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Risk perception and knowledge of protective measures for flood risk planning: the case study of Brindisi (Puglia region)

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Abstract

Floods are among the most frequent natural hazards, and flood risk management is a paramount task when planning solutions to reduce their impact on communities. In the last decades, policy makers' actions for flood risk management have been redirected from purely physical self-protective measures towards integrated management strategies by including social components. Assessing flood risk perception and the level of knowledge of citizens regarding protective measures is becoming a pillar for generating innovative flood integrated management strategies.

This study aims to highlight multiple aspects which can influence flood risk management in urban areas, providing a preliminary assessment of citizens' flood risk perception and knowledge of protective measures. Proposed methodology is based on E-survey in order to gather data and Mann-Whitney and Kruskal-Wallis tests to analyze them and has been applied to the case study of Brindisi (Puglia region, Southern Italy).

The results suggest that flood risk perception depends on intrinsic components of individuals, mainly related to trust in public strategies and risk communication. It hardly depends on hazard proximity but is uniformly distributed over the whole city, demonstrating that the perception of flood risk can not be related only to river floods. Knowledge of protective measures appears uniformly low by category of citizens and territorial area, particularly for teenagers.

The methodological approach has allowed to bring out how the different nature of floods could produce a spatial and social heterogeneity in citizens' flood risk perception and knowledge of protective measures, revealing latent risk features useful for supporting flood risk planning.

Keywords: Flood, Risk Perception, Knowledge, Measures, Flood Risk Planning

Abbreviations:

- CPBG: Civil Protection Behavioral Guide
- PAI: Piano di Assetto Idrogeologico (Hydrogeological Management Plan)

1. INTRODUCTION

Floods are the most frequent and complex among natural hazards. From 1994 to 2013 they affected 2.4 billion people with a rate that reached 43% of the world's population (Guha-Saphir et al., 2016). The risk complexity associated is due, among others, to their wide variety of underlying physical generation phenomena that produce different types of floods (Bates et al., 2008). In recent decades, several studies depicted how their probability of occurrence can be modified by human-dependent factors, as climate and land-use changes (e.g., Milly et al., 2002; Allamano et al., 2009; Salas and Obeysekera, 2014).

Therefore, flood risk can arise from the integration of multiple physical and social components, such as perceptions, spatial cognitions, citizen interactions, and socio-economic dynamics. For these reasons, over the last decades flood risk management policies have evolved to redirect policy makers' actions from purely physical defensive measures towards integrated management strategies (Schanze, 2006). It is the result of a common scientific understanding of structural problems on traditional management strategies that have neglected the systemic nature of risk, characterized by high complexity and uncertainty, defined in terms of individual objectives with problem-solving approaches and top-down management strategies (Ferber, 1999; Tsoukias, 2008).

Updating current flood risk management strategies is becoming a very important task in planning both at design and institutional levels with an increased focus of the complexity of natural and social processes associated with floods (Kellens et al., 2011).

Evidence shows that the communities' response to flood risk is associated with the social context in which a specific flood occurs (Wickes et al., 2015). A wide range of sociodemographic characteristics, but also the psychological factor of risk perception and awareness, exposure and communication techniques have been identified as factors affecting citizens' behavior (Miceli et al., 2008; Becker, 2014; Lechoskwa, 2018). Even though these aspects are well known in the scientific field, at present their implementation in planning tools is still very limited (Bradford et al., 2012).

The characterization of the social processes could improve the effectiveness of flood risk planning strategies because it allows to define those elements that contribute to the risk reduction and knowledge of protective measures of exposed communities. In fact, correct behavioral responses to flooding events by communities can help to reduce damages up to 80% (Grothmann and Reusswig, 2006).

Many studies (e.g., Fielding, 2012; Scolobig et al., 2012; Mondino et al., 2020) highlight how the population is often not aware of its exposure to flood risk. Specifically, Charalambous et al. (2018) documented how in Cyprus 77% of the survey respondents did not know if they lived in a designated flood risk area. This data can be reflected in the different nature of floods, remaining the question of their proper definition already in a planning context. In addition, another element that plays an important role in flood management is risk communication (Kellens et al., 2013). The choice to implement stakeholders' involvement in the flood management process must include the activation of targeted communication mechanisms to reach all citizens (Charalambous et al., 2018). Some authors (e.g., Haer et al., 2016; Kreibich et al., 2017) investigated the role of wrong alerts in the trust reduce in warnings and in the institutional subject in charge of them. The characterization of the state of trust in institutions is important from two different perspectives: (i) in the planning phase of the effectiveness of warning measures, since a relationship of mutual trust is required with the subject that transmits the warning, and (ii) in the management of the post-event emergency, where the possibility of a capillary transmission of information is fundamental.

Understanding the social context through the way citizens perceive and respond to the flood risk is crucial to determine the social elements that could be considered to improve flood risk management

(Miceli et al., 2008; Bradford et al., 2012; Bubeck et al., 2012; Fox-Rogers et al., 2016). Therefore, the estimation of risk perception and the factors affecting it represents a critical task in flood risk management (Rundmo and Nordfjærn, 2017).

Starting from this evidence, this paper seeks to contribute to existing research on bottom-up approaches used to support decision-making for flood management.

It seeks to better understand how citizens living in flood-prone areas can perceive flood risk and their knowledge about protective measures.

The methodology has been experimentally applied in the city of Brindisi (Puglia region, Southern Italy), which is susceptible to be affected by floods of different nature (as river, coastal and pluvial floods). To achieve this goal, an E-survey-based approach was proposed, to collect data which can explain the citizens' heterogeneity in risk perception and preparedness knowledge. Then, Mann-Whitney test and Kruskal-Wallis test have been used to analyze data retrieved.

The remaining part of the paper is structured as follow. Section 2 describes a theoretical framework applied in this study; Section 3 illustrates the case study, while Section 4 presents the methodology applied. Section 5 outlines and discusses main results. Final remarks and future developments close the paper (Section 6).

2. FACTORS AFFECTING FLOOD RISK PERCEPTION AND KNOWLEDGE OF PROTECTIVE MEASURES: A THEORETICAL FRAMEWORK

According to a common scientific understanding, risk perception consists in the interpretation of an event by citizens, it is socially constructed (Boholm et al., 2003) and can be defined as the process by which risk (composed of the combination of hazard, vulnerability, and exposure), is observed and internalized by each individual (Thistlethwaite et al., 2018).

Over last years, in the field of flood risk management, research on perception has increasingly sought to analyze influencing factors, investigating, among others, the link with human behavior and factors such as danger awareness (Sjöberg, 1998; Miceli et al., 2008), previous experiences (Weinstein et al., 1998; Lindell and Hwang, 2008; Leckowska, 2018) and perceived responsibility in carrying out mitigation actions (Terpstra and Gutteling, 2009).

The perception of flood risk is also correlated with geographical characteristics, institutional and community factors, as social dynamics, socio-economic aspects (Botzen et al., 2009) and participation and community trust in institutions (Weinstein et al., 1998; Renn and Rohrmann, 2000; Sjöberg et al., 2004, Miceli et al., 2008), as well as the sociodemographic variables of age, income, education, or home ownership (see review of Leckowska, 2018).

A deep understanding of public perception is useful because allow to understand how people act to reduce risk (Slovic and Peters, 2006; Xia et al., 2017). An action can either amplify or reduce the risk depending on whether an individual engages in protective behaviors or not (see review of Andráško et al., 2021). Therefore, a study of risk perception, implies a necessary knowledge of the social context, of the community and its relationship (Renn et al., 2000).

Knowledge, as reported by Weichselgartner and Pigeon (2015) has a dynamic nature that is constructed through social interactions. In fact, knowledge creation does not occur simply by providing new data/information, but rather when that information is elaborated in social process. According to Davenport and Prusak (1998), knowledge is "a fluid mixture" constructed through social interaction and experience.

In this study, knowledge was investigated in two ways. The first one, as a dimension of perception and refers to citizens' knowledge of the possible effects of the event; the second, as a separate but related entity to risk perception, refers to citizens' knowledge of protective measures.

In order to structure the perception and knowledge measures, in the present work the theoretical frameworks are defined as follows:

(i) the theoretical framework of flood risk perception has been built according to a literature review, and among others taking inspiration from the works of Renn and Rohrmann (2000), Renn (2000) and the review of Leckowska (2018). The choice to use as a bibliographic reference of Renn and Rohrmann (2000) and Renn (2000) from the field of psychology, has been used to investigate the main variables that influence the perception of risk, beyond the risk examined. On the other hand, Leckowska's review, focused on the perception of flood risk, helped to confirm, implement, and expand the variables that describe flood risk perception in the works of the last decades. It considers:

- *cognitive dimension*. It refers to subjective judgments of probability regarding the occurrence of a future flood disaster in the studied area and its consequences. Subjective judgments on the probability of risk and concern have been considered as separate measures of risk perception as it happens in works such as (see Peters, Slovic, Hibbard, & Tusler, 2006; Sjoberg, 1998);
- *awareness dimension*. It refers to citizens' awareness predictability of a flood event; risk awareness can be defined as the knowledge of the presence of a risk (Slovic, 1987);
- *knowledge dimension*. It refers to the degree of citizens' knowledge regarding to the possible effects of the event on the city. In outlining the role of knowledge in disaster risk reduction, Weichselgartner and Pigeon (2015) clearly emphasize the dynamic character of knowledge, which is constructed through social interactions that shape the data, information and facts that each individual is processing. In fact, knowledge creation does not occur simply by providing new data/information, but rather when that information is processed;
- *risk communication dimension*. Citizens are asked for their opinion in relation to the degree of effectiveness of risk communication. The effectiveness of a risk communication strategy is capable of increasing perception and awareness as demonstrated in the work of Bodoque et al. (2019);
- *the dimension of trust towards public actions, existing measures and public participation in order to reduce the flood risk in the city*. The level of trust in authorities and public protection measures plays a significant role in shaping perception and the relationship with preparedness (Leckowska 2018).

In this work these concepts are synthesized with the following terms: *Cognitive*, *Awareness*, *Knowledge*, *Risk communication* and *Trust*.

The dimensions of risk perception will be measured on the basis of socio-demographic variables that characterize the user profile.

(ii) assessment of the knowledge of protective measures has been carried out relying on the Civil Protection Behavioural Guide, which suggests measures to be used before, during and after the phenomenon, in open and closed spaces. The measures are published on the official website of the Civil Protection of the Municipality of Brindisi.

The degree of knowledge will be measured according to socio-demographic variables that characterize the user profile.

The processing of this information allows to better understand how citizens living in flood-prone areas may perceive flood risk and know protective measures, and to demonstrate that it is possible to derive useful information elements to support the decision-making process for flood management through a bottom-up approach.

The perception analysis is characterized by high complexity because the risk is perceived differently for each citizen in a community (Renn and Rohrmann, 2000). Further, factors (especially social) contributing to risk definition, are not static over time and hard to be evaluated.

3. CASE STUDY

Brindisi is a coastal city located in the southeastern part of Puglia region (Southern Italy) with a population of more than 85,000 inhabitants. The settlement and development of this city were favored by a large natural inlet which was the ideal location for the presence of a natural harbor since the time of the Roman Empire. As reported in the Regional Landscape Masterplan (see Regione Puglia, 2013), its urban structure has historically favored the docking of ships. In Figure 1 the urban zoning of the city and mainstream network are reported. Going from North-West to South-East, it is possible to recognize a) Canale Cillarese, a stream characterized by the presence of the homonymous embankment dam; b) Canale Patri, the stream mainly connected to the urban texture, and at the end, in the industrial area, c) Fiume Piccolo and Fiume Grande streams.

Figure 1 - Urban zoning of Brindisi and mainstream network (in red the name of the neighborhoods; source: Google Earth)

In Figure 1 it is possible to recognize how the central urban core is surrounded by Canale Cillarese and Canale Patri, which flow in the internal port. The complexity of the hydraulic stream system is confirmed by Figure 2, where the floodable areas for an event with a return period of 30 years are reported (http://webgis.adb.puglia.it/gis/map_default.phtml).

A preliminary analysis of the flood occurrences was conducted exploiting the AVI dataset (Guzzetti et al., 1994) and integrating floods information during the time interval between 1950-1999 by collecting data from local newspapers, recording 65 flood events news. Among others, each flood record was integrated with the following information:

- the amount of daily rainfall for the day to which the event was noticed;
- if a stream (and its name) was indicated as responsible of floods;
- involved streets and/or neighborhoods (and their names)
- observed/estimated water depths;

In Table 1, the number of citations of flood events in newspaper articles is reported (when greater than 3), while in Figure 2 their position is illustrated.

Figure 2 - Flooding maps for an event with a return period of 30 years (in blue) (PAI, 2019) and flooded streets landmarks (in black). Figure modified from Google Map

Table 1 – Census of flooded streets reported by local newspapers

Street name	Neighborhood	Number of Events (1951-1999)
Via Torpisana	Commenda	18
Via Appia	Cappuccini	10
Via Commenda	Commenda	10
Via del Mare	Centro	8
Via Imperatore Costantino	Commenda	7
Via Porta Lecce	Centro	6
Via Bastioni San Giacomo	Centro	5
Via Ciciriello	Paradiso	5
Via Provinciale per S. Vito	Paradiso	5
Via Carmine	Centro	4
Via Liguria	Commenda	4

Via Nicola Brandi	Paradiso	4
Via Cinque Giornate	Santa Chiara	3
Via Provinciale Lecce	Perrino	3

From data in Table 1, it emerges how positions of these streets can define three clusters, referred respectively to Canale Cillarese and Canale Patri and to the neighbourhood behind the railway.

4. METHODOLOGY

The methodology proposes the combination of E-survey to collect data regarding citizens' flood risk perception and knowledge of protective measures and Mann-Whitney and Kruskal-Wallis test to analyze collected data (Figure 3).

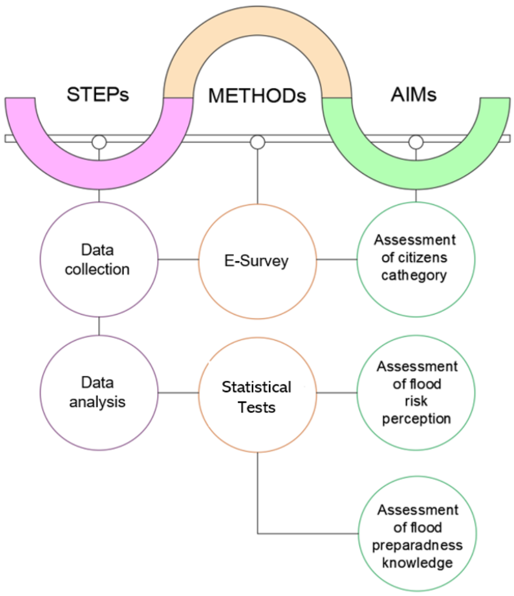


Figure 3 - Methodology applied

The E-survey was built and shared using Google Modules, a free online tool, significantly different from classical participatory approaches (see the revision done by Voinov and Bousquet, 2010). Such use generally precludes the direct involvement of communities in the decision-making process but allows to acquire information that can be modelled downstream by the analysts (Voinov and Gaddis, 2008) and used in the decision-making process for flood mitigation.

The assessment of citizens' flood risk perception and knowledge of protective measures was carried out through the statistical tests. Specifically, the Mann-Whitney test (MWT) allows measuring the variation of two independent variables among different socio-demographic categories (Mann and Whitney, 1947); the Kruskal-Wallis (KWT) test allows measuring the variation of more than two independent variables among different socio-demographic categories (Ostertagova et al., 2014). In both cases null hypothesis of these tests_test states that samples are drawn from the same distribution.

In this work, the choice of these statistical tests was made because the data meet the requirements for the adoption of the test (Birnbaum, 1956): (i) the dependent variables (flood risk perception categories) are measured at the ordinal level (Likert scale); (ii) the independent variables are composed of groups (sociodemographic variables); (iii) there are no relationships between observations in each group or between the groups themselves; (iv) the variables are not normally distributed.

With reference to flood risk perception analysis, due to many observations (perception categories), the Bonferroni correction was applied which is used to adjust p-values due to the increased risk of a type I error when performing multiple statistical tests (Armstrong, 2014).

4.1 E-Survey design

The E-survey was tested in two pilot sessions starting in November 2019 and May 2020. The first pilot test involved experts in the field of hydraulic and planning engineering, whereas the second one involved the non-expert knowledge. The suggestions made by the participants after the first pilot test concerned the formulation of contents of some questions; some small changes were suggested from non-expert knowledge and concerned the understandability and reading of some questions (user acceptability).

Among the different data collection techniques, the E-survey has the advantage for the analyst to create a structured database and to boost the information collected through a wider audience using a web platform (Jansen et al., 2006), as compared to most typical citizen-techniques (Voinov and Bousquet, 2010). In fact, a well-structured survey is able to bring out not only the current state of society but can also provide indications for reconstructing flood phenomenology and, therefore, be characterized by a predictive ability.

Sampling methodology belongs to the family of *snowballing sampling*, with the possibility of disseminating online surveys by using social media, telephone and online banner. Our choice was motivated by the exploratory nature of this work and to difficulties in reaching the population by other type of approaches, finding an adequate balance with limitation typical of such approach (e.g., biased samples).

The choice to use an online tool as E-survey is justified by two main reasons: (i) the online tool aims to facilitate the collection of information through a broader audience than the normal participation techniques provided in the literature (workshops, seminars, paper interviews, door-to-door, etc.); (ii) the online tool allows for the collection of data in a more structured way than the citizen engagement methods mentioned above (Voinov et al., 2016). On the other hand, the use of this methodology might have two limitations: (i) excluding the knowledge of citizens who do not use the web platform and (ii) providing results in an aggregated form that recognizes an "average" of citizens' perception.

The survey was composed of 40 questions and took between 15 and 25 minutes to be completed. The type of questions could be classified into closed questions, including multiple-choice, checkboxes, and ranking via Likert scales and open questions aimed at finding a subjective opinion with regard to a particular described context. The questions were organized in four sessions in order to investigate: (a) citizen profile; (b) degree of citizen flood risk perception (c) degree of citizen knowledge regarding flood prevention measures; (d) level of knowledge of space in case of flood evacuation.

For this study, data related to the profile of citizens and responses related to risk perception were used. The questions were structured according to a Likert scale and investigate the dimensions of perception, as defined in section 2. In addition, within this section, an open-ended question aimed to learn about the places in the city perceived to be most at risk by citizens.

The socio-demographic variables used to characterize the citizen profile are listed in Table 2. For this study, the first two sections relating to risk perception and preparedness knowledge were analyzed (i.e., ii-iii).

Table 2 - Socio-demographic variable

Socio demographic variables	Description
Gender	Male; female
Age	<18; 18-30; 31-45; 46-60; >60
Family composition	Number of family members; the presence of disabled people
Flood Experience	Previous experience
Hazard proximity	Living in a flood-prone area (neighborhoods)
Length of residence	Habitant, commuter

The degree of citizen risk perception has been investigated through factors emerged according to a literature review (see Section 2).

Citizens answered questions for each category (Table 3). For each question, citizens were asked to express a preference on a Likert scale of 7 (1: not at all; 7: very much). It has also been introduced an open question asking which street in Brindisi was perceived by the respondent as being most at risk.

Table 3 - Items of the survey regarding risk perception

Dimension of risk perception	Question	Question: select 1 to 7 according to your preference (1: not at all; 7: very much).
Cognitive	1	How much could your neighborhood be exposed to flooding?
	2	How much flooding could be probable in your neighborhood?
	3	How dangerous could be flooding in your neighborhood?
Awareness	4	How much do you think a flood is predictable in Brindisi?
Knowledge	5	How much do you think you are informed about the effects of a flood in Brindisi?
Risk communication	6	How effective do you think is risk communication in Brindisi?
Trust	7	How much confidence do you have in the actions of public administrations in Brindisi?
	8	How much confidence do you have in the existing mitigation measures in Brindisi?
	9	How much do you believe in public participation as an approach to improve flood management?

Also, citizens were asked to select the recognized Flood Protection Strategies (FPS) from the set of alternatives in the Civil Protection Behavioral Guide (CPBG). The set of alternatives includes indoor and outdoor measures. The degree of citizens' knowledge regarding the FPSs provided in CPBG has been measured through a Likert scale. As before, for each measure citizens were asked to express a preference on a scale of 7 (1: not at all; 7: very much). The list of measures is shown in Table 4.

Table 4 - Items of the survey regarding knowledge of protective measures

	Question: select 1 to 7 according to your preference (1: not at all; 7: very much).
Indoor measures	Do not get to the lower floors to secure your property
	Do not leave home to protect your car
	If you are in a basement room or on the ground floor, go up to the upper floors
	Avoid the elevator
	Turn off the gas and turn off the electrical system
	Do not go drinking water from the tap
	Restrict cell phone use: keeping lines free makes rescue easier
	Keep yourself informed on how the situation evolves and follow the indications provided by the authorities
	Moving away from the flooded area

Outdoor measures	Reach the highest neighboring area quickly
	Be careful where you walk: there may be chasms, potholes, open manholes etc.
	Avoid using the car
	Avoid underpasses, embankments, and bridges
	Reduce cell phone use: keeping lines free makes rescue easier
	Keep yourself informed on how the situation evolves and follow the indications provided by the authorities

4.2 Participants

The survey was filled out by 301 citizens. Table 5 shows that the gender of respondents is quite homogeneous (59% male, 41% female). The most representative age of the people sample is between 30 and 60 years. The 17% of participants are under 18, because the survey was also disseminated among students. Most respondents live in a four-person household where there are no people with disabilities. The 68% of respondents have never had any direct experience with flooding. 42% of citizens live in a flood-prone area. The neighborhoods of Brindisi have been subdivided into flood-prone and non-floodable areas according to Hydrogeological Management Plan maps for an event with a return period of 30 years (PAI, 2005) (Table 6).

Table 5 - Sample characteristics

Socio demographic variables	Description	Percentage
Gender	male	59%
	female	41%
Age	<18	17%
	18 - 30	13%
	31-45	24%
	46-60	25%
	+60	21%
Family composition: number of family members	1	9%
	2	22%
	3	20%
	4	42%
	≥5	7%
Family composition: presence of disabled people	No	85%
	Yes	14%
Flood Experience	Yes	31%
	No	68%
Hazard proximity	Live in flood-prone area	42%
	Live in non-floodable area	57%
Length of residence	Resident	75%
	Commuter	25%

Table 6 - Neighborhoods subdivided according to PAI (2005) flood-prone areas

NEIGHBORHOOD	FLOOD-PRONE AREA	
	YES	NO
Bozzano	x	
Cappuccini		x
Casale		x
Centro	x	

Commenda	x	
La Rosa		x
Minnuta	x	
Paradiso	x	
Perrino	x	
S. Chiara		x
S. Angelo	x	
Sant'Elia	x	
Sciaia		x

5 RESULTS AND DISCUSSION

The following section is divided in four parts. The first two are related to the results and discussions on risk perception (Section 5.1) and knowledge of protective measures (Section 5.2) respectively. The third part (Section 5.3) proposes a summary of the results with proposals for decision makers, while Section 5.4 contains a final discussion aimed in providing an overview of main potential implications of results

5.1. Risk Perception

This section illustrates the results related to citizens' flood risk perception. The nine scores regarding the flood risk perception (see Table 3) provided by the respondents were analyzed to identify heterogeneities using the socio-demographic variables listed in Table 2.

Table 7 shows the MWT and KWT p-values compared with a Bonferroni corrected level of significance related to flood risk perception.

Table 7 - MWT and KWT p-values for risk perception analysis (bold font is for statistically significant values)

Socio demographic variables	Cognitive			Awareness	Knowledge	Risk communication	Trust		
	1	2	3	4	5	6	7	8	9
Gender	0.033	0.012	**0.000**	0.052	**0.000**	0.061	**0.000**	0.032	0.073
Age	0.021	**0.000**	0.012	**0.000**	**0.000**	0.071	0.012	0.013	0.042
Family Composition: n° of family members	0.072	0.021	0.042	0.083	**0.000**	0.072	0.102	0.063	0.061
Family Composition: disabled people	0.032	0.053	0.061	0.051	0.072	0.053	0.042	0.013	0.051
Flood Experience	0.021	0.043	0.032	**0.000**	0.112	**0.000**	**0.000**	**0.000**	0.021
Hazard proximity	**0.000**	**0.000**	0.022	0.012	**0.000**	0.043	**0.000**	**0.000**	**0.000**
Length of residence	0.063	0.021	0.082	**0.000**	0.063	0.112	**0.000**	**0.000**	**0.000**

While the values reported in Table 7 show the level of statistical significance referred to each question in relation to the variables, they do not allow assessing the specific nature of each variable unambiguously. More detailed information emerges from boxplots visual analysis in Figure 4, that have been generated only for statistically significant variables. The presence of disability in the family does not seem to influence in any way the perception of flood risk and for the sake of simplicity discussion of statistical tests output will be carried out without no references to this category.

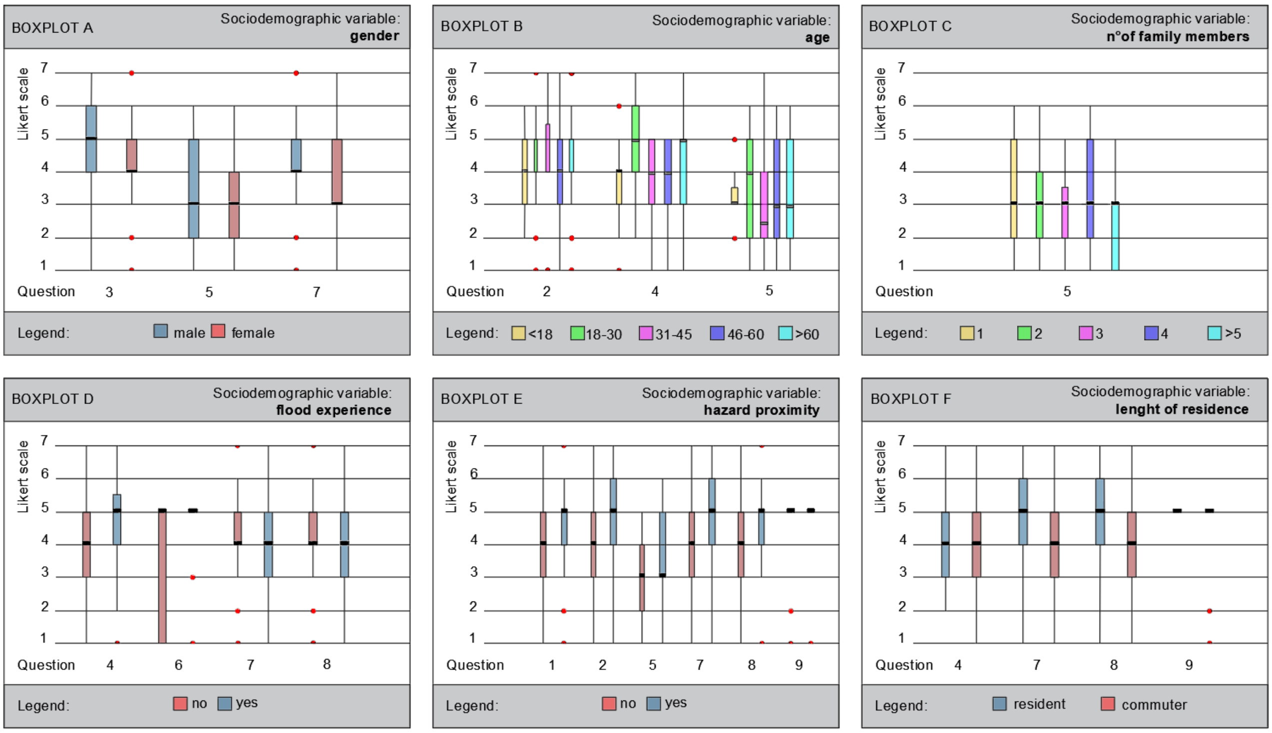
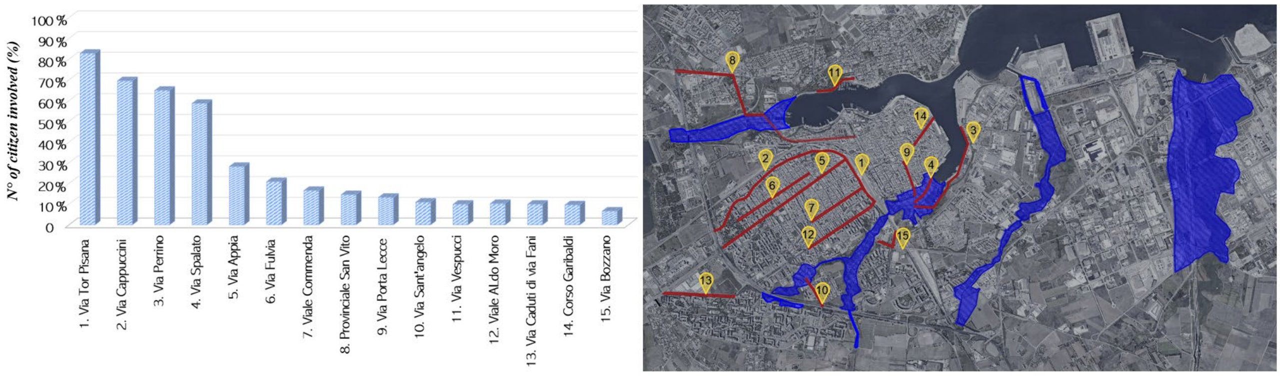


Figure 4 - Boxplots of statistically significant risk perception variables

The cognitive dimension refers to questions 1, 2, 3 of Table 3. Observing the boxplots in Figure 4 it is possible to observe that, among the results, the cognitive component of those who live in areas at risk is significant. They appear to have a higher perception than those who do not live but there is a not negligible perception even in areas where there is apparently no source of risk.
Further confirmation of what stated is visible through Figure 5, where the answers of the citizen in relation to the question "select the street in the city you perceive most at risk" is reported. For example, via Tor Pisana and via Cappuccini (landmarks 1 and 2 in Figure 5) are the most perceived landmark at risk, even if they are not in floodable areas. Such information could help the decision-maker to investigate the nature of floods in these areas. A greater justification can be found, instead, in via Perrino and via Appia (landmarks 3 and 4 in Figure 5). Reason of all these results can be found in the fact that the city of Brindisi is located in an area characterized a groundwater aquifer with low permeability and porosity, and whose dynamics in response to short and intense rainfall cause a raising of the water table implying flooding of depressed areas and hydrogeological risk (Spizzico et al., 2006).



Flooded streets landmarks perceived *Floodable areas with a return period of 30 years (in blues) and flooded streets landmarks perceived*

Figure 5 - Landmarks of perceived flooded streets

Moreover, another interesting result is related to the values of the medians between those who live in flooding areas and those who live outside the risk areas (boxplot *e*, Figure 4). These values differ from a minimum of 3 to 5 on the Likert scale. This type of information could allow the planner to understand whether those living in risk areas underlie the risk (Wachinger et al., 2012). This behavior is well-known in the literature because prolonged exposure tends to underestimate the effects by creating a mechanism known as "risk bias" (Apel et al., 2009).

The awareness dimension is represented by question n. 4 in Table 3. Results suggest that awareness is greater for people with flood experience and for residents.

The knowledge dimension (question n. 5 in Table 3) arises for the *age* variable (boxplot *b*, Figure 4), where the highest median value for belongs to the category 18-30. In addition, it is interesting to note that the demographic variables of gender, hazard proximity and the number of family members have also emerged. This can lead to useful reflections for policy makers about the importance of a proper communication of self-protection measures and can be integrated with evidence about the effectiveness of communication measures (question n. 6 in Table 3).

The results obtained from this study have been confirmed by the literature in the field of communication in risk management. Renn (2008) stresses the importance of adapting risk communication to people's specific needs, making people easier to judge their risk situation and take informed decisions based on personal preparation and security measures. Effective communication, or its absence, can have a great influence on how people are prepared for a disaster. Also, recent studies confirm these findings (Arai, 2013; Medford-Davis and Kapur, 2014; Bradley et al., 2014).

The most significant results are obtained for those who live in flood prone areas of the city (Hazard proximity in Table 6). This population have a high perception, and this can be related to the presence of Canale Patri, which was experienced by periodic floods, causing economic damages (e.g., in the flood event of 2005). Literature shows a strong relationship between risk perception and public trust in the actions of authorities, communication, existing protective measures but also the community itself. Also, in this case, the results can be mixed and depend heavily on the contest and the methods used to analyze it. Studies by Tepstra (2011), Carlton and Jacobson (2013), and recent work by Cannon et al. (2020), show that higher levels of trust result in lower perceptions of risk. This in turn reflects negatively on citizens' predisposition to take protective measures. In opposition, Samaddar et al. (2014) showed that higher trust leads to higher risk awareness and better acceptance of preventive actions to reduce risk.

5.2 Knowledge of protective measures

This section illustrates the results related to preparedness. Table 8 shows the MWT and KWT p-values evaluated with a Bonferroni corrected level of significance related to protective measures. In Figure 6, instead, boxplots for all demographic variables are reported.

Table 8 - MWT and KWT -values for knowledge of protective measures variables (bold font is for statistically significant values)

SOCIO DEMOGRAPHICS VARIABLES	CATHEGORY OF MEASURES	
	indoor measures	outdoor measures
Gender	**0.025**	0.415
Age	**0.000**	**0.000**
Family Composition: n° of family members	0.095	**0.000**
Family Composition: presence of disabled people	0.355	0.085
Flood Experience	0.455	**0.000**
Hazard proximity	**0.000**	0.255
Length of residence	**0.005**	0.020

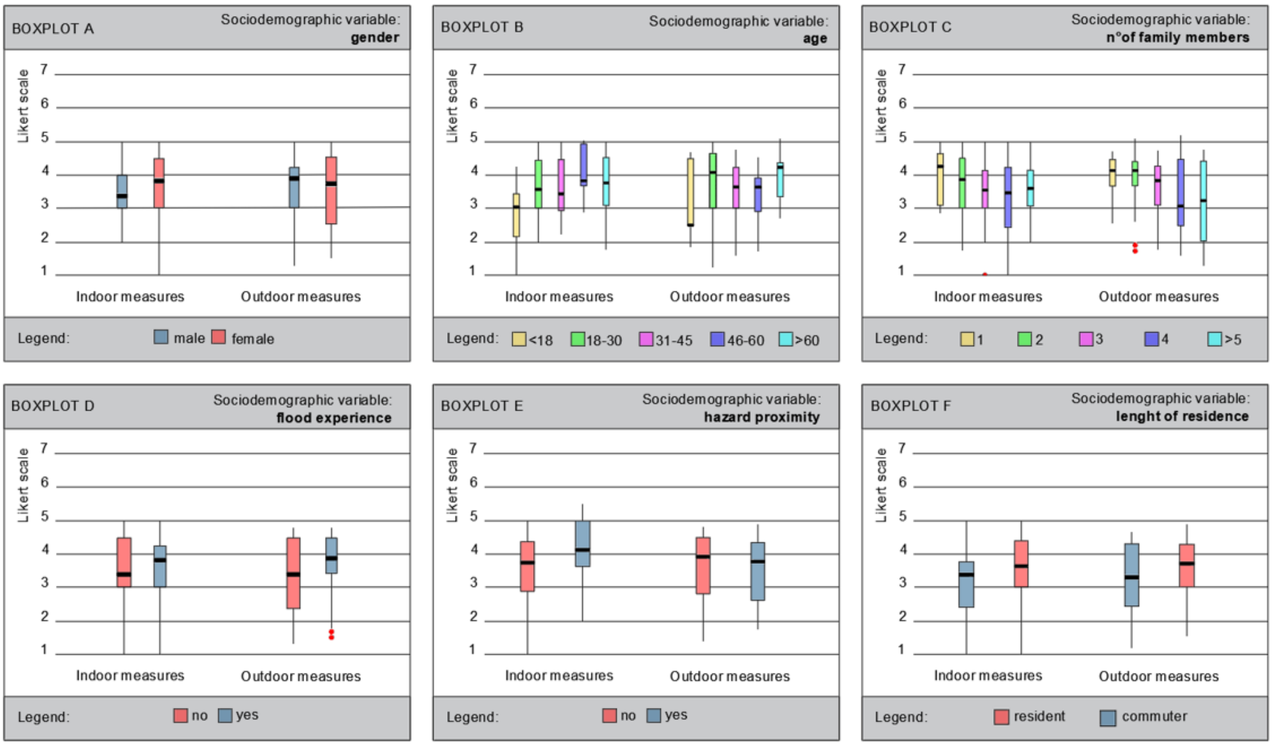


Figure 6 - Boxplots of knowledge of protective measures variables

As a first note, it is clearly showed that, also in this case, the presence of disabled people in the family group is not statistically relevant. Figure 6 shows that median values for each category and both measures of knowledge are often lower than 4, whereas maxima reach the value of 5. This demonstrates a generally low-medium level of preparedness diffused across all categories.

From Table 8, it is possible to note as the null hypothesis of the corrected tests is rejected for both indoor and outdoor measures, demonstrating a homogeneity in gap distribution. In the case of *age* category, the weak class is the youngest one, and the reason can be traced back to the lack of experience, besides not adequate information at the school level. On the other side, results of *length of residence* variable for indoor can be motivated by the residential factor. In fact, people who lives in Brindisi show a greater knowledge of measures, and this difference is marked for outdoor activities, probably due to an experience factor. This statement is confirmed by the positive output of the statistical tests for outdoor measures for flood experiences and indoor measures for hazard proximity. These results are not in contradiction; being plausible to assume that the greater knowledge of outdoor measures is linkable to direct experience, boosted to the different type of floods, while hazard proximity role in shaping indoor measures for the high level of risk due to river floods.

Results of this step of our survey analysis are particularly interesting because they can provide inspiration for identifying gaps in implemented flood risk management strategies and, at the same time, able to give tangible elements to institutional agents for planning future ones.

As remarked before, there is a generally low-medium knowledge of safety measures. This is a relevant issue because one of the main abilities of this approach is in drawing out societal fragilities, leading to a better characterization of population. For example, the survey shows how sensitive categories are young people and families with respect to inadequate outdoor measures knowledge. Consequently, it can be remarked that, in case of flood, they are more susceptible to higher exposure to flood effects.

5.3 Results summary and some suggestions to support the decision-making process for flood management

To understand the effectiveness of the bottom-up approach to support decision making for flood management, the results were organized in order to define measures and suggestions placed temporally and spatially.

The identification of variables that influence community heterogeneity can be useful for policymakers, disaster managers and several practitioners who must coordinate and communicate with different levels of government, classes of actions, and at various times in the disaster management cycle. To this end, using the methodology applied in this paper, it is possible to propose risk reduction actions temporally and spatially placed, according to specific categories of citizens (Table 9).

Table 9 - Time positioned suggested flood mitigation measures

TIME POSITIONED	MAIN RESULTS OF RISK PERCEPTION AND KNOWLEDGE OF PROTECTIVE MEASURES	MEASURES	AIM OF MEASURES
PRE EVENT	The perception of flood risk is lower for women while they have a higher knowledge of indoor measures; commuters and citizens without previous flood experience have a low perception of risk in relation to cognitive, knowledge, and trust dimensions of risk perception and little knowledge of preparedness measures.	Promote participatory processes and forums open to citizens	to decrease the gap of perception and knowledge between different categories of citizens
			to increase collaboration between public and private sectors to inform commuters (workers and students) about the flood risk areas
			to involve those who have previous flood experiences to allow the transmission of memory
	People between 18-30 represent the age group with the highest perception of flood risk. People under 18 represent the age group with the least perception of risk. Preparedness is characterized by an inversely proportional relationship between family group size and knowledge.	Improve communication strategies	to evaluate the effectiveness of the alert means used so far (as well as their knowledge), measuring the degree of trust of people in institutions
			to calibrate in a manner consistent with the target user (for example, school seminars to reach under 18s; social channels for >40s; social campaigns on local TV, in the streets for >60s) taking care to ensure its effectiveness by ensuring its reception and clarity;

	People who live near streams have a higher flood risk perception of risk and knowledge of preparedness measures. The flood risk perception of people who live in areas where there is apparently no source of risk is not negligible. They have low knowledge of the preparedness measures.	Manage public interventions	to evaluate the presence and the effects of different types of flood on the territory, thus validating the current works of mitigation of the risk and calibrating the communication of measures in an appropriate way;
			to improve integrated risk management: the implementation of a communication strategy that is able to contemplate the transmission of measures in other types of risk (e.g., seismic), describing the usefulness of individual actions and avoiding the occurrence of overlapping information;
			to obtain scenarios on the behavior of the population capable of improving the predictive ability on the possible behavior of the agents during the event;
DURING EVENT	Areas of the city perceived to be more at risk have emerged	Improve the management of alert techniques and risk communication	Taking targeted action of civil protection activities

Working in the planning phase means reducing the possibility of major effects in the recovery phase (post-event). Knowing citizens' perception and knowledge of the measures allows to better respond to the event in an effective way. It can be done for example by means of:

- the provision of special areas of population convergence that take into account the possible behaviors and conflicts of the population (both social and individual), providing appropriate relief and support measures;
- the efficient management of economic relief measures for those affected by the flood;
- the preventive planning of technical interventions necessary to restore the regular flow of water;

5.4 Discussion

The applied methodology aims to structure the planning phase for flood risk reduction starting from the elicitation of citizens' flood risk perception and knowledge of protective measures. The results show that this methodology can become a useful tool for planning risk mitigation activities.

According to the review of Kellens et al. (2013), most studies regarding flood risk perception are characterized by an exploratory nature and there isn't a theoretical framework available in social science research. As a result, there is no methodological standardization in measuring and analyzing people's flood risk perceptions and their adaptation behavior.

In this study the methodology based on the combination of E-survey to collect data regarding citizens' flood risk perception and of protective measures and statistical tests to analyze collected data, has been applied due to: (i) exploratory nature of investigation, (ii) difficulties in reaching and completely define the population and (iii) impossibility of dispose of adequate financial and human resources for carrying out an opportune statistical sampling.

Findings related to knowledge of measures appear to be in alignment with literature. Many studies provide evidence that even if individuals have experience and a high perception of risk, they rarely adopt adequate knowledge and preparedness actions (Bradford et al., 2012; Siegerist et al., 2006; Hall et al., 2009; Scolobig et al., 2012). The link between perception and protective behavior appears to be very weak (Bubeck et al., 2012; Wachinger et al., 2012; Miceli et al., 2008).

In Sections 5.1 and 5.2. homogeneities in investigated population categories were investigated, highlighting their main characteristics and distributions. This led to several considerations about the origin of the responses and helped us in a deeper understanding of the social and environmental framework.

A complete description of boxplots of Figure 4 and 6 needs to be supplemented by dwelling on their outliers. The importance of these points clearly arises by considering the lowest of them as weak elements, potentially related to a negative impact of flood events. These consequences cannot be only categorized as of *direct* type (borrowing the terminology from the field of damage assessment), but can affect other spheres of human being, as that psychological. Psychological consequences are more complicated to be treated, are related to the personal status of each person and can be influenced by other factors connected with their own life. Pieces of evidence of post-flood psychological diseases were documented in different studies (Krug et al., 1998; Clemens et al., 1999; Gordon et al., 2011; Alderman et al., 2012; Lowe et al., 2013).

Moreover, thanks to E-Survey it has been possible to collect data regarding the perception of risk communication. The results can help practitioners and policymakers in defining adequate strategies for improving communication on the correct way of behaving by combining information highlighting gaps in risk communication and knowledge of measures. As reported by Renn (2005), it is critically important to tailor risk communication to people's specific needs. This facilitates and maximizes the decision-making process of people acting on preparedness and personal safety measures.

This work relies on the use of traditional statistical testing to investigate the heterogeneity in risk perception and preparedness knowledge by testing the null hypothesis: the distributions of both populations are equal. This was achieved by investigating if and how multiple demographic variables and hazard proximity influenced the answers for the nine items measuring the risk perception and the two items measuring the preparedness knowledge. The Bonferroni correction was adopted in this work to mitigate the risk of a type I error (i.e., the mistaken rejection of a null hypothesis) when making multiple statistical tests. This approach has the limitation of increasing the chance of having a type II error (i.e., the mistaken acceptance of the null hypothesis) (Armstrong, 2014). However, this correction should be considered when a large number of tests are carried out in this work without having a priori hypotheses (Streiner & Norman, 2011). This was the case for this study, as multiple tests were carried out (see Tables 7 and 8) without pre-planned hypotheses aimed at confirming existing theories or conceptual models. On the other hand, this approach might have increased the change not to identify some factors explaining the heterogeneity in risk perception and preparedness knowledge (i.e., type II error) in the data used in this work. As such, further investigations are required to identify theories and conceptual models which could explain such heterogeneities in the Puglia region and to define well defined a priori hypotheses to be tested, together with a proper assessment of statistical power of tests

6 CONCLUSIONS

This study aims to understand how citizens living in areas exposed to hydrogeological risk perceive floods risk and to what extent they known protective measures to adaptively address a future flooding event. This paper seeks to make a contribution to the field of research that addresses bottom-up approaches to support the decision-making process for flood management through a bottom-up approach. To achieve this goal, an E-survey was developed to collect variables describing citizens' flood risk perception and degree of knowledge of protective measures and statistical tests were used in post analyzing collected data.

Specifically, E-survey aims to collect data regarding citizens' flood risk perception and knowledge of protective measures and Mann-Whitney and Kruskal-Wallis test to analyze collected data.
The degree of citizens' flood risk perception has been investigated through five dimensions of risk perception subdivided into Cognitive, Awareness, Knowledge, Risk communication and Trust.
The degree of citizens' preparedness knowledge was gathered by asking citizens to recognize flood protection strategies from the Civil Protection Behavioral Guide.

The results show that flood risk perceptions are strongly linked to variables such as trust in institutions, institutional communication, and information as well as among citizens. This is even more reflected in the categories aged less than 18 years and below. The presence of disabled people in the household does not act in any way in either perception or adaptation; previous experience, in relation to flood perceived risk, plays a role in the awarness dimension alone while in relation to knowledge of protective measures, it is slightly higher for those who have experienced the event. In addition, a slightly higher perception emerged for those living in risk areas, but the results of the remainder show that there is a non-negligible perception even where there is apparently no source of risk. This is reflected in the different nature of the floods that have affected the city and should serve as an input for policymakers to carry out investigations about the latent risks.

The E-survey methodological approach has the advantage for the analyst to create a database to be checked and analyzed in a short time, information to be spatially localized, and data to be used for more accurate analyses. Elements that would improve the flood risk management process by planning more precise strategies focused on specific categories of citizens according to their demography and location in an urban area at risk.

On the other hand, the use of this methodology may have two limitations: (i) excluding the knowledge of citizens who do not use the web platform and (ii) providing results in an aggregated form that recognizes an "average" of citizens' knowledge and perception. While the former might be addressed by relying on a larger consideration of more traditional, in-person investigation methods, aiming at implementing a hybrid integrated approach, the latter limitation could be more effectively dealt with only by using a more disaggregated, inclusive and refined methodology. In this concern, a reference to multi-agent models, as developed from intelligent systems science, will be investigated starting from recent literature in the field of environmental resource management and planning at large.

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