b)

Fig.8 (a) Population density and distribution of the waiting areas and (b) waiting areas' accessibility

These units have been defined according to the partition proposed by Urban Atlas. Hence, the level of accessibility of each unit has been calculated based on the accessibility level of the road sections adjacent or intersecting the unit itself.

Following this procedure, the whole territory has been classified into three group of served areas, characterized by different distances from the closest waiting area (Fig.8b):

- areas that have a distance minor than 200 mt;
- areas that have a distance between 200 and 500 mt;
- areas that have a distance greater than 500 mt.

It is worth emphasizing that a distance of 500 mt can be walked, in peacetime and by a person in normal conditions, in about 6-8 minutes on foot: hence, the areas that are far more than 500 mt from the nearest waiting area have to be considered not adequately served.

Finally, to estimate the population actually served by the waiting areas, the perimeters of the census units provided by ISTAT (2011), have been overlapped to the served areas. By considering a uniform distribution of the population on the surface of each census unit, the population living in the served areas whose distance from the waiting area is less than 200 mt is about 65%, while about the 15% of the population live in areas showing a distance from the waiting area between 200 and 500 mt.

This rough estimate allows highlighting that the number and distribution of the foreseen waiting areas can be considered adequate to serve the majority of the population. However, an in-depth evaluation of the effectiveness of these areas should take into account, besides their accessibility, also their safety, already discussed above, and their capacity to accommodate the served population, which has not been evaluated in this study.

With reference to the evacuation gates, it is worth reminding that the Evacuation Plan for the Phlegraean Fields takes into account both autonomous and assisted evacuation and that in a time span of 72 hours, the population should reach, or should be accompanied to, the meeting areas located outside the red zone (Fig.3), through the first level gates identified by the Plan itself.

The closest gates for evacuating the three considered municipalities are: the G03 located in Giugliano, the G04 and G05 located in Pozzuoli and the G07, placed at the Agnano exit of the urban highway in Naples (Fig.9). With respect to these gates, the travel distances from each residential area have been calculated.
In detail, following the methodology previously adopted in respect to the waiting areas, the accessibility of each gate has been firstly calculated along the roads. Hence, the road network has been divided into sections according to the distance of each road section from the nearest gate.
The provided classification refers to both spontaneous and assisted evacuation, which should occur through shuttles and buses departing from the waiting areas identified by the civil protection plans and shown in figure 9.
Then, in order to assign a level of accessibility to the different residential areas, we referred to the HSUs previously considered. The level of accessibility of each unit has been calculated according to the accessibility level of the road sections adjacent or intersecting the unit itself.
Based on this procedure, the whole territory has been classified into three group of areas characterized by different distances from the closest gate (Fig. 9):

- areas that have a distance minor than 2 km that, considering a speed of 50 km/h, can be traveled by car in about 2,5 minutes;
- areas that have a distance between 2 and 5 Km (6 minutes);
- areas that have a distance greater than 5 Km.

The maximum distance has been calculated in 10 km: hence, at a speed of 50km/h, the most distant residential areas could reach the closest gate in about 12 minutes. However, travel times have been calculated with reference to the maximum speed limit in built-up areas (50 km/h), without taking into account nor the congestion phenomena that could occur during the evacuation, slowing down the evacuation process, nor the features of each road section (slope, width, etc.).

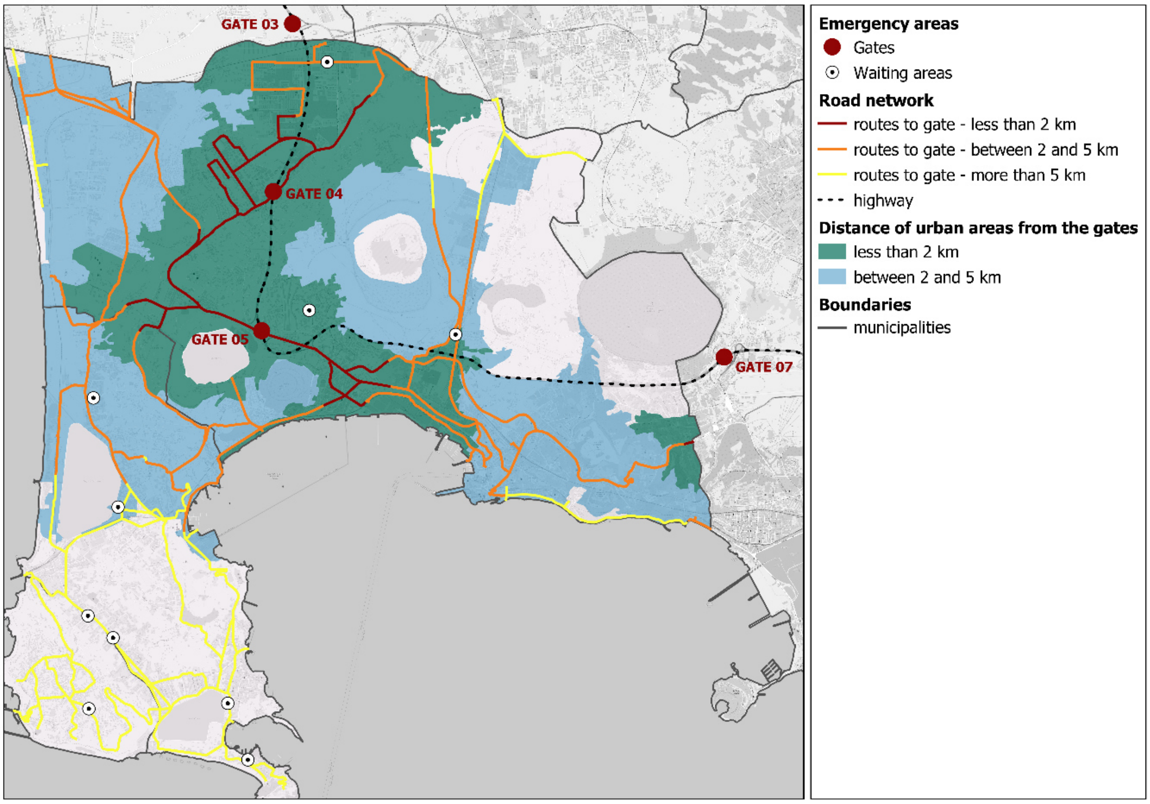


Fig.9 Evacuation gates' accessibility

3.3 Redundancy of the road network

Redundancy is one of the characteristics that may contribute to increase resilience of urban systems in the face of hazardous events (Bruneau et al., 2003; Papa et al. 2015). Therefore, the capacity of road infrastructures to effectively perform their functions in case of emergency has been here evaluated also in respect to their redundancy (Tilio et al. 2012), interpreted as the presence of alternative routes in respect to those identified by the emergency planning tools. In the red zone, indeed, each municipality had to identify the main access routes to the gates, in accordance with the provisions of the Evacuation Plan, providing for a temporal staggering of the flows and taking into account the flows due both to the autonomous and assisted evacuation. Moreover, each Municipality had to consider both the flows of the resident population both those coming from other municipalities. Due to the location of the gates, which are not equally distributed in each Municipality, the flows from Monte di Procida burden on those of Bacoli which, in turn, partially burden on those of Pozzuoli.

Thus, with respect to the general accessibility to and from strategic facilities examined in sub-paragraph 3.2, here the focus has been shifted to the number of routes, alternative to the main evacuation route, within each HSU, delimited as described in subparagraph 3.1 (Fig.10). In detail, to evaluate the redundancy of the road network, the number of alternative routes (Ar) available in each HSU has been calculated as follows:

$$Ar = n - 1 \qquad (5)$$

where n is the number of nodes of the road network. Hence, each HSU has been classified according to three levels of redundancy:

- areas where no alternative routes are available;
- areas characterized by one or two alternative routes in addition to the main one;
- areas where more than two alternative routes are available.

Hence, the higher is the number of alternative routes, the lower is the possibility that a given area remains isolated in case of obstructions or congestion of the main route, even though the difficulty of managing traffic flows at intersections might partially increase.

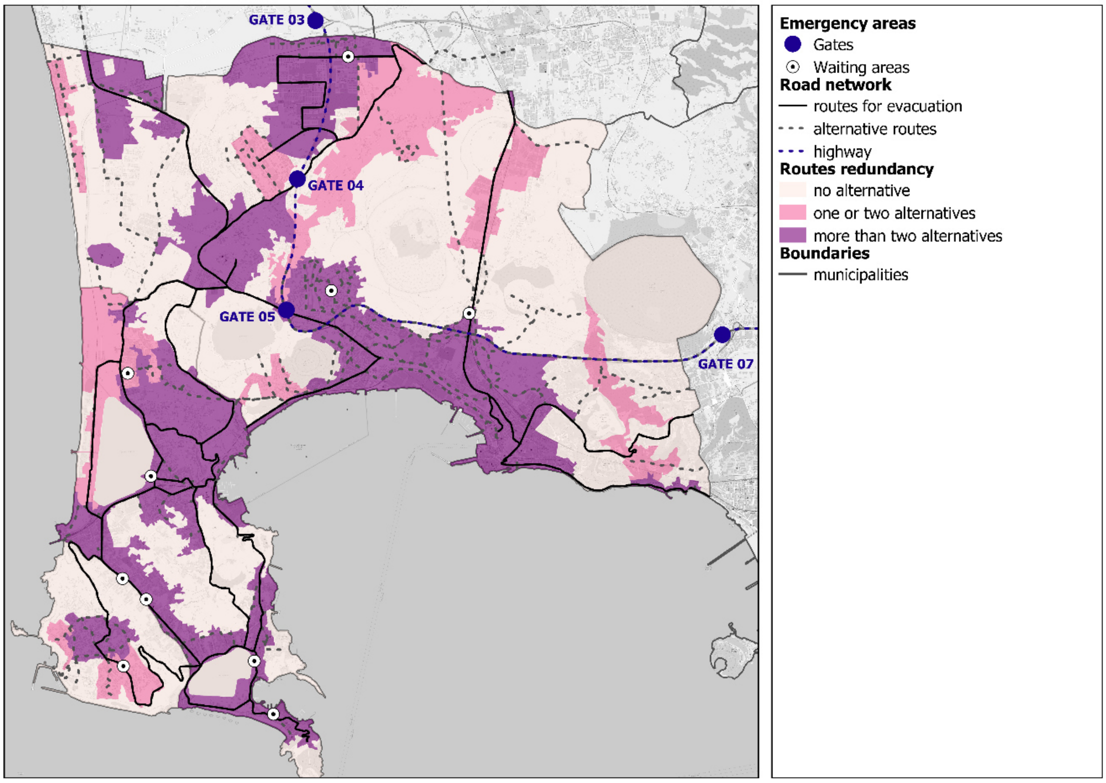


Fig.10 Redundancy of the road network

4. Discussion and Conclusion

The three-steps analysis carried out to evaluate the effectiveness of the complex system of strategic facilities (buildings, areas) and infrastructure that current emergency planning tools rely on sheds light, first of all, on the importance of adopting a systemic, multi-risk and multiscale perspective in emergency planning. The adequacy of the emergency network, crucial to ensure an effective response of territorial systems in the face of hazardous events, depends indeed both on the 'safety' of each element, in a multi-risk perspective, both on the relationships among the different elements of the network and among these elements and the urban tissues they belong to.

Moreover, the case study and in particular the close interdependency between the considered Municipalities of Bacoli and Monte di Procida clearly demonstrate the importance of a multiscale approach, capable of grasping the relationships between the individual elements of the emergency network both within each Municipality and in the wider territorial context that each Municipality belongs to.

Furthermore, the numerous criticalities related to the safe location as well as to the accessibility of strategic facilities and infrastructure in the case study area highlight the need for improving current cooperation between emergency and spatial planning tools. The latter could provide, indeed, a significant contribution, on the one hand, to preventively reduce the multiple risks these territories are exposed to – by avoiding, if possible, the occurrence of hazards or minimizing their impacts by acting on exposure and vulnerability – on the other hand, to improve current road network by enhancing, directly or indirectly, both its accessibility and redundancy even in the emergency phase. The analyses carried out on the case study area clearly highlight that risk informed spatial planning tools could positively affect the effectiveness of current emergency plans. Spatial plans at different scales could, for example, favor a more balanced distribution of activities, which might result into a reduction of flows along the most congested sections of the emergency road network, or could promote seismic adaptation of the existing building stock in the most critical territorial units, where the key elements of the emergency network are located.

Unfortunately, as mentioned above, to date only Monte di Procida has approved a spatial plan, while Bacoli has approved only a preliminary plan and Pozzuoli has a spatial plan approved in 2002, which is actually outdated. Hence, current relationships between urban and emergency planning tools can be examined only with reference to the municipalities of Monte di Procida and Bacoli.

Monte di Procida is a paradigmatic example of misalignment among different planning processes within the same municipality. On the one hand, in fact, it is one of the few municipalities in the Campania region that approved, more or less in the same time span, both the spatial urban plan and the civil protection plan. On the other hand, the analysis of the two planning tools does not reveal an explicit attempt to integrate them, even though there were the conditions for a full integration, since the civil protection plan was approved in 2017 and the spatial plan in 2020. Furthermore, the spatial plan at stake includes a detailed analysis of its compatibility with all the planning tools currently in force in the municipal area: the Extract Plan for Hydrogeological Risk, the Territorial Landscape Plan, and the Territorial Coordination Plan of the Metropolitan City of Naples, although the latter has been only adopted in 2016, but not yet approved.

Despite the lack of explicit references to the civil protection plan, the spatial plan of Monte di Procida devotes large attention to risk issues, by providing an in-depth analysis of the hydraulic hazard, with a discretization of the single homogeneous zones affected by the hydraulic hazard and a report related to the interventions for the hydrogeological safety of the sea ridges.

With respect to the volcanic risk, the spatial plan does not include specific strategies aimed at reducing current residential density, such as incentives for relocation in safer or more accessible areas. However, in accordance with the rules of the landscape plan in force, which do not allow any increase in the overall settlement load, the plan does not include new residential areas.

As regards the road network that, as highlighted above, shows numerous criticalities, the spatial plan explicitly addresses some of them, such as the numerous interruptions that currently characterize the road network, the high levels of congestion, the difficulties to reach the extra-municipal road network, and defines some actions aimed at completing the road networks and eliminating the dead-end roads. Although there is no correspondence between the indications provided by the spatial plan and related to the roads to be adapted and to the new roads and those provided by the civil protection plan in respect to the roads to be strengthened and adapted, the combination of the actions envisaged by the two plans could lead to an overall reduction of traffic congestion in some critical points and to a higher redundancy of the existing road network.

However, it has to be clearly remarked that the effectiveness of the road network of Monte di Procida is strictly dependent, on the one hand, on the morphological features of the municipal territory itself, which determine its tortuosity and the reduced width of numerous road sections; on the other, on the close interdependency between Monte di Procida and Bacoli, through which the main access and exit roads to and from Monte di Procida pass.

In the Municipality of Bacoli, the civil protection plan was approved in 2016 and updated in 2018, while the preliminary spatial plan, carried out in 2015, was revised in 2017. Here, the need to better cope with volcanic risk by improving, expanding and adapting the road network also for improving its functionality during the emergency phase was already highlighted by the 2015 preliminary plan.

The 2017 revision of the plan has led to a realignment of the planning strategies with the provisions of the civil protection plan approved in 2016. Thus, current preliminary spatial plan devotes large attention both to the risk management, namely to the hydrogeological risk management, and to the improvement of accessibility and evacuation routes. In detail, it recognizes the criticality of the interconnections with the municipality of Monte di Procida, but also the opportunities arising from a better integration between the strategies of the two municipalities for improving the key points for both accessibility and exodus in case of emergency. Furthermore, current preliminary plan highlights the need for improving the safety of the whole municipal area, and in particular of the road network, with respect to hydrogeological risk. The strategies concerning the road network provide, therefore, solutions addressing the reduction of both current road network congestion, which also depends on the significant touristic flows that reach high peaks in some periods of the year, and hydrogeological risk conditions that characterize some of the escape routes and emergency areas identified by the civil protection plan.

Summing up, also the most recent spatial urban plans, despite showing a higher attention than in the past to risk reduction and emergency management issues, do not include any explicit reference to the civil protection plans, highlighting that an effective integration between emergency and spatial planning processes, even when they develop almost contemporarily, is still far to be achieved. Unfortunately, emergency planning still represents a sectoral planning process, not yet interpreted as a further and crucial dimension of the overall urban planning process.

Authors' contribution

Although this paper is the result of a common work, AG supervised the entire work and wrote section 1. AG and GG wrote section 2; GL was responsible of data elaboration and representation in GIS environment and wrote section 3; AG, GG and GL wrote section 4.

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Image sources

Fig.1: Authors' Elaboration on data provided by ISTAT (https://www4.istat.it/it/archivio/209722), Civil Protection Department (http://www.protezionecivile.gov.it/attivita-rischi/rischio-vulcanico/vulcani-italia/flegrei/piano-nazionale-di-protezione-civile), Authority of the Regional Park of Phlegraean Field;

Fig.2: Authors' Elaboration on Urban Atlas 2006, 2012, 2018. https://land.copernicus.eu/local/urban-atlas;

Fig.3: http://www.protezionecivile.gov.it/delegate/JapsImgResource?imageName=allontanamnto_flegrei_d0.jpg;

Fig.4: Authors' Elaboration;

Fig. 5: Authors' Elaboration;

Fig. 6: Authors' Elaboration on contents of Municipal Emergency Plans and Central Campania Regional Basin Authority;

Fig.7: Authors' Elaboration on contents of Municipal Emergency Plans and ISTAT census 2011;

Fig.8 (a) and (b): Authors' elaboration on contents of Municipal Emergency Plans and ISTAT census 2011;

Fig.9: Authors' elaboration on contents of Municipal Emergency Plans and Evacuation Plan;

Fig.10: Authors' elaboration on contents of Municipal Emergency Plans and Evacuation Plan;

Tab.1: Moccia, 2018 and Authors' updating (December 2020) based on information provided by the websites of each Municipality and of Campania Region;

Tab.2: Authors' elaboration based on information provided by the websites of each Municipality and of the Campania Region.

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