

Mapping Citizens' Knowledge and Perception. What Support for Flood Risk Planning? Some Tips from Brindisi Case Study

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Abstract. Flood risk management strategies are of paramount importance in ensuring the safeguard of people and assets. It is now widely recognized the importance of defining adequate nonstructural measures in coping with flood risk to be implemented in urban planning tools. The importance of evaluating citizens' knowledge and perception of risk represents a key factor in order to support the decision-making process of planning mitigation activities. However, attempts to map this information are still far from a complete formalization. In this study an integrated approach combining historical events news and survey-collected information about flood risk perception for the city of Brindisi (southern Italy) is described. Collected information has been analyzed and georeferenced in order to define and provide three different layers of maps, each highlighting a peculiar aspect of flood risk. The mutual analysis of these layers allows to detect interactions between different aspects of risk management and can constitute a precious source of information for implementing flood risk mitigation strategies in urban context.

Keywords: Flood Risk Mapping · Non-structural Mitigation Measures · Urban Planning

1 Introduction

It is estimated that the continued increase in population and economic resources in flood-prone areas, could increase global flood exposure by a factor of three by 2050 [1]. Traditional spatial planning policies such as zoning and building codes do not seem sufficient to reduce the exposure and vulnerability of people and assets [2]. In this context, synergies between urban planning and flood risk management become essential.

Structural and non-structural measures can be adopted in order to substantially reduce the incidence of the resulting damage in case of flood events. These include actions aimed at rational and sustainable urban planning, more effective emergency management strategies and the adoption of preventive behavior to mitigate flood risk from a socio-psychological perspective. [3]. As reported in *A Whole Community Approach to*

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Emergency Management: Principles, Themes, and Pathways for Action [4], the involvement of local communities represents an indispensable basis during the emergency planning phase of risk. Their contribution helps in building a deeper knowledge deriving from their experiences, composite background, expectations and the proposed hypotheses of behavior in case of risk. It allows to elicit weaknesses and vulnerabilities that would not emerge through analyzes based on traditional tools and methods and increase citizens' sense of responsibility. Therefore, an accurate characterization of risks and a better evaluation of the effectiveness of risk management strategies should consider the integration of community behavior and behavioral adaptation dynamics in complete flood emergency management strategies. In this sense, a challenge in quantitative risk assessment is represented by the need to introduce the interpretation of the role of individual risk perceptions and understand how these perceptions influence risk reduction behaviors. Undoubtedly some factors such as previous direct/indirect experiences of flooding, level of education, socioeconomic status, frequency and severity of catastrophic events influence the choices of individuals to adopt precautionary measures against natural and flood risks. Furthermore, the scientific community put the reduction of social vulnerability as another key element in the mitigation of flood damage. As a matter of fact, the behavioral attitudes of citizens, companies and government agencies can heavily influence the impact and recovery time both before, during and after a disaster [5].

In this context, an important role is attributed to the knowledge of the places offered by inhabitants or people so familiar with the area to be defined as "local experts". Therefore it becomes essential to access the knowledge of 'expert' agents in the traditional sense [6], i.e. agents who have formal knowledge, even partial, in relation to their specific skills, able to read "the place from the inside" thanks to the time spent there, the life experience accumulated there, the knowledge of the places handed down from previous generations, the possibility of observing the trend of the dynamics of urban transformation over time. Often, they are not experts in urban planning and regulatory techniques but can contribute to the construction of the general knowledge framework [6].

This informal, non-expert knowledge must be brought into play alongside the expertise of emergency planners and managers. Therefore, emergency plans should represent the result of multidisciplinary and multi-actor processes that aim to anticipate, with the available resources, urgent needs that cannot be satisfied during the emergency phase. In this sense, the preparatory process to support flood risk planning must be coordinated and cooperative and must include the elaboration of general plans and procedures also aimed at specific sectors such as education, health, industry and commerce. Procedures that must involve the participation of a wide variety of first responders, technicians and citizens. A further complication of emergency planning is the need to integrate different dimensions also in governmental terms, allowing the overlapping of plans and measures to different hierarchies in response to local, regional, up to national and international emergencies. In fact, first aid begins at the local level and when local resources become insufficient, inter-municipal, regional, national or even international scales come into play. Emergency and territorial planning tools often overlap, acting on different geographical scales, involving different and not always coherent actors [7]. However, it is noteworthy that natural hazards still remain multidimensional phenomena with a strong spatial component.

Based on these premises in this work, local knowledge and risk perception have been spatialised in order to build a multi-layers map to support flood risk planning with some remarks regarding the implications for urban planning. The innovative character can be glimpsed in the attempt to spatialize data relating to the social sphere and combine them with some of the existing physical information of the territory, such as data deriving from geographic information systems (GIS).

Their use allows cartographic approaches to physical risk mapping, integrative spatial risk modeling and disaster response planning [8]. They offer the advantage of representing a huge variety of climatic, demographic, economic and sociological data by making information on places, buildings, services and resources available to users and at the same time allowing their punctual and specific localization throughout the territory [9].

Testing the effectiveness of using maps of a social nature could open up an implementation perspective in the current Territorial Information Systems (SIT) used by public administrations for the planning, management and use of risks and of the land management.

A multistep methodology has been used and experimentally applied to the case study of the city of Brindisi.

2 Materials and Methods

Data exploited in this study were collected at the same time as those exploited in Santoro et al. (2022) and properly updated for this study. Further details and descriptions can be found in [12].

2.1 Study Area

Brindisi is an Italian municipality with 82,773 inhabitants [10]. It lies on a natural harbour on the Adriatic coast of Puglia (Fig. 1).

From a hydraulic point of view, the city is crossed by several streams, Canale Cillarese (Fig. 1, a), characterized by the presence of an embankment dam; Canale Patri (Fig. 1, b), the stream mainly interacting with the urban fabric, Fiume Piccolo (Fig. 1, c) and Fiume Grande (Fig. 1, d).

The presence of these streams, combined with the hydrogeological characteristics of the area and the dense urban network have caused several flooding events over the years, analysed below. High flood hazard areas identified in this areas are illustrated in Fig. 2 [11].



Fig. 1. Stream network of the city of Brindisi (a: Canale Cillarese; b: Canale Patri; c: Fiume Piccolo; d: Fiume Grande).



Fig. 2. Flood hazard map for an event with a return period of 30 years (in blue) (PAI, 2019).

2.2 Mapping the Risk

In the field of flood risk planning, it is not enough to focus on goods at risk but local perceptions, traditions, economies, the safety of vulnerable people, their social reactions, inclusion activities and participation in emergency planning processes come into play. It is necessary to overcome the physical dimension of the disaster and ensure greater integration between specialist knowledge and local knowledge, favoring shared

solutions with the local community [13]. Although integrating community responses and behavioral adaptation dynamics into disaster planning is known to improve management strategies, efforts in social vulnerability research [14] are still heavily overlooked.

To deal with these additional elements of complexity, currently one of the key challenges in quantitative risk assessment is represented by the introduction of the role of individual risk perceptions and the influence they exert on risk reduction behaviors [15]. Obviously, the qualitative approaches to the definition of disaster risk reduction must be accompanied by quantitative assessments capable of estimating the extent and frequency of natural hazards, the exposure and vulnerability of goods and people in those specific conditions of danger [2]. This multiplicity and complexity of elements requires the use of more specific skills and sophisticated tools capable of collecting and processing information from different and detailed sources.

A valuable support in emergency planning comes from the introduction of Information Systems (GIS) capable of managing and implementing a more in-depth knowledge of the multi-faceted elements not only in terms of exposure but also of vulnerability. In this sense, the spatial dimension should be considered together with the functional, social and economic one both in the emergency phase and in the post-event phase, which is often very critical [7].

However, GIS practitioners, being experts in software and spatial data manipulation and modelling problems, focus fundamentally on technological aspects, often neglecting user perceptions, cognitive responses and their own perceptions [16]. A general neglect of human interaction problems often appears in their applications. This is most likely due to the fact that human behaviour and risk perception represent an extremely and intrinsically complex topic to understand and quantitatively integrate into their methodologies. Indeed, in these circumstances human behaviour is often unpredictable probably because, according to one branch of the literature, populations in high risk areas are often unaware of the dangers of flooding. This results in a low perception of risk and, consequently, they maintain a low level of concern, not adopting appropriate protective measures [2].

However, this data is challenging to be implemented in GIS systems. On the other hand, the lack of awareness of the risk or its underestimation due to lack of recent experience of the danger, or due to a lack of information provided by risk managers [17] results in underinvestment by households in flood protection of their assets, even when such measures are cost-effective [18].

In an emergency, a series of complex individual and group interactions occur. The key factor becomes the speed of spatial movement of people, assets and services. Maps allow for such representations, but the way in which the elements of a map are organized is critical to enabling fast communication of the message. In fact, under evacuation conditions, under time constraints the map must be able to provide the user with a complete photograph already after a quick glance. Alternatively, if poorly designed, it could leave the reader both visually and intellectually confused and disoriented [19, 20]. Negatively influencing his behaviour. A clear hierarchy of maps is, therefore, the most important cartographic element [19]. Dymon and Winter [19] demonstrated that a clear hierarchy of maps allows users to quickly extract relevant information. Crossland [25] argues that users' decision times are reduced after studying a GIS display when compared

with the times deriving from the use of paper maps, also improving the accuracy of the choices made. The design of cartographic presentations must, therefore, be carefully studied.

During emergencies, maps provide vital geographic information and facilitate preventive evacuation processes. They are therefore powerful tools for communicating risk analyzes and the results of their assessment. In this way they favour the decision-making process both in the preliminary investigation phase and in the definition of risk management strategies, becoming a fundamental element both in the coordination phase of preventive activities and during evacuation, protection and rescue operations. For these reasons they should become an integral part of emergency plans [19]. The purpose of risk analysis is to spatially identify where the risk is greatest and to indicate possible escape routes, allowing for the rapid spatial movement of people, goods and services.

Maps address different audiences and play a critical role. Therefore, it would be appropriate, in the design phase, to consider not only the choice of data to be collected, but also the cultural, educational, socio-economic factors that influence people's ability to use maps effectively [21]. The adoption of the cognitive and social approach would make it possible to implement the spatial behaviours adopted by the users, the daily routines, the public conceptions of the local geography, the knowledge of the local tradition, thus favouring the development of flexible plans. In fact, it is known that, in the event of an emergency, people tend to choose their own evacuation routes rather than using the planned ones [19]. These sociologically recognized spatial behaviours should be integrated into risk planning tools and consequent representations. Such diverse and multiple data can only be managed by a GIS tool capable of choosing the elements to represent, sourcing from numerous databases.

Starting from these premises in this work, local knowledge and risk perception have been spatialised in order to build a multi-layers map to support flood risk planning.

2.3 Multi-layers Maps Design

The methodology adopted to create the multi-layers map to support flood risk planning in the city of Brindisi involved three main steps (Fig. 3).

1. collection of historical event data;
2. analysis of floodable roads in accordance with citizens' local knowledge;
3. analysis of districts perceived at risk in accordance with citizens' flood risk perception.

The results from the above-mentioned analyses were geolocated in GIS maps, constituting what is referred to as *layers.*

STEP	HISTORICAL FLOOD DATA COLLECTION	ASSESSMENT OF THE MOST FLOODED ROADS according citizens' knowledge	ASSESSMENT OF THE MOST FLOODED DISTRICTS according citizens' perception
METHOD	Qualitative analysis from AVI dataset 2021 and local newspapers (from 1950 to 1999)	Qualitative analysis from on-line interviews	Risk perception analysis from on-line interviews
OUTPUT	Layer 1	Layer 2	Layer 3

Fig. 3. Methodology process

The first step involves a preliminary collection of flood events from the AVI dataset, available until 1999 [3]. Therefore, a newspaper-based analysis allowed to deepen and verify the data collected of occurrences of floods, allowing to retrieve also affected streets and neighborhoods, as well as notices about hydrological and hydraulic dynamics of events. Analysis has been focused during the years 1951–1999 and an amount of sixty-four events has been identified.

In order to extend this investigation to recent years, a further study using online newspapers was conducted finding on average a couple of flood events per year. Nevertheless, it has not been possible to verify the robustness of the available online information due to the different nature of references.

It should be remarked that not for all of them the information about streets or neighborhoods was available. For the purpose of this analysis, we decided to focus only on affected streets, and the localisation of the information about the number of flood events gave rise to *layer 1* (Fig. 4).

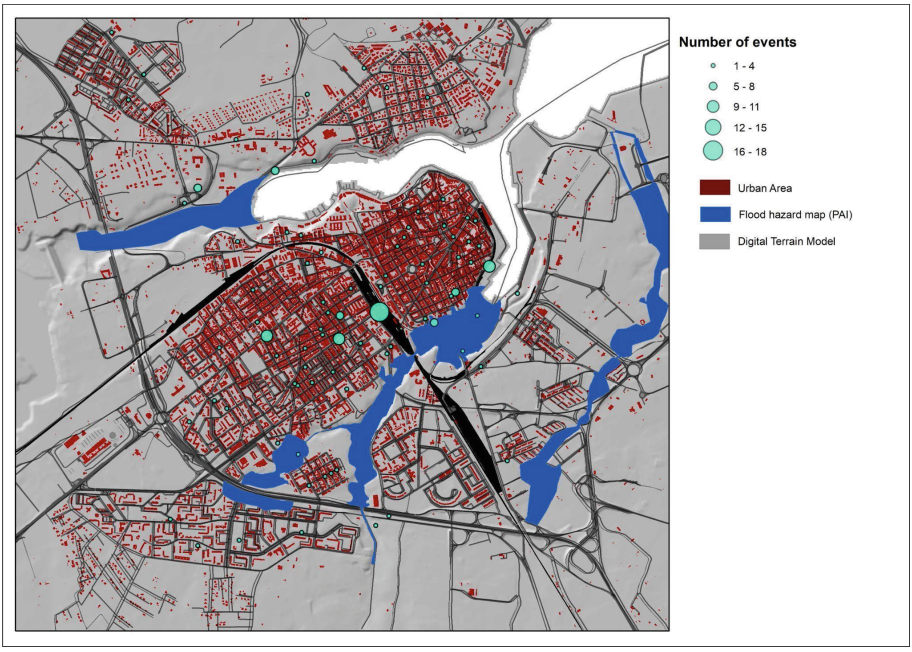

Fig. 4. Layer 1: geolocalised historical flood event. The size of the sphere indicates the number of events recorded [4].

The analysis of roads and districts susceptible to being flooded in accordance with citizens' knowledge has been possible from analysis of data collected during online interviews, took place from November 2019 and May 2020 and involved 301 citizens.

Specifically, as part of work defined in more detail in [12], citizens have been asked through an open-ended question, which road would be most at risk of flooding in the case of heavy rainfall.

The street names have been recorded and structured according to the histogram below (Fig. 5).

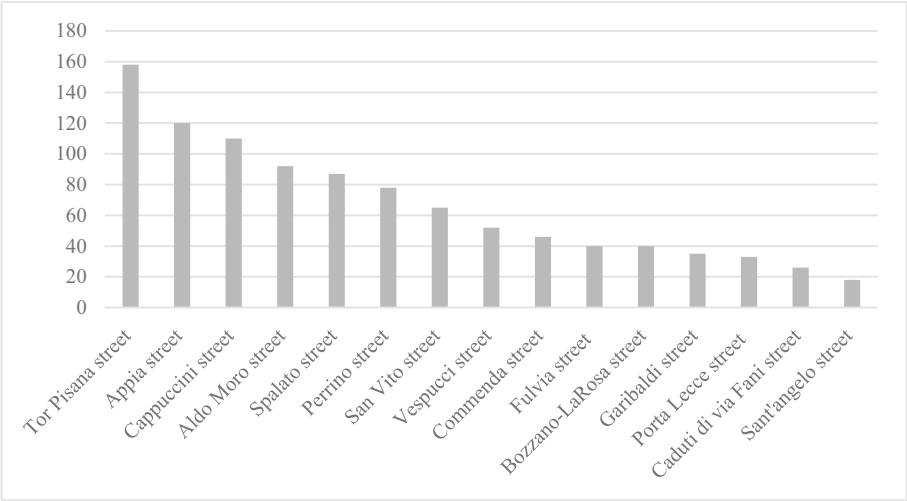

Fig. 5. The flood risk roads in accordance with citizens' knowledge

The geolocalisation of this data gave rise to *layer 2* (Fig. 6).

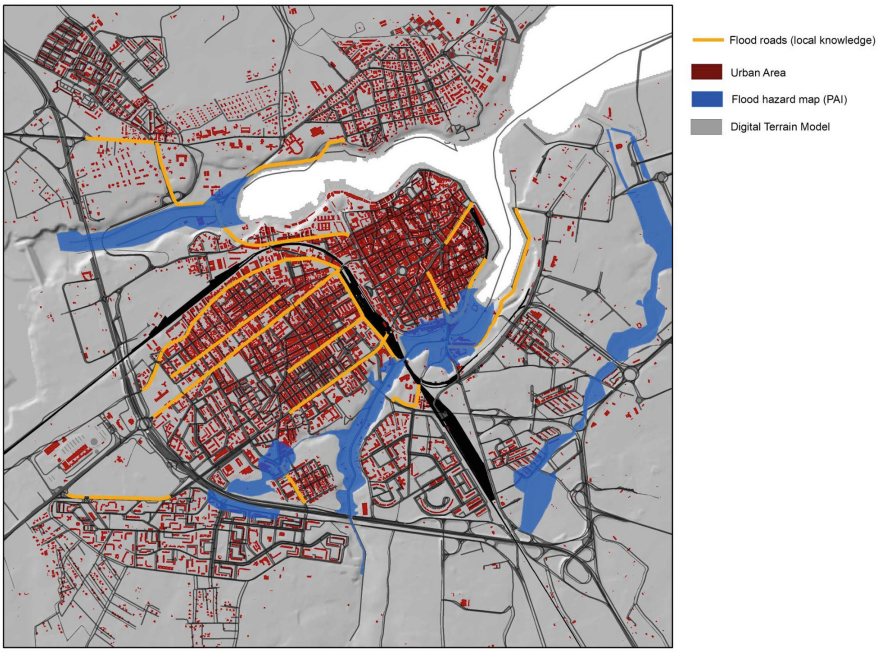

Fig. 6. Layer 2: geolocalised flood risk roads in accordance with citizens' knowledge

With respect to the evaluation of districts perceived to be subject to flood risk, an online semi-structured interview (SSIs) has been built in order to collect data regarding citizens' flood risk perception. The questions of SSIs were structured according to a Likert scale (from 1 to 7) and investigated five items of perception according to the theoretical framework of [22–24], as Cognitive, Awareness, Knowledge, Risk Communication and Trust.

In this work, the perception dimension has been measured by taking into consideration the resident population, without any distinction between gender, age and other socio-demographic characteristics analyzed in the above-mentioned study. The reason for this choice lies in the fact that the above-mentioned study showed that there is little difference in perceived risk between those living in a flood-risk area and in a non-risk area. Therefore, the subdivision would be irrelevant.

The assessment of flood risk perception was carried out instead by using the Mann-Whitney test (MWT).

The geolocalisation of this data gave rise to *layer 3* (Fig. 7).

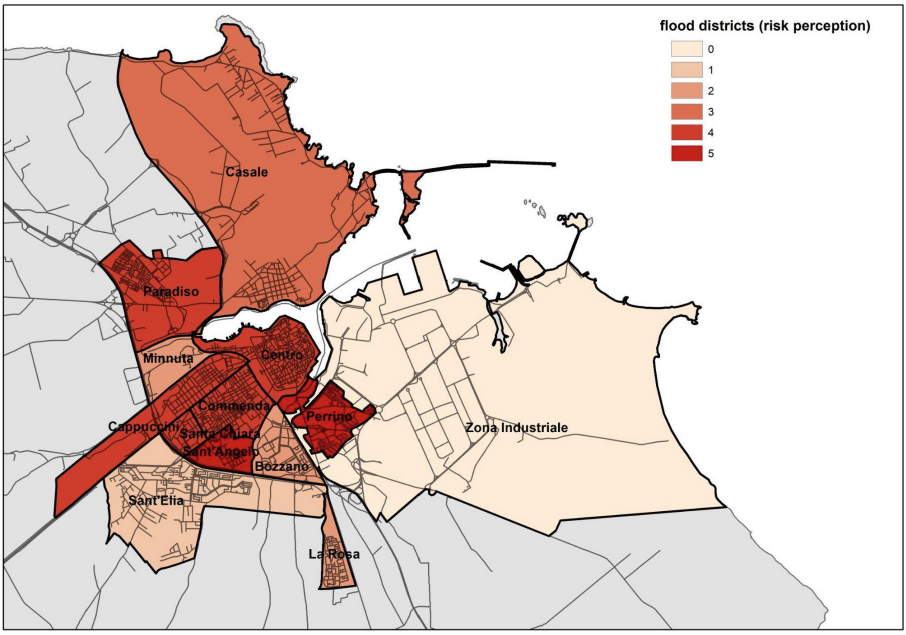

Fig. 7. Layer 3: geolocalised flood risk district in accordance with citizens' perception

The overlap of the three layers give rise to the final map (Fig. 8).

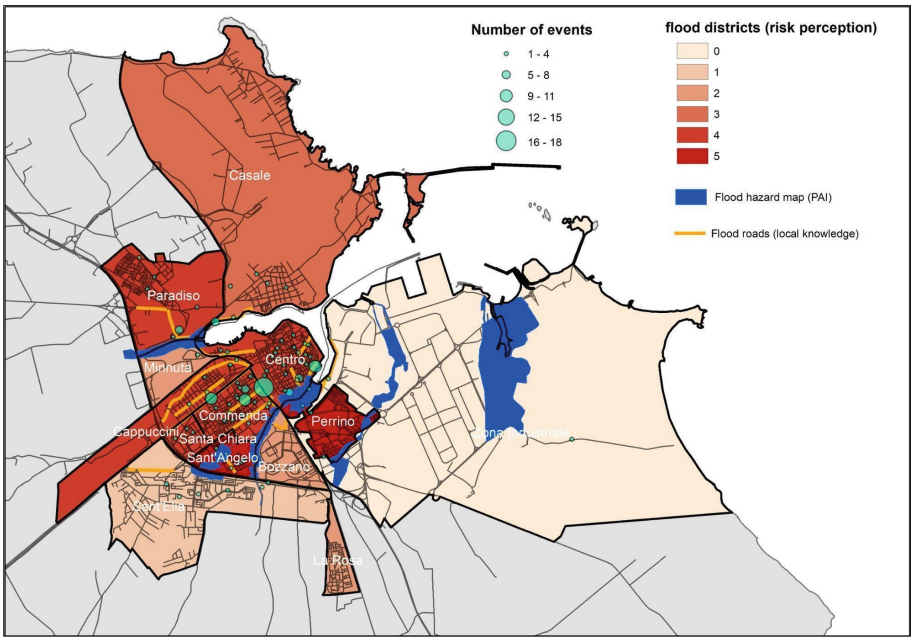

Fig. 8. Final Map

3 Results and Discussion

As already highlighted, this study exploits and extends data and conclusions described in the work of Santoro et al. (2022), that was based on the structuring of citizens' knowledge and perception of flood risk through statistical methods. As a consequence, the assumption of this work is to define and provide three different layers, each highlighting a peculiar aspect of flood risk. Moreover, historical investigation activities have been carried out in relation to flood events.

Interesting insights can be made from the observation of the final Map.

Observing geolocalised historical flood events, it is possible to remark that the census events are not localised only in the high hazard areas, which are closely linked to the presence of the stream network. This result may trigger new considerations useful for decision-makers responsible for adopting policies and strategies to cope with flood risk that are based on the identification of the nature of floods and their potential effects. For example, it may support the identification of problems related to under-dimensioning or mismanagement of urban drainage systems.

Furthermore, progressive urbanization and population of residential districts can explain the temporal inhomogeneity in the noticing of flooded streets. The hydrogeomorphological characteristics of the area where the city of Brindisi is located make the situation more complex, as already documented by Santoro et al. [12].

Observing geolocalised flood risk roads in accordance with citizens' knowledge it is possible to remark that it confirm the results emerging from data regarding historical flood event. The citizens' knowledge coincides with the historical occurrence of the events. This is an important point to highlight, because of the historical analysis carried out stops at 1999. The reasons could be twofold: (i) either there has been memory transmission of the effects caused by the flood events, (ii) or the roads are still being damaged by heavy rainfall.

From the point of view of emergency planning and related correlation on urban strategies, interesting suggestions could be defined, as detailed investigation to carry out on streets perceived to be at risk, in order to adequately implement mitigation and prevention strategies. Prevention and mitigation here are intended not only limited to structural measures but, in a broader sense, involving awareness-raising activities and increasing citizens' information (soft measures).

Another element in agreement with the findings of *layer 1* is the presence of roads at flood risk, far from high hazard areas. Other roads, on the other hand, were not detected by the historical collection of events. This may probably be due to the fact that historical analysis has not been carried out to date due to a lack of data, but this result should invite decision-makers called upon to investigate the nature of flooding in these areas to reflect and make more in-depth assessments.

Finally, observing geolocalised flood risk district in accordance with citizens' perception highlights that the highest perception is detected in the Perrino, Centro and Commenda districts. For the first two districts this result is easily interpretable due to the presence of the Canale Patri, whose floods have had significant effects on the ground over time. Deeper and detailed investigations are instead required for the Commenda district. A similar distinction and homogeneous reasons can also explain the high value of risk perception for Cappuccini and Santa Chiara districts.

The risk perception detected in the industrial area is equal to zero as the questionnaire was not administered. This result represents a limitation of the tool used (online survey) and shows that the study should be deepened considering the effects that the 2003 flood caused in this area.

As can be seen, the overlap of only three layers built a map in which a lot of useful insights for decision-makers in the field of risk planning. At this time, this study is purely explorative. The future goal is to continue working on structuring other social aspects related to flood risk and geo-referencing them. These results represent a starting point for studying methods of mapping the qualitative aspects that contribute to the definition of flood risk in urban areas.

4 Conclusions

The importance of considering the citizens' knowledge and perception of risk in order to support the decision-making process of planning mitigation activities is now widely recognized in the literature, however, attempts to map this information are still far from a complete formalization. In fact, while on the one hand maps containing qualitative elements, implemented in physical maps, could facilitate risk classification in a specific area and could help policy makers and planners to plan more timely interventions, on

the other hand it is true that the formalization of knowledge and perception of risk is very complex and uncertain.

In the event of a preventive or protective evacuation, the maps provided to the public are an integral part of the emergency plans. Map design is a rather complex task due to the multiplicity of elements to consider and the need to transfer clear and easily readable information to most users. The aim should be to design optimal maps that, in the preventive phase, help potential risk managers to study correct prevention/mitigation measures that bring into play all the aforementioned elements and, during the event, help users navigate towards the exit area. A challenge is represented by the issue that the risk scenarios evolve constantly as for the characteristics of the hazard and the characteristics of the potentially affected areas changes [26]. To deal with the uncertainties related to the available knowledge of the risks or to unforeseen impacts, maps and planned measures should be flexible and adaptable too.

In this context, the present study tries to construct a multi-layers map based on qualitative elements. According to the results of a previous study, a methodology was built which envisaged three main phases: the collection of historical data of the events; the analysis of flood-prone roads based on citizens' local knowledge and the analysis of flood-prone districts based on citizens' perception of risk.

The output of this study is the construction of a multi-layers map. Such a tool obviously brings along an interesting potential in terms of supporting flood risk planning. Such support can integrate traditional flood hazard mapping strategies and could represent a possible future outlook of this study.

Given its exploratory nature, the presented methodology represents a starting point for investigating ways of mapping the qualitative aspects that contribute to the definition of flood risk in urban areas.

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